

Functional program of requirements for planning and cost

Deliverable report D 3.1



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INSITER - Intuitive Self-Inspection Techniques using Augmented Reality for construction, refurbishment and maintenance of energy-efficient buildings made of prefabricated components.

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Deliverable report 3.1

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Colophon

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Fulfilment of the Description of Action (DoA) in D3.1

Fulfilment of WP, Task and Deliverable scopes and objectives

Summarised objectives as stated in DoA	Results in this deliverable addressing the DoA
<p>WP 3 scope and objectives:</p> <ul style="list-style-type: none"> - To develop software applications for self-inspection based on the advancements of existing software tools for quality and energy-performance assessment, planning and cost monitoring, and decision-support systems - BIM and self-inspection and self-instruction interfaces in software tools 	<p>Addressed:</p> <p>This deliverable is drawing the landscape of the available functionality within state-of-the-art software in the context of the requirements coming from the test cases and current state of work within INSITER. The deliverable shows what is possible and more important what are the gaps between the requirements and state-of-the-art software in the context of planning and cost estimation software. Based on this it shows what development work within Task 3.1 will be done to meet the requirements without reinventing the wheel.</p> <p>Not addressed:</p> <p>Assessment and decision-support systems are not included as they can be found in D3.3 and both documents are aligned. Also the development itself (part of D3.2 due M36) is not part of this deliverable but will be based on the findings in this deliverable D3.1.</p>



<p>Task 3.1 scope and objectives:</p> <ul style="list-style-type: none"> - Avoid redundant effort by construction workers and provides live status data for improved project management. - <u>Reviewing state-of-the-art software tools for planning and cost monitoring connected to BIM.</u> - <u>Developing a reference software model for performance, complexity and cost analysis in building construction.</u> - Analysing the potentials for improvement with regards to time duration, the critical path in a planning process, possible parallelization of phases, possible standardization. - Embedding key performance indicators and developing use case scenarios for decision making. - Realisation of the connection to the BIM platform. - Support systems for decision makers. 	<p>Addressed (please explain to which extent):</p> <p>The requirements lead into practical integration of cost and planning data into the onsite and offsite workplace. The visualization of the current state, the different processes and the object based (potentially aggregated) cost and quantities improve the effectiveness of the construction workers.</p> <p>The review of state-of-the-art software tools for planning and cost is executed where the focus was on software with BIM support, even BIM via open standards.</p> <p>An integrated, 'everywhere available', quickly access and integrated view on planning and cost data will make critical paths more clear and trigger people to optimize as understanding of the bottle necks are more clear.</p> <p>As the review is not only looking at state-of-the-art software but also at the latest developments within creation of widely accepted open standards and the BIM platform is based on the same open standards the connection is covered.</p> <p>Not addressed:</p> <p>The reference software model is not created. Use case scenarios are missing, however all test cases are integrated and where possible potential use cases on these test cases are identified. As soon as the use cases become available within INSITER this document will be updated against the different use cases.</p> <p>Support systems are handled in D3.3, however the results available in BIM in the context of cost and planning will be fed to the support system from D3.3 what makes it possible to use this technology in the context of Task 3.1.</p>
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<p>Deliverable D3.1 scope and objectives:</p> <p>Functional requirements and integration architecture of applications for process, planning and cost, which will serve as the underpinning for further software development addressing planning and cost management.</p>	<p>Specific results fulfilling the deliverable objectives:</p> <ul style="list-style-type: none"> • Requirements Collection (based on test cases) • Requirements Clustering (and selection of relevant requirements) • State-of-the-Art software review on Cost and Planning software with BIM integration • BIM Software Architecture • Proof of Concept
<p>Project's progress relevant to the deliverable within the corresponding timeframe (Year 1 - 2 until M18):</p> <ul style="list-style-type: none"> - Most relevant software is reviewed to define the functional needs and required interfacing (e.g. DEMO RE Suite for condition assessment and asset management, DWA MONAVISA for energy and comfort assessment, tools for scheduling and cost management). - KPIs are integrated in the self-inspection protocols/manuals. Simultaneously, the reviewed and optimized energy performance and condition assessment norms, references and calculation methods are embedded into the analytical software. 	<p>Achievement percentage:</p> <p>[100%] Reviewed Software</p> <p>[40%] KPI's, use cases, test cases</p> <p>Explanation:</p> <p>Most of the relevant software has been reviewed. This is not 100% yet as in the area of BIM, Cost, Quantity Take-Off and Planning data the world is changing quickly.</p> <p>Not only software is reviewed, but also used standards, especially in the area of planning recent open standards give good opportunities to improve support of Planning and Design in one BIM model.</p> <p>KPI's Use Cases and Test Cases are currently based on the Test Cases extended where possible. As soon as the Use Cases become available this deliverable will be updated.</p>



Publishable executive summary

This deliverable describes the requirements in the context of cost and planning software. The requirements find their origin in different KPI's and different use cases, an important source for this was D1.1 Best practices and existing shortcomings. Since use cases are not available during the development of this report the test cases are used as basis instead. This deliverable will be updated after the use cases become available. All requirements are collected and clustered.

To create the software for INSITER the “to be developed functionalities” first have to be defined. There are two possible directions from where those features will be defined: on one hand there are the named functionalities given in the Description of Action (DoA) which highlight some relevant features. And on the other hand there are required functionalities coming from the Use Cases (respectively from the Test Cases since the Use Cases are not finally defined yet). After creating a list of all relevant functionalities an additional list of requirements for the software will be derived. Comparing this list of the functionalities from already available software in the market will reveal the gaps, which have to be closed by the “to be developed software” in the INSITER project.

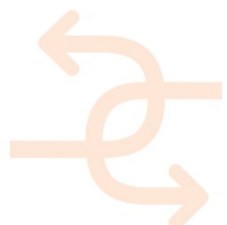
The review of state-of-the-art software and widely accepted open standards shows what is currently available in the market as well as what can be expected in the near future. Based on this review we check what requirements are fulfilled directly by existing solutions or solutions that are expected to come to market very soon and what requirements are not fulfilled by state-of-the-art software at this moment. This deliverable identifies the gaps between requirements and (soon to be) available solutions and secondly it identifies the gaps needed to full fill the requirements.

When identifying the gaps between requirements and available solutions the following basic principles are kept in mind:

- When possible existing software should be used, INSITER is not to reinvent the wheel or re-develop software solutions that already exist;
- When possible the focus will be on use of widely accepted open standards;
- The main central component is the BIM server based on open standards;
- Markets are changing rapidly , therefore when solutions are not available yet, but could be expected soon they will be included as feasible option;
- Developments to be done within D3.2 have to be feasible within the scope of available time/resources within task 3.1.

The final conclusion is that an integrated view of cost, planning and design available 'anywhere' is missing in the current field of applications. This is also something that can be developed as a plug-in of the Open Source BIM server. A complex part of making this visualization is already solved and available in this solution that can be used as the basic starting point.

Within the standardization area important improvements are made in the area of scheduling/planning the latest release of IFC (ISO 16739:2013). Also for cost calculation, which is heavily depending on Quantity Take-Off relevant developments are found like QTie. However in this area INSITER can bring important improvements to standardization area by adding quality/trust of given quantities.



List of acronyms and abbreviations

- AR : Augmented Reality
- BIM : Building Information Modeling
- DoA : Description Of Action
- EeB : Energy efficient Buildings
- IFC : Industry Foundation Classes
- HTML: HyperText Markup Language
- KPI : Key Performance Indicator

Definitions

Augmented reality

A live view of the real world where elements are augmented with graphics, video, sound or location data.

Building Management System

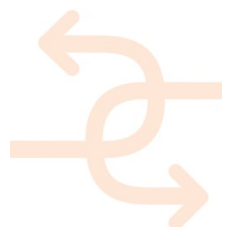
A computer-based system for controlling and monitoring mechanical and electrical equipment of a building.

Hypertext Markup Language

A standard markup language for creating web pages.

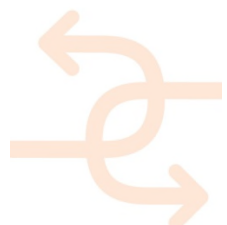
Key Performance Indicator

Key Performance Indicator is a quantifiable output measure, agreed upon beforehand, that can be used to estimate or compare performance of buildings or (sub)-systems.



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1. Introduction and scope

1.1 Task description and objectives

This deliverable is drawing the landscape of available functionality within state-of-the-art software in the context of the requirements coming from the test cases and current state of work within INSITER. The deliverable shows what is possible and more important what are the gaps between the requirements and state-of-the-art software in the context of planning and cost estimation software. Based on this it shows what development work within Task 3.1 efforts will be done to meet the requirements without reinventing the wheel.

Task 3.1 within INSITER is active until M36, this deliverable is due M18 and followed by the second and last deliverable D3.2 in this task. D3.2 contains the developments done in Task 3.1, the developments are based on the output of this deliverable D3.1. The goal of Task 3.1 is to support construction and installation. The construction workers should be effectively and efficiently provided with the most actual insight in each step of their working process. On the other hand data acquisition with mobile devices and direct online progress reporting from the construction workers will avoid redundant effort and provides live status data for improved project management.

At the time of writing the INSITER research proposal the following functionalities were foreseen for this task:

- 3D or 4D Design Coordination System to reliably manage the resolution of clashes before construction starts;
- Tracking of design, fabrication and delivery status on building element level;
- 3D and 4D information system interlinked with all relevant design data available for the side team ;
- data acquisition with mobile forms, processed through automated workflows to provide live status data;
- 4D progress documentation (for fabrication and installation);
- management dashboard with KPIs and regular reports (e.g. design status, bad weather brake down, fabrication progress and QM);
- GIS for information and documentation purposes regarding environment and infrastructure.

The main subjects / activities within this task are:

- Reviewing state-of-the-art software tools for planning and cost monitoring connected to BIM. The review will also address the possible use of these tools for quality control activities.
- Developing a reference software model for performance, complexity and cost analysis in long-term building construction. The reference model will take into consideration the project objectives as well as the requirements from the working force and the environment.
- Analysis, evaluation and determination of the requirements.
- Systematization of all planning phases (beginning with investment and performance planning to maintenance and training) and of their corresponding activities/steps and planning objects, together considered as conditional and mandatory for smooth progress of the construction process.
- Analysing the potentials for improvement with regards to time duration, the critical path in a planning process, possible parallelization of phases, possible standardization.



- Embedding KPIs (key performance indicators) as defined in D1.1 and developing use case scenarios (use of forecasting methods to explore the robustness of decision making in different scenarios).
- Realisation of the connection to the BIM-based inter-operability platform.

1.2 Contribution of partners

The main development of this deliverable is done by DMO, HVC, CARTIF and RDF.

Work Package 3 leadership is done by DMO, task 3.1 leadership is done by HVC and RDF is responsible for this deliverable. Next to the monthly meetings from the start of INSITER focussing on WP2, WP3 and WP4, there were several physical meetings between DMO, HVC and RDF in Netherlands and Germany.

The same partners DMO, HVC and RDF are working also intensively together on WP4 and produced deliverables D4.1 and D4.3 by end of month 12 with help of CARTIF.

There were a few physical meetings and several teleconferences specifically on D3.1 and on the combination of D3.1 and D3.3. The software architecture from D4.3 is used to position the results within the overall software architecture picture of INSITER. On the area of the BIM architecture and the connection of reviewed software solutions towards the BIM server there was important and valuable input from CARTIF.

Furthermore DRA and IAA gave valuable input on the requirements.

1.3 Relation to other activities in the project

WP1: Input regarding the definition of KPIs and of the KPIs themselves. This is most important due to the fact that the requirements towards the to be developed software are derived from those KPIs. Also this WP delivers input regarding the planning phases included in the building process.

WP2: Input from different measurement devices and the specific raw data and processed data formats they produce. This is necessary as there are several more requirements – in addition to those coming from the KPIs – coming from the data input which have to be considered.

WP3: Assessment and decision support systems from task 3.2
Combined working on deliverables D3.1 and D3.3 to be able to create a matching software solution in the end of INSITER project.

WP4: Actual models from different test cases, i.e. the lab test case from UNIVPM and the factory test case from DRA. Also the software / BIM architecture model where the software solutions have to become part of. All those information and data will serve as the foundation for the to be developed software.



2. Requirements

The requirements are derived from utilization fields of INSITER and are the key to the outcome of this deliverable. Requirements found in this chapter will be reused in the next chapter and lead to the definition of the needed functionalities. In addition to this the requirements will distinguish the gap with existing state-of-the-art software. Being aware of the necessary functionalities and the existing gaps will enable practical developments and work to be performed in this work package.

This deliverable will focus on cost and time planning as well as BIM integration. However this chapter will take a more generic view on all use-cases (respectively test-cases, since use-cases are not finally defined yet) within INSITER and narrow down the relevant requirements after clustering the results in the next chapter.

Within INSITER there are three Demonstration-Cases, the CARTIF building in Spain that is already existing, the 3L building in Germany that is a new development/extension and the refurbishment case in Italy (Pisa). A more detailed description of the demonstration cases can be found in WP5, there is an inventory list available for each individual demonstration case. Although a spread in both process and locations is good for capturing a complete set of use-cases, it is expected that any new real-life project will raise new use-cases. In order to optimize the results from this Work Package we do not purely look at the Use-Cases but also the underlying Test-Cases and Demonstration-Cases. The following picture shows the relation between the three concepts:

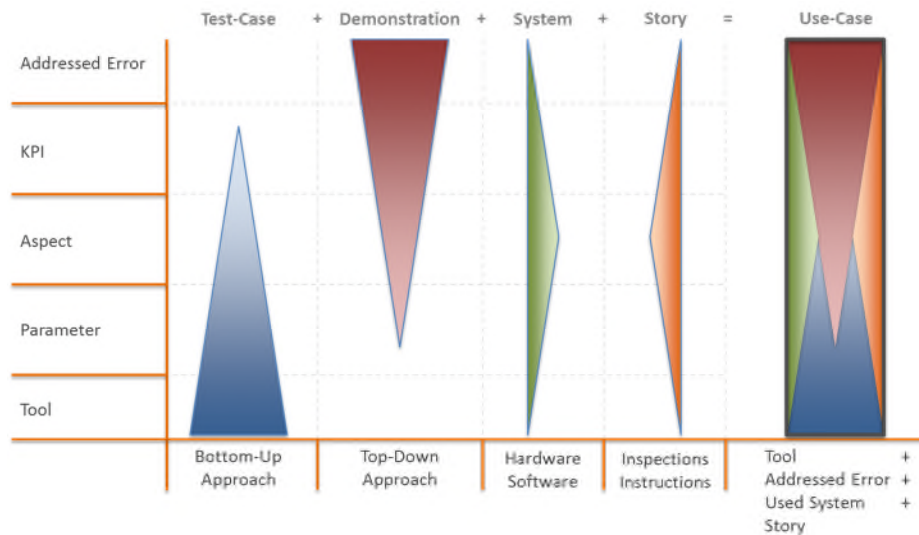


FIGURE 1

The image shows addressed errors as real practical issues, going down via KPI's and aspects being already more conceptual issues eventually ending up in parameters and tools that are practical from the technical point of view but unrelated to any specific practical issue as such. Test-Cases are looking at the tools first and in this context show how they help to support a practical error. Demonstration-Cases start with the practical error and based on this select the tools needed to solve it. Where Demonstration-Cases are specific situations happening in real-life a Use-Case is a



generalized Demonstration-Case happening in a certain context (the Story) and given a certain selected set of hardware/software (the System). A specific Use-Case can be applied at different locations, collecting its requirements and solving how to act will help solving the Use-Case when it happens. The input for this deliverable is therefore the expected set of Use-Cases that are relevant in INSITER and should be supported.

Use cases are expected to happen in real-life projects. At the moment there are three real-life projects, all in different countries (Germany, Spain and Italy) and in a different phase of the process. The following image highlights the approach for verifying the several functionalities of the software beginning with the test-cases and ending with real-life tests within the demonstrator-cases.

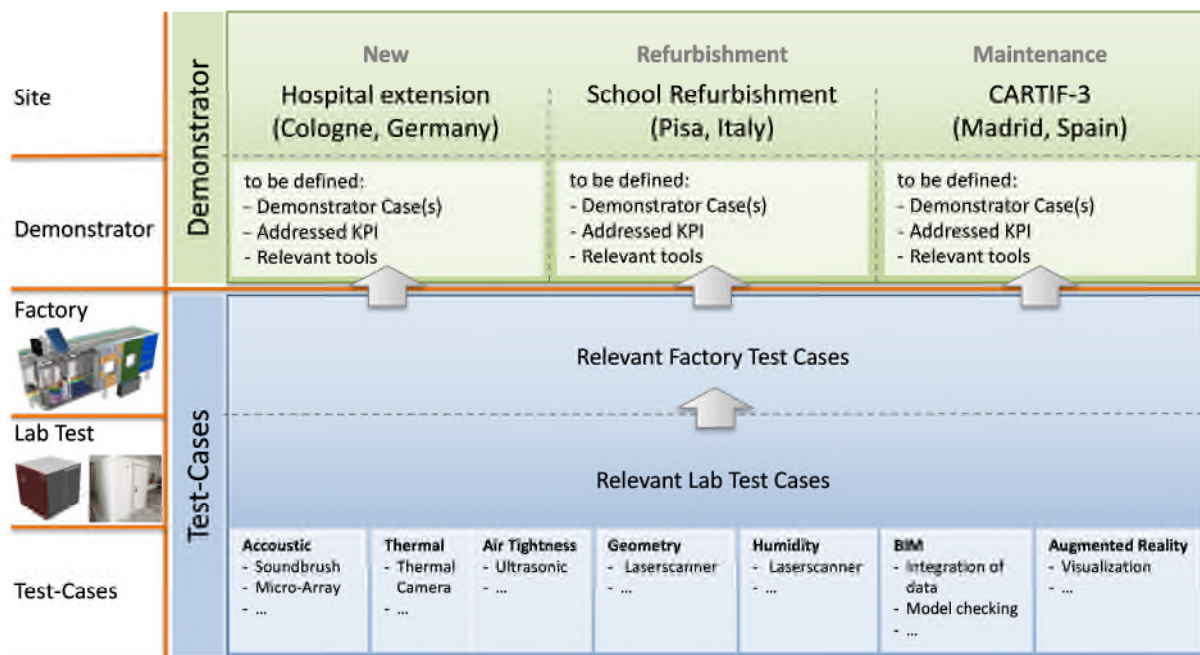


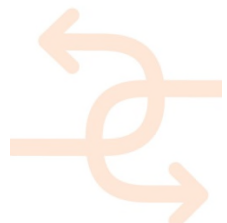
FIGURE 1

The basic building blocks for 'solving' the Use-Cases are coming from the Test-Cases. This is also the reason why the requirements will be derived from the Test-Cases based on the expectation that these requirements will align with all possible relevant requirements from the Use-Cases.

The following Test Cases have been identified for the INSITER project within technical meetings by all partners:

- Acoustics (e.g. Soundbrush, Microphone-array)
- Thermal (e.g. Thermal Camera)
- Air Tightness (e.g. Ultrasonic)
- Humidity (e.g. Laserscans)
- Geometry (e.g. Deviation Analysis using Laserscans)
- BIM (e.g. Integration of measurement results, Model Checking)
- Augmented Reality (e.g. Visualization)
- Software (e.g. developed software functionalities)

The upcoming paragraphs will describe the functional, technical and interface requirements per test case. The following chapter will combine and cluster all technical and interface requirements.



2.1 Acoustics Inspection

Within the Acoustic test case the following functions will be fulfilled:

- Determine the sound transmission loss of prefabricated building system (as described in D1.1)
- Detect acoustic insulation problems at panel/window junctions
- Characterise MEP/HVAC systems in terms of their acoustic directivity

Used devices:

- Siemens LMS microphone array: measurement of the sound pressure distribution on building component
- Siemens LMS Sound-Brush sound intensity probe: measurement of sound transmission loss of panels and measurement of the sound intensity field for sound source / acoustic leakage localisation

The test case will be applied in:

- Lab Test Environment (UNIVPM - "Cooling Room")
- Factory Scale Environment (DRAGADOS - prefabricated Building Envelope)

2.1.1 Functional requirements

Visualization of the results of the acoustic test case in the context of the complete (or partial) BIM model is the main requirement, together with storing the results, both the raw data as well as the image resulting from processing the raw data. Creation of these images is done by a software package. These packages however are part of the device (embedded software) as the raw data is not always stored in a widely known open standard.

2.1.2 Technical requirements

To be able to integrate the result images into BIM leads to the technical requirement to be able to connect the generated images with existing BIM data.

2.1.3 Interoperability requirements

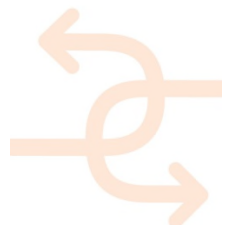
Based on the technical requirements to connect images in any kind of format to BIM the following interface requirements can be defined:

- upload and link images in a suitable way to BIM objects
- visualize the measurement result images in relation to the BIM model

2.2 Thermal Inspection

Within the Thermal test case the following use cases could be foreseen:

- Thermal Transmittance of Façade
- Thermal bridge of Insulation-Façade
- Structural Integrity of prefab panels



The Thermal test case will generate images in any kind of format (tif, bmp, png), ascii text and binary data.

The test case will be applied in:

- Lab Test Environment (UNIVPM - "Cooling Room")
- Factory Scale Environment (DRAGADOS - prefabricated Building Envelope)

2.2.1 Functional requirements

Visualization of the results of the thermal test case in the context of the complete (or partial) BIM model is the main requirement, together with storing the results, both the raw data as well as the image resulting from processing the raw data. Creation of these images is done by a software package. These packages however are part of the device (embedded software) as the raw data is not always stored in a widely known open standard.

2.2.2 Technical requirements

The Thermal test case will generate any kind of image format, spreadsheet format and/or text format.

2.2.3 Interoperability requirements

Based on the technical requirements to connect images in any kind of format to BIM the following interface requirements can be defined:

- upload and link images in a suitable way to BIM objects
- visualize the measurement result images in relation to the BIM model

2.3 Air Tightness Inspection

This test case determines the air tightness of the joints through ultra sound measurements just after the prefab elements are mounted. In this situation the building envelope is not airtight. This means that the common blower door test is not possible at this stage. The advantage of testing the air tightness in an early stage is to take corrective measures direct after the assembly with lower costs and time loss.

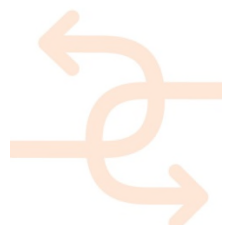
Within the Air Tightness test case the following function will be executed:

- Air Tightness of the joints of elements in the building envelope.

Note: *Air Tightness has a strong relation with sound insulation, water tightness, prevention of draft problems, prevention of moisture problems in the construction and transmission loss.*

The test case will be applied in:

- Lab Test Environment (UNIVPM - "Cooling Room")
- Factory Scale Environment (DRAGADOS - prefabricated Building Envelope)



2.3.1 Functional requirements

Visualization of the results of the Air Tightness test case in the context of the complete (or partial) BIM model is the main requirement, together with storing the results – both the raw data as well as the image resulting from processing the raw data. Creation of these images is done by a software package. These packages however are part of the device (embedded software) as the raw data is not always stored in a widely known open standard.

2.3.2 Technical requirements

The Air Tightness test case will generate a .png image.

2.3.3 Interoperability requirements

Based on the technical requirements to connect images in any kind of format to BIM the following interface requirements can be defined:

- upload and link images in a suitable way to BIM objects
- visualize the measurement result images in relation to the BIM model

2.4 Humidity Inspection

The Humidity is defined by 3D Laser Scanner / Index of reflectivity (L) [decimal value between 0 and 1]. The gradation of colours of the reflectivity index may be accompanied by quantitative validation with thermo-hygrometers for each type of material [%: water content in weight percent of dry mass].

The test case will be applied in:

- Lab Test Environment (UNIVPM - “Cooling Room”)
- Factory Scale Environment (DRAGADOS - prefabricated Building Envelope)
- Demonstrator Environment: (CARTIF - CARTIF-3 Building, Boecillo (Valladolid), Spain)

2.4.1 Functional requirements

Visualization of the results of the humidity test case in the context of the complete (or partial) BIM model is the main requirement, together with storing the results, both the raw data as well as the image resulting from processing the raw data. Creation of these images is done by a software package. These packages however are part of the device (embedded software) as the raw data is not always stored in a widely known open standard.

2.4.2 Technical requirements

The raw data of the used laser scanner must be able to process.

2.4.3 Interoperability requirements

Based on the technical requirements to connect images in any kind of format to BIM the following interface requirements can be defined:

- upload and link images in a suitable way to BIM objects
- visualize the measurement result images in relation to the BIM model



2.5 Geometry Inspection

The Geometry test case enables the capability of dimensional inspection without the implementation of complex rules via software by means of the overlapping between point clouds and BIM models, allowing stakeholders the easy-view quick inspection of geometrical errors.

The geometry test case can be part of one of the previous test cases but could also be applied stand-alone.

The test case will be applied in:

- Lab Test Environment (UNIVPM - “Cooling Room”)
- Factory Scale Environment (DRAGADOS - prefabricated Building Envelope)
- Demonstrator Environment: (CARTIF - CARTIF-3 Building, Boecillo (Valladolid), Spain)
(AICE - School Complex, Pisa, Italy)

2.5.1 Functional requirements

Generation of point clouds produce very large raw data sets with points in 3D and in some cases limited extra Meta information per point, like for example reflection factor and/or direction. The challenge is to create more meaningful data from the raw set of points generated.

2.5.2 Technical requirements

In the context of INSITER one of the goals is to compare, check and optimize the BIM model towards the real-life data. This procedure is also called “deviation analysis”.

2.5.3 Interoperability requirements

Based on the technical requirements the following functionality is required:

- Compare IFC 3D models with point clouds
- Convert E57 models (and other point cloud formats) to BIM, although partly possible with dedicated applications
- Reduce, interpret and enrich Point Cloud data with semantics

2.6 BIM Utilization

To ensure that all related processes and workflows are working the proper way the BIM model has to fulfil several requirements. Therefore it is necessary to check the model for correctness in order to avoid any obstacles which would lead to failure of the software. This should be done via Clash Detection (regarding geometrical conflicts) on one hand and on the other hand rule based model checks will be used for evaluating attributes, naming conventions and similar modelling rules.



The BIM test case will focus on:

- Geometrical Clash Detection
- Rule Based Model Checks

Currently the most known software in the market for rule based model checking is Solibri. The company behind this software application is recently sold to Nemetschek. We saw this party before in our state-of-the-art review of software concerning the BIM+ platform. With the partners in WP3 and WP4 we have identified tools like Desite MD (see also D4.3 as it is a conclusion from this deliverable) that have similar querying capabilities and a more open application program interface (API) to connect new developments.

The test case will be applied in:

- Lab Test Environment (UNIVPM - "Cooling Room")
- Factory Scale Environment (DRAGADOS - prefabricated Building Envelope)

2.6.1 Functional requirements

Given that we use BIM for storing all kind of data around the project we want to integrate as much as possible planning of the process. Using BIM means practically an IFC model, the native CAD model, accompanying documents.

The planning either already exists partly in Microsoft Project or Primavera, or needs to be created from scratch.

The functional requirement is to have a visual 4D representation of the planning in combination with the 3D part of the BIM model. This visualization needs to be accessible by all partners working on the building from any device they use, like a laptop (either Windows or Mac), but also on any modern tablet and phone.

2.6.2 Technical requirements

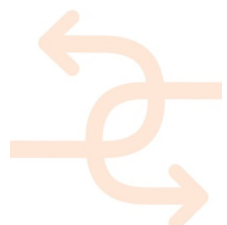
The BIM test case will require a correct and rich enough BIM model on one hand, but on the other hand it must be guaranteed that the performance of the BIM is at a high level.

2.6.3 Interoperability requirements

BIM Viewing capabilities

2.7 Augmented Reality Utilization

Augmented reality (AR) is a live direct or indirect view of a physical, real-world environment whose elements are *augmented* (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data. In the context of INSITER Augmented reality will be used on-site to combine the actual as-is situation with BIM data and to support self-inspection and self-instruction techniques, see also D1.1.



It is expected that AR will be applied in:

- Lab Test (AR Visualization Tests) (UNIVPM - “Cooling Room”)
- Demonstration Case (3L - Health Care Centre Cologne)

2.7.1 Functional requirements

To be able to apply AR in the demonstration cases as well as part of the self-inspection and self-instruction techniques the following functionality is required:

- Geometrical and semantic data defined in BIM converted into standards used for AR
- Functionality to recognize positioning relation between real world view and digital model
- Functionality for combined visualization of digital data and real-life camera image

For a large part these functional requirements are similar for AR in general. Because Fraunhofer has extensive experience with AR the INSITER project will take their proposed platform already able to perform generic AR. This means the generic functional requirements are fulfilled by the selection of this platform and we focus on technical requirements for AR in the context of INSITER.

2.7.2 Technical requirements

The technical requirements for AR that are specific for the INSITER case are:

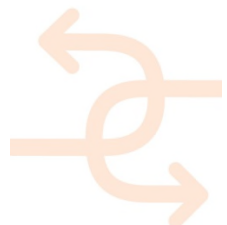
- Correct and up-to-date BIM model, i.e. to understand how the digital information and the actual camera capture are positioned towards each other parts of the digital model needs to be recognized in the camera capture. This requires a digital data or at least digital reference points that are exactly positioned as in the real world. In many cases there are slight discrepancies between the BIM model and the real world
- The BIM data need to include the geometric shape representations of the 3D model geometry of physical and spatial elements, using tessellated geometry in form of triangulated tessellations for describing the body shape (supported by IFC4). Tessellated data representation enables an efficient way of exchanging 3D shape data, both for data set sizes and for processing time. Moreover, also 3D models consisting of the X3D data format can be visualized and applied for AR
- Merge/compare point cloud data with a BIM model, i.e. point cloud data available from the real-world can be relevant as it could be used to improve the digital BIM model to have correct positioning of its elements/reference points (see “Geometry Test-Case”)
- Conversion of BIM data into X3D format, i.e. the X3D format is used by the proposed platform from Fraunhofer.
- Time Planning / Scheduling of products and processes for self-instruction and self-inspection
- Select components from the BIM-model to connect to self-inspection or self-instruction content

2.7.3 Interoperability requirements

The following interface requirements are resulting from the AR Test Case:

- Integration of IFC and actual data/geometry
- Conversion from IFC towards X3D
- Conversion of scheduling data towards the platform

IFC is expected to be in IFC 2x3 TC1, IFC4 or IFC4 ADD1 format



2.8 Software Utilization

In every test case we will make use of software, e.g. for each measurement device several software tools are available to generate the raw data and where possible to process this raw data in something more meaningful (i.e. more semantically rich). For example the generation of images by several devices is a form of software processing of the initial raw data to make the outcome of the sensor data better understandable. Also in case of the BIM and Augmented Reality Test Cases different software platforms and dedicated tools are available. In this Software Test Case we will focus on the software relevant for INSITER, but not directly connected to one of the other Test Cases.

This software is specifically focussed on:

- Cost Planning, and strongly related quantity take-off
- Time Planning, also called Scheduling
- Self-Instruction and Self-Inspection software

All software is expected to work based on BIM data.

2.8.1 Functional requirements

The functional requirements for cost planning:

- Being able to calculate quantities in volume, area etc. with a clear certainty
- Being able to visualize quantities and geometry in a clear combined view to improve trust and understanding in the computer generated quantities

The functional requirements for scheduling:

- Being able to attach process information from Microsoft Project and Primavera to a BIM model
- Being able to create process information attached to a BIM model:
- Being able to show combined planning and BIM model information in a 4D view

Being able to show this 4D view on any device, from PC/Laptop with Windows, OSX, Linux to Tablets/Phones with iOS/Android/Windows

2.8.2 Technical requirements

- IFC model access
- IFC upload / download
- Process definition support\

2.8.3 Interoperability requirements

- Time Schedule exchange (MS Project, Primavera format support or alternative exchange format support)
- Support for combined BIM and Process data (either combining it in IFC or another solution)
- Support for Visualizing combined knowledge in a 4D view
- Enabling visualization of 4D view on any modern device



3. “Clustering Reqs”

In the previous chapter the functional requirements, technical requirements and interface requirements are described based on the individual test cases. Each test case generates their own technical and interface requirements, in this chapter we will cluster the identified requirements in groups.

Based on the requirements we have defined the following clusters:

- BIM related requirements => WP4 (also described in D41/D43 and improved during time) /WP3 software handling of requirements
- Cost Calculation related requirements
- Scheduling related requirements
- Visualization related requirements
- Conversion related requirements

This deliverable focusses mainly on Cost Calculation and Scheduling; therefore not all found requirements are relevant for this deliverable. But they should be mentioned nevertheless to give a whole overview of all requirements.

3.1 BIM related requirements

BIM related requirements	processed in
IFC upload / download	Deliverable D4.3
IFC model access	Deliverable D4.3
Support for combined BIM and Process date (either combining it in IFC or another solution)	Deliverable D3.2
Clash detection and Rule based Model Checking	Deliverable D4.3
Upload (Measurement data) and connect textures to a BIM model	Deliverable D3.3 (+ further investigation)

3.2 Cost Calculation related requirements

Cost calculation related requirements	processed in
Being able to calculate quantities in volume, area etc. with a clear certainty	Deliverable D3.2
Being able visualize quantities and geometry in a clear combined view to improve trust and understanding in the computer generated quantities	Deliverable D3.2



3.3 Scheduling related requirements

Process (Time Scheduling) related requirements	processed in
Process definition support	Deliverable D3.2
Time Schedule exchange (MS Project, Primavera or alternative exchange format support)	Deliverable D3.2 / D4.1

3.4 Visualization related requirements

Visualization related requirements	processed in
Support for Visualizing combined knowledge in a 4D view Task 3.1	Deliverable D3.2/WP4
Enabling visualization of 4D view on any modern device	Deliverable D3.2

3.5 Conversion related requirements

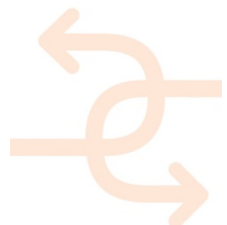
Conversion related requirements	processed in
Conversion from IFC towards X3D	WP2 / WP3
Not yet known Conversions	WP4

3.6 Scope

After clustering all relevant requirements it is essential to identify the relevant issues for development in this Task 3.1. In the context of this deliverable we focus on cost and scheduling. This means from the five identified clusters the following clusters are most important for development:

- Cost Calculation related requirements
- Scheduling related requirements

The other three clusters are also of importance for INSITER and the found requirements deviated per task or deliverable will be sent to the according task leaders. Many of the found requirements in these clusters have however close relation with the work in WP3 and Task 3.1 and will therefore in practice be partly be solved in this task. For example some of the conversions that integrate relevant cost and planning data will be solved in close collaboration between Task 3.1 and WP4. Also BIM related requirements that lead to specific components to understand scheduling and cost calculation output is part of D3.2 in this task.



4. Software functionalities (features)

As already stated in the introduction and scope the required features of the software will be defined on one hand out of the requirements of the use cases towards the software and on the other hand some are already defined in the description of action. Since the requirements have been handled in the previous chapter, this introduction of chapter 4 will focus on defining the functionalities of the required features of the DoA.

3D or 4D Coordination system

There are several tools on the market which are focussing on finding issues related to 3D design and rule based issues (functionalities to find geometrical conflicts and rule based issues will be addressed in work package 4). Detecting issues has become a common standard while BIM models are used for project development. Errors will be detected, communicated and addressed by using reporting functionalities provided by the investigating tools.

But there are few or no functionalities to coordinate and solve issues while tracking the current status of an issue. There are several requirements which should be fulfilled to get rid of the problems.

a) Providing all relevant information

To be able to coordinate an issue the decision maker has to have all relevant information at hand. Otherwise it is not possible to find an optimal solution. Therefore the coordination system must provide all necessary and furthermore additional information as there are at least:

- Information about the location (coordinates x, y and height or level), optional: map of location
- Date when the issue has been detected
- Description of the issue and related trades
- Additional information like 2D drawings

b) Fields to enter coordination information

For all participating persons it must be possible to enter information into the coordination system to solve an issue. Therefore it must be possible for the design coordinator to enter decisions on how an issue will be solved and on the other hand it must be possible for a designer and/or site worker to leave information about performed actions.

Following information is relevant to be attached to those issues:

- Classification of an issue (must this issue be solved in design phase or might it be handled on site)
- Status of the conflict (is it new, has it already been coordinated but still unsolved, has it been fixed already)
- Due Date (until when has the issue to be fixed to avoid any delays and additional costs)
- Responsibility (who is responsible to solve the issue)
- Coordinated Solution (what is the approach to solve the item)
- Completion Memo (to enable the responsible person to leave feedback)

To enable all involved person to be informed about tasks to be done and status of the several issues, the coordination system should be an online solution which is accessible for all participants.



Tracking of design, fabrication and delivery status

To create the functionality for tracking design, fabrication and delivery status the software system must be able to receive information about the status of a building object. This might be possible via an automated workflow which informs the system by changing an attribute value if a specific action has been performed (e.g. upload of a required 2D drawing is finished) or it might also be an manual process step (e.g. a site worker enters information about the progress of a specific installation). These options lead to some requirements towards the software for INSITER project as there are:

- a) Receiving information - The software must be able to receive information (automated or via manually input) and store them in the context of the relevant building part.
- b) Workflows - If information has to be triggered in an automated way it must be possible to create workflows which perform a certain action.
- c) Mobile Forms - To enable Site Workers to enter information they must have options at hand to enter the relevant information. To attach information (e.g. progress status) they will use mobile forms which will be filled in on a mobile device and attach all relevant information into the system (where it will be automatically be attached to BIM)

To enable tracking and progress reporting the requirements are an input interface (e.g. mobile forms), the interoperability with the BIM (to attach information to the relevant building element) and automated workflows to trigger further actions (e.g. sending notification mails).

Information System and Dashboard functionality

To enable decision makers like project managers to keep track on their project and to be able to initialize counter measures in case of any unforeseen events, the project manager must be able to have as much information at hand as possible. Due to the fact that it is impossible to search for all relevant information manually in a short time period, it must be possible to request related information from the system as soon as an issue occurs. This leads to following requirements towards the software:

- a) Linked information - All relevant information (e.g. documents, values and dates) must be interlinked with each other to enable user of the information system to gather all related information on demand. If possible this should be possible on several information levels (e.g. show all information about a specific wall element or show all building elements which a specific sub-contractor has delivered)
- b) Access to information - All information should be accessible via a selection within the 3D model (show all information related to this particular wall) or via lists (show all 3D objects which belong to level 5).
- c) Dashboard - The software should be able to compare available information with predefined KPI values and present them in an intuitive way, which means that critical values will be highlighted to warn the project manager about critical issues.

Requirements from these features are the accessibility of all available data, the links between related information and an interface to present the information in an intuitive way.



To complete the list of required features the following sub-chapters focus on the software functionalities that we foresee to be needed, based on the requirements. We will only review state-of-the-art software areas in the following areas:

- Cost Estimation Software
- Scheduling Software

In both areas we will focus on state-of-the-art applications in this specific discipline and how they are related towards BIM or more specifically how IFC import/export is arranged or could be created.

4.1 Cost Estimation Software

For every selected application we look specifically at the following items:

- Correct quantitative values; is it possible to see how quantitative values are generated and
- Overview of aggregation of values

The integration of and support for BIM is the main subject of interest.

Several state-of-the-art software applications in the area of cost calculation that have support for BIM could be found. Some of them focus on distribution in many different countries, sometimes even world-wide. However also several real state-of-the-art applications with sales limited to one country, like ISY Calculus for Norway or PRESTO and ARQUIMEDES for Spain, are found.

As the market seems fragmented and using a new tool dedicated for this discipline is complicated it is not expected a generic advice for selection of specific tooling is functional for the use-cases. People should use what they currently use. The next chapter will therefore focus on functionality and capabilities in the context of BIM and IFC. When we know what to expect of state-of-the-art at the moment we understand what part of requirements can be covered with correct selection of software.

Even if in specific use-cases these requirements are not met by the used software but other existing solutions are available it is not effective to solve this in INSITER. It makes more sense to push the existing software updating its functionality or advising the use-case to transfer to more modern available software solutions.

4.2 Scheduling Software

The number of scheduling software packages that also support BIM are limited. When we look at the standardization efforts done in the past years it can be expected this will change in the short term. In the next chapter 'Standardization related state-of-the-art on Planning' will explain more clearly what the reason for this expectation is.

However as we need to understand the current state-of-the-art situation at the moment, we will look at one application that is really BIM enabled in the context of planning. Also one scheduling application will be shown where BIM is not integrated but as it has a flexible and powerful API an external partner could create a connection to BIM via the delivered API.

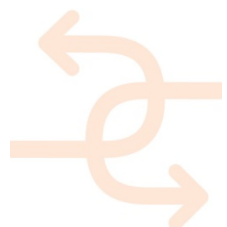


4.3 Missing Software

Based on the requirements it is already mentioned that the above named state-of-the-art applications do not cover all requirements. Looking at the not covered requirements we see the following typical software that is missing:

Online viewing of:

- 4D scheduling (question IFC 2x3 of IFC4, maybe for scheduling part we need different format) including, site logistics/construction site / progress monitoring
- Cost / Quantities per object and aggregated objects and clear certainty of the quantities based on comparison of calculated values and given values by CAD



5. State of the art software

This chapter will review state-of-the-art software relevant in the context of this deliverable. By understanding what state-of-the-art software is capable of doing it is possible to define the gaps between actual available functionality on the market and requirements coming from the use cases, demonstration cases and test cases.

A review of state-of-the-art BIM server applications and BIM viewer applications can be found in D4.3. In this Chapter we will review the following areas:

- Cost Calculation for BIM
- Scheduling for BIM
- Cost Calculation for BIM Standardization
- Scheduling for BIM Standardization

5.1 IFC (Industry Foundation Classes)

As this chapter will focus on BIM integration in software applications and activities in the area of standardization this paragraph shortly explains the main BIM open standard IFC. IFC is the short name for Industry Foundation Classes and a standard finding its first use as such in 1994 while its origin goes back to the early days of the STEP community even 10 years earlier.

IFC is since 1995 an open standard developed and supported by the organization Building SMART. IFC tries to cover meaning full exchange of information between all disciplines in the building and construction sector and for the complete process from design to demolition. However it is fair to say the standard is currently mainly active in the process phases from early design till when the physical building is just finished although interest in the area of facility management is growing rapidly also.

IFC is a relatively complex and large open standard with a large widespread community and strong activities in Europe. With hundreds of applications supporting IFC in the fragmented landscape of software solutions for the industry it is the main open standard for data exchange between applications. Especially in the area of Computer Aided Design (CAD) all major software vendors have high quality support for this open standard.

One of the mistakes often made is that IFC is expected to be a 3D exchange format. Although 3D is an important part, it is all about the objects, the semantics, i.e. the meaning of objects, properties and behaviour as well as about relations and networks within the data. It does not only exchange what you see, but it also stores (part of) the meaning of the building information exchanged in an object based manner. More details on IFC and BIM can be found in D4.1 and D4.3 also.



5.2 Review of Cost applications all BIM enabled with support for IFC

The review of applications is done with the focus on the support for and integration of BIM and more specifically on IFC support.

5.2.1 ISY Calcus (NorConsult)

ISY Calcus is a Cost Calculation application mainly developed for the Norwegian market. It is part of a larger product suite G-prog that connects different elements. The product ISY Calcus has support for BIM and IFC for a long period of time (it is going back for 10 years).

A new visualization of the BIM model makes it much easier to navigate in the model. NorConsult put a lot of effort into improving the quality of amounts from the IFC file. One cannot rely on the quantities that CAD programs export to IFC files in all cases; therefore it calculates all the amounts based on the actual geometry as a control. The program is able to work with large documents and make changes to many objects simultaneously.

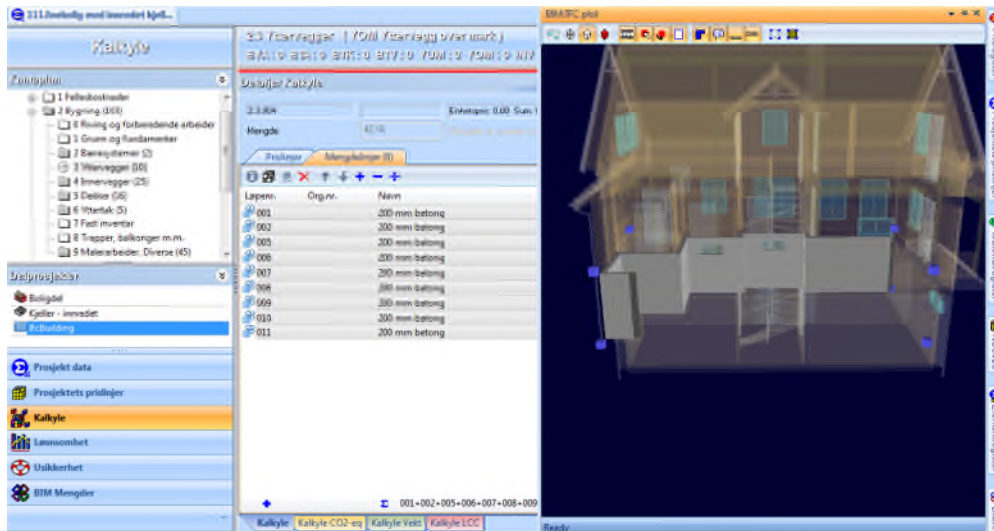


FIGURE 2



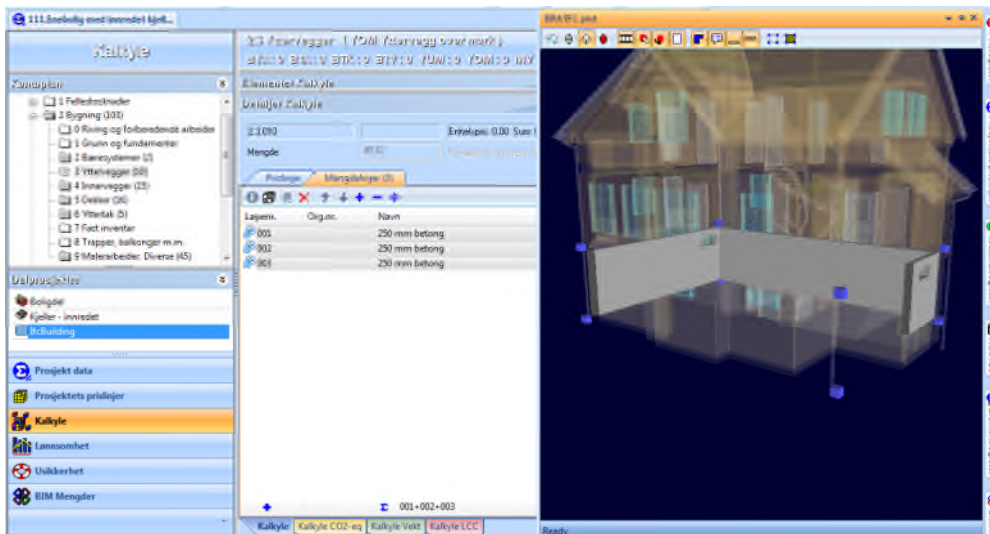


FIGURE 3

New and updated items can be displayed separately with the old and new amounts. This enables a view on the history of IFC objects during several imports. Selected objects and quantities can be visualized in the context of the complete building as shown in figure 4. Quantities will be retrieved from properties generated by CAD application and by recalculation of quantities based on the geometry.

5.2.2 CostX (Exactel)

CostX is an international application for Cost Calculation developed in Australia. Since a few years it is used more frequently in Europe as well. CostX is BIM based and has a long term IFC support as is the case with Calcus.

Within Exactel 6 dimensions in Building & Construction are identified where Cost is the 5th dimension:

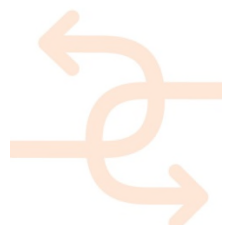
- 2D: 2 Dimensions - Paper Drawings, 2D CAD files
- 3D: 3 Dimensions – Models, 3D CAD Virtual Models •
- 4D: Adding the aspect of Time (Scheduling) •
- 5D: Adding the aspect of Cost (Estimating)
- 6D: Adding the aspect of Life Cycle Management (Owning) BIM is about sharing knowledge. It provides a basis for Integrated Project Delivery

CostX has the following capabilities:

- Read, edit and interrogate native BIM files
- Add relevant QS, BS, PM or FM information
- Import and export to other systems such as IFC
- Extract quantities from BIM models and able to import QS data from an external database

The typical benefits for use of BIM in 5D

- Dramatically reduced measurement time
- Elimination of errors and improved accuracy
- Definition of scope and cost is transparent to all project stakeholders
- Continuous real-time updating of costs with design
- Greater accountability in management of projects



5.2.3 CostOS (Nomitech)

CostOS focusses not only on BIM but also on GIS. According to their own description CostOS is truly 'BIM enabled'. Similar with the previous two state-of-the-art applications CostOS has a long history with BIM and IFC support for a long time. With others Nomitech was active within the QTie substandard from Building SMART.

The philosophy behind CostOS is that the internal structure is object based and quantities are directly derived from the geometry and its representation. The driver of the quantities and the cost is the individual object as defined in the model.

Keeping BIM and objects as fundamental base-line is something seen at several Cost calculation applications, this is probably one of the reasons that BIM and IFC are so well integrated in the state-of-the-art applications we found.

5.2.4 iTWO 5D enterprise solution (RIB)

iTWO offers a complete 5D (Schedule and Planning) solution, therefore this product could also be added to the next paragraph. This solution introduces next storing project specific data, also integrated data over past projects. The knowledge from previous projects can be used to improve current projects and review initial cost planning against actual situation, as well as reuse 'templates' of cost calculation.

Estimated items can be connected through the individual BIM objects throughout the complete lifecycle. iTWO has support for BIM as well as certified import for IFC. It is possible to create rules on top of the BIM model and flexibility is very good.

5.2.5 Autodesk Quantity Takeoff - QTO (Autodesk)

Autodesk Quantity Takeoff is an extension on Autodesk Navisworks. Navisworks is especially good in supporting many different file formats and showing them in one view. Although NavisWorks itself is expensive its resulting files can be visualized for free on any system.

Also Navisworks allows you to add support for your own formats if not included already via the same API they use themselves to create import of file formats. Not only adding import formats can be supported but also creating plug-ins is possible within NavisWorks. In case very specific functionality is needed the API enables users to build/extend this themselves.

Navisworks has support for IFC, this was not a perfect implementation however it improved over the last years. Next to that as Autodesk is also developer of Revit and AutoCAD the implementation of the DWG format is better than most applications, the result of DWG being a closed proprietary format. The same counts for the native Revit format.

5.2.6 PRESTO (Presto SA)

Presto is a Spanish BIM oriented budgeting and measurements software, designed by Presto SA, that integrates management and control of costs for building and civil works, comprising the different needs of all actors involved in all phases, including architects, engineers, quantity surveyors, BIM managers, project managers and contractors.



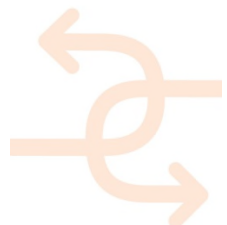
Presto is designed to facilitate the standardization, use and exchange of data between the different actors of the construction sector.

All information is integrated in the budget, from planning to certification, including the economic control of the work, the quality management and the documentation of the finished work, providing a shared environment and orderly project management.

More details on the functionalities and advantages of each Presto module at each stage are shown below:

Construction Phases	PRESTO Modules	Functionalities and advantages
Budgeting	PRESTO Budgeting	Budgeting and measurements: Making budgets and offers for building and civil engineering works
		Customize reports: Customization and creation of new reports
	PRESTO Cost-It	DWG drawings: Retrieval of measurements from DWG AutoCAD drawings.
		BIM: Automatic generation of budgets from a Revit BIM model by means of Cost-It plugin in the format of Presto.
Planning	PRESTO Planning	Planning: Economic planning, financial planning, costs and time schedule.
Execution	PRESTO Execution	Contracting: Entire contracting process and procurement of the necessary resources to execute the works.
		Project management: Certification and economic monitoring of the construction works.
		Billing and control: Production, billing and cost control for construction companies.

The Presto tool is easy to customize, flexible to use in different legal and cultural environments, which provides multiuser access to works in local network and through the Internet. Presto is bi-directionally integrated with Microsoft Office, Primavera, Revit and other software used in the design and execution of construction works. In addition, Presto develops and allows the creation of plug-ins or via an API (Application Programming Interface) to meet the specific needs of customers.



5.2.7 **ARQUIMEDES (CYPE Ingenieros SA)**

Arquimedes is a complete Spanish tool for Project Management, designed by CYPE Ingenieros SA, that allows to control and manage constructions works, including budgeting and measurement, bills of quantities, project certifications and specifications. Arquimedes works with parametric price banks (including those compiled in DLLs), with multiple prices (prices for labour, materials, etc.), and with specifications (if the price bank you are working with includes them). It includes a dictionary to quickly locate concepts based on key terms, and associates graphics to job items, chapters and unit prices. More details on the functionalities and advantages of each Arquimedes module are shown below:

Functionalities	ARQUIMEDES Modules		Advantages
Purchase management		Arquimedes & Job control	The Purchase management module of Arquimedes and Job Control allows users to calculate the supplies required to execute a job and foresee invoice payments from suppliers and subcontractors.
Automatic quantity import from drawings and link with CAD programs	Arquimedes	Arquimedes & Job control	Using this module, quantity lines can be obtained from DXF or DWG files. Quantities which can be imported include: counted amounts of elements, linear lengths, polygonal lengths, circular perimeter lengths, rectangular areas, polygonal areas, etc.
BOQ Consolidation	Arquimedes	Arquimedes & Job control	The BOQ consolidation module of Arquimedes allows for several existing bills of quantities to be included in a base bill of quantities (which can be empty), and maintain the link between the incorporated job units and their original bills of quantities. This way, the base bill of quantities can be updated with the changes which are carried out in the original bills of quantities.

Further information can be found in the Arquimedes website, <http://arquimedes.en.cype.com/#index> (in English).

5.2.8 **Summary**

What we see in Calculation applications is a long term support for BIM and open standard IFC. Integration started early and support for this standard is taken very seriously. This is not only limited to support for visualization of geometry and properties from CAD, but also quantity take off based on the geometry and comparison with actual values is embedded in some of the applications.



5.3 Review of Planning applications

5.3.1 Synchro Pro (Synchro Ltd.)

The most important advantage of Synchro Pro in comparison to other scheduling tools is the direct combination of time scheduling and the handling of a BIM model. This means that working on a time schedule and creating a 4D simulation will be done in parallel. Scheduling mistakes become obvious at once and may be directly adjusted.

The classical approach on creating a 4D simulation is to set up a time schedule and separately create a BIM model. Both elements have to be combined with each other to get a visualization of the 4D sequence. To solve upcoming issues the native software for scheduling and/or model creation is used and afterwards the process of combining both parts has to be done again in another iteration.

Synchro Pro offers a great advantage by combining those two tools and speeds up the time scheduling process (in case the process planning should be done in 4D).

It should be mentioned that Synchro only offered simplified modelling tools and does not aim on replacing fully functional CAD software.

5.3.2 MS Project (Microsoft)

Microsoft Project is a project management software program, developed and sold by Microsoft, that is designed to assist a project manager in developing a plan, assigning resources to tasks, tracking progress, managing the budget, and analysing workloads. Microsoft Project was the company's third Microsoft Windows-based application, and within a couple of years of its introduction it became the dominant PC-based project management software

While part of the Microsoft Office family, it has never been included in any of the Office suites. It is available currently in two editions, Standard and Professional. Microsoft Project's proprietary file format is .mpp.

Microsoft Project and Microsoft Project Server are the cornerstones of the Microsoft Office enterprise project management (EPM) product.

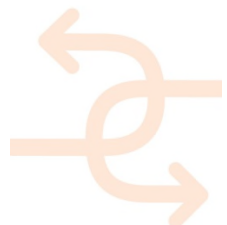
There is no out-of-the-box solution to support BIM. However MS Project has a clear API where it is possible to program a dedicated application against and include this extra functionality as plug-in for any other user of this software.

Integration of such plug-ins enables including BIM even with a 3D visualization to enable a clear comparison between the BIM model and the planning, it is possible to store handles in any specific planning to remember and exchange such knowledge.

Within the scope of INSITER development of such a tool is out of scope as it will take a lot of resources and the benefit over existing applications seems to be limited. Where MS Project does not support BIM directly, the schedules can be exported and imported in applications that do like Synchro Pro discussed above.

5.3.3 Summary

Integration of BIM and more specifically open standards like IFC is much more limited than what we found in Cost Calculation applications. Nevertheless it does not make sense to redevelop or extend existing applications within the scope of INSITER. As we will see in the next chapter support for planning in the latest release of IFC is heavily improved and therefore it is expected support for IFC makes much more sense using the latest version of IFC. While IFC4 is gaining interest quickly it is expected that more planning applications supporting BIM/IFC will come to market in the next few years.



5.4 Standardization related state-of-the-art on Cost Calculation

An important but already older standard is the QTie (Building SMART alliance Quantity Takeoff information exchange) standard. This standard is part of Building SMART, the same organization that has also control over open standard IFC. This QTie standard is already a bit older and not actively supported, nevertheless several important 'rules' for QTO standards in general can be found in QTie:

- declared for all objects
- noted with method of measurement
- base quantities based on geometry for early stage design: volumes, areas, lengths.
- regional verification needed for detailed measures
- metric and imperial allowed.

The open standard IFC is important for INSITER and widely accepted. IFC allows roughly two ways of storing information relevant for Quantity take-off:

- Quantitative Properties (as PropertySets)
- Calculation Geometry issues

Quantitative Properties have a schema component that defines the type of measurement independent of unit or object/value it is defined on, the available schema types are IfcQuantityLength, IfcQuantityArea, IfcQuantityVolume, IfcQuantityCount, IfcQuantityWeight and IfcQuantityTime. IFC has a standard set of roughly 3000 properties that are described, it is also possible to create own application or even user specific properties.

The geometry itself is exactly defined, otherwise visualization would be complicated. This means that components that visualize the geometry can also be used to calculate quantities of this geometry. Typical measures that could be calculated are Volume, Area, Perimeter and Centroid. However there are much more calculated values possible, for example the inner wall area for example needed for painting area.

Note:

in many cases the calculated values are different from the values given by the CAD system, as quality of measures is of essence and both methods are redundant it is possible to say something about the quality of measurement values. We found similar functionality in Calcus.

5.5 Standardization related state-of-the-art on Planning

IFC is meant as exchange solution for all disciplines, this means support for scheduling is available for a long time at least for a decade already. IFC2x3 Final and IFC 2x3 TC1 are available for a long time and at moment of writing the later one is still the main standard used. Scheduling was complicated but possible in this version, however many modern scheduling applications have capabilities that cannot be stored in IFC 2x3.



IFC4 and IFC4 ADD1 are the new releases of IFC and available for years already, however adoption in the market goes slow and even new development at this moment are frequently based on the previous version. In the area of scheduling / planning / 4D the capabilities in IFC4 (ADD1) got a major upgrade. Although still complicated the capabilities of storing schedules in IFC4 are in line with what modern scheduling applications offer and store in their own exchange format. IFC4 (ADD1) important large updates on Planning capabilities (very close to capabilities of MS Project XML exchange format), these include:

- Major efficiency improvement for 4D and 5D (Cost).
- Rework of the scheduling definitions, adding calendar support, switch to ISO 8601 time format, and simplification of task relations.
- First prototypes show full support for MS Project and 75% decrease of model footprint.
- Add type/occurrence concept for processes.
- Re-usable definitions for tasks, events and procedures.

See also a screenshot from the heart of the IFC4 scheduling schema update.

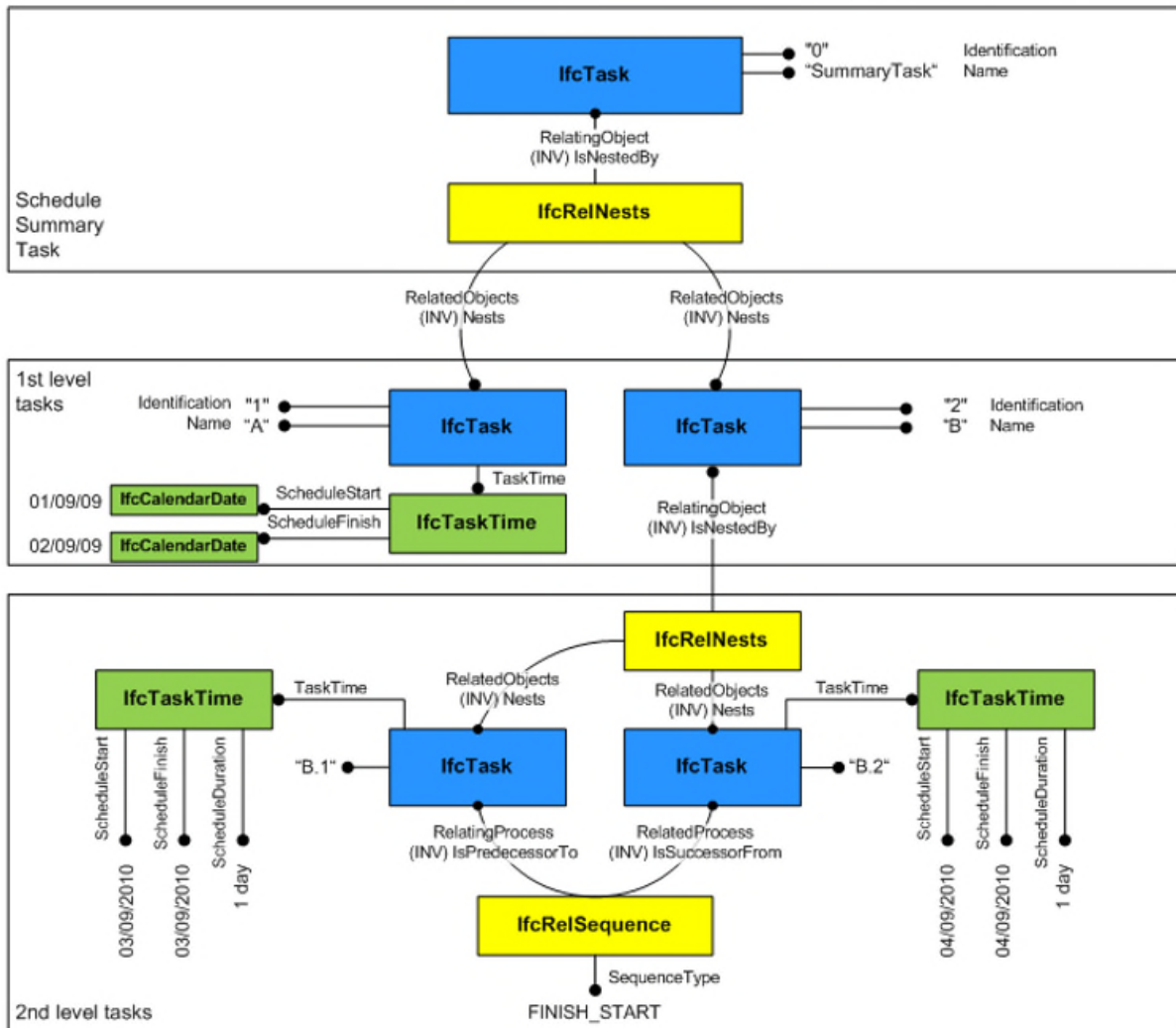


FIGURE 4



6. Software architecture (BIM)

The global high-level architecture comprises the total concept of the INSITER project, covering multiple Work Packages objectives which interact among them. Apart from that, the architecture is a multi-layer design that divides functionalities. From bottom, data acquisition layer represents the data sources that feed the INSITER tools. Next, an adaptation layer is envisaged for the translation of data from the multiple data formats in a common language to handle the information. Third layer is the BIM one which makes up the core by means of the BIM platform, services and extended functionality. Finally, at top, the application layer is basically the graphical interfaces. It is important to remark that the arrows display data exchange between layers and not among components. Thus, the data flow goes in the direction of the arrow from one layer to another.

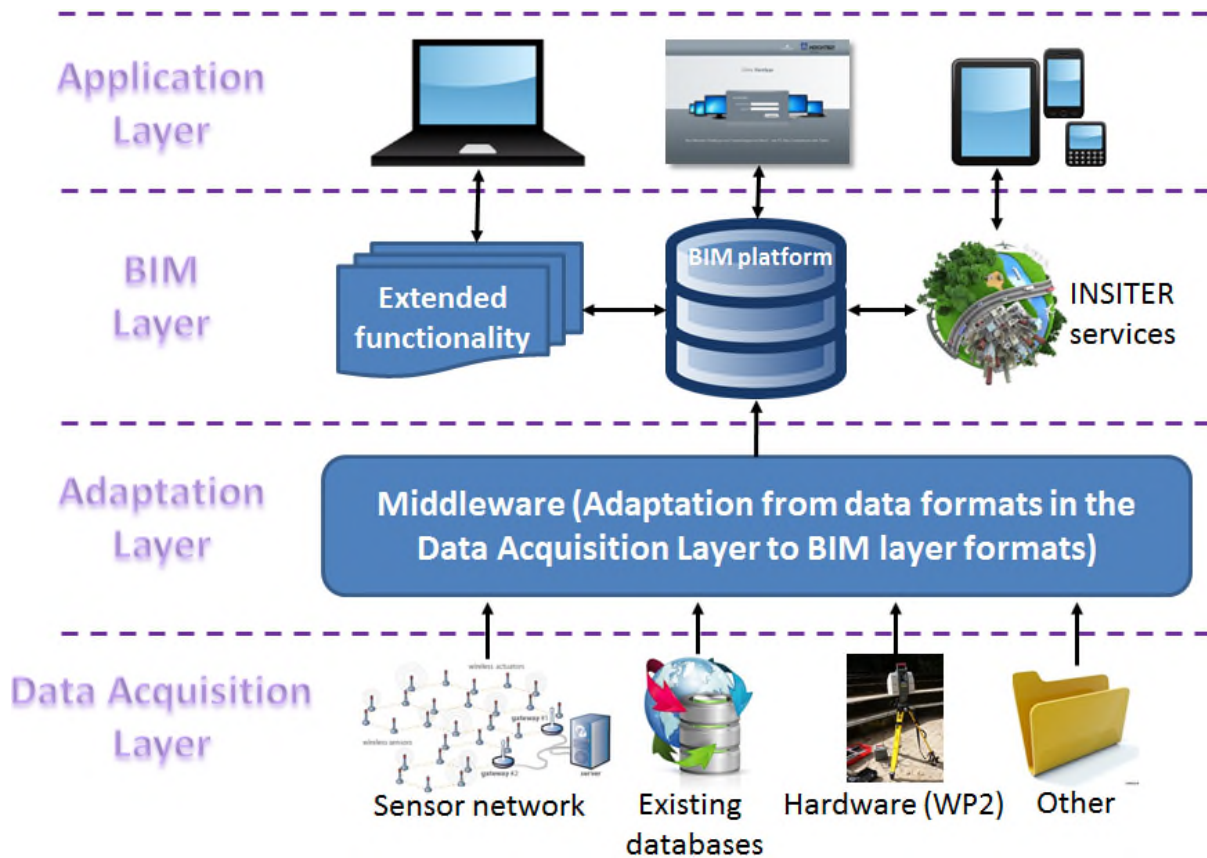


FIGURE 5

This figure is showing the overall architecture as defined in Task 4.2 and explained in detail in D4.3. In this Chapter we link the overall architecture with the subjects of interest in this deliverable. To prevent double work, the connected chapter in deliverable D3.3 focusses on application interdependencies. More details of the layers are explained here under.



6.1 Data acquisition layer

This layer contains all the data sources which are useful for the self-inspection and self-instruction tools in INSITER (mostly from WP2). First of all, existing or new sensor networks in the buildings give dynamic information of the building status which are helpful for the maintenance and operation of buildings. This process is also integrated in INSITER, therefore, the communication with these resources have to be taken into consideration. Besides, existing databases feed the INSITER tool. These databases are widely understood as dynamic (historic) data from the building, static (building information) databases, common errors (database from D1.1), etc. As well, data from the hardware equipment (WP2) need to be integrated in the platform as the hardware provides the meaningful information for the self-inspection and self-instruction techniques. Finally, other data could be integrated as happening with the INSITER SharePoint, GIS information or any other useful data required for the INSITER tools.

6.2 Adaptation layer

As aforementioned, each one of the elements in the data acquisition layer “speaks a different language”, therefore data formats differ among them. Then, this layer treats the adaptation of the data formats into the BIM data to be stored. It is common to name these functionalities via middleware platforms. Then, WP3 (in conjunction with WP2) develops a middleware which is able to connect the data resources and generate data in BIM-interoperable information.

6.3 BIM layer

This layer is composed by multiple elements. First of all, the BIM platform selected in the WP4 is the core of the layer and the INSITER tools are based on the BIM information. It is likely to need the extension of the functionalities of the selected BIM platform. For example, commonly the BIM platforms make use of internal databases to store BIM data. However, additional information is not possible to be stored into these databases. Then, an extended functionality could be required, such as another database that persists INSITER data (e.g. files). Another example would be the extension of the BIM platform by plugins for planning or cost in order to create 4D BIM concepts. In this case, WP3 and WP4 work together with the aim of defining, developing (when needed) and integrating these extensions. Finally, for the INSITER tools of self-inspection and self-instruction, a set of services are required. WP3 then develops those services according to the use cases and KPIs. These services make use of the INSITER hardware tools and software so as to implement those services which cover the definition of the use cases.

6.4 Application layer

Last but not least, the visualization is one important part in the INSITER platform because the end-users require to show and interact with the services via browsers and mobile devices. Then, from the WP3 perspective, a set of Web-based tools are foreseen.

In the particular case of the WP3, only a set of layers are applicable, but it is important to remark the interaction required with other WPs and that is the reason for presenting the global architecture within this deliverable. Then, WP3 is in charge of the middleware and application layer mainly, although it is also involved in the BIM layer together WP4.



6.5 Layers applicable for WP3

Details within WP3 are described below.

6.5.1 Adaptation layer ('Middleware')

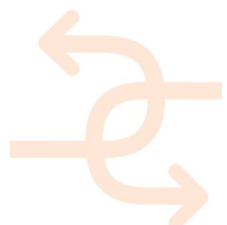
From WP3 perspective the adaptation layer is one of the most important layers because it is responsible for data gathering. First of all, taking into account the test use cases and the requirements obtained from them, the middleware layer implements the interface with the different sources of data. In the case of the hardware instruments, WP2 defines a set of data formats by which the measurement devices would send data (e.g. png images from thermal cameras). Then, WP3, via middleware platform, should be able to convert this output into input for the BIM (e.g. from images to textures) as it has been established within the interface requirements of the equipment above. Additionally, other data sources could be necessary for the proper behaviour of the INSITER platform. That is the case of the SharePoint where information in files format could act as input for the BIM functionalities; therefore, the middleware would require to parse also these files. Besides, in the scenario of buildings' maintenance, sensor networks provide helpful information for the self-inspection and/or self-instruction tools, thus, although not being mandatory, this interface has to be considered for assuring extensibility. Last but not least, existing databases of the building (e.g. common errors, historical data...) could be interesting for the proper implementation of the functionalities. Thus, SQL and non-SQL databases could be required, but available ones would be analysed in further deliverables. Finally, the output of the middleware is data flows compliant with IFC in order to be stored in the BIM platform. Nevertheless, other data could be stored in multiple formats within the extended functionality, i.e. SQL databases, files etc.

6.5.2 Application layer

This layer is also important from the WP perspective because, at the end, the INSITER platform should run through visual applications which provide the stakeholders useful information and the capability of interacting with the tools, as well as exchange data for running the self-inspection/instruction tools. Then, WP3 develops the graphical interface with the aim of allowing the visualization and interaction. In terms of D3.1, plug-ins, ad-hoc applications or any other solution will be determined in order to implement the services for cost and planning where the management of project costs and schedules is the main goal. Then, available software is merged with the INSITER development with the aim of integrating tools so as to create a more powerful application to be used by the end-users. Moreover, from the use cases and technical requirements above, additional features of the visualization tools could be necessary. For instance, the overlapping of hardware textures with the BIM information is related with one of the use cases where step-by-step (planning) results are envisaged for the construction works with the objective of providing intermediate outputs to the stakeholders in order to solve and/or avoid errors in the following steps of the construction.

6.5.3 BIM layer

Finally, in spite of the fact that this layer is focused on WP4, WP3 needs to collaborate in terms of extended functionality and services. Firstly, WP4 defines SQL databases (mainly PostgreSQL) with the aim of storing non-IFC data. Then, WP3 needs to interface this database to extract data from these databases, together BIM information. Additionally, in conjunction with WP4, self-inspection and self-instruction services have to be implemented (within T3.1 associated with costs and planning). This service will be the main input for the visualization tools; therefore, WP3 is also involved in the implementation of these services.



7. Software proof of concept

This chapter describes what is already available on the market based on the State-of-the-Art software review in Chapter 5 and how this fits in the BIM architecture as described in Chapter 6. It shows what is already available in existing software and what we would like to develop in the scope of INSITER.

7.1 Cost Estimation Software

Support for IFC in different cost estimation applications is already available. There is no need to invest largely in developing a competitive application. One of the challenges is that clear definition of properties in IFC concerning quantity take-off is missing and many viewers and components have issues importing correctly geometry. This means an always correct and safe value for volume, area and other quantity calculation values cannot be promised. INSITER can apply a solution over here by showing the user in how far he can trust the values given.

Technologies and agreements in creating a value for trust worthiness of a certain quantity value is relevant. Therefore in the area of standardization it is relevant and possible to improve and extend open standard IFC4 ADD1.

Especially Cost Estimation applications seem to be well integrated with BIM and open standards. Even applications that fell out of scope for our state-of-the-art are able to handle open standard IFC and more generic BIM information in some kind of way. There is still an important issue with understanding and trusting the calculated quantities, however in the context of INSITER it does not make sense to reinvent the wheel and create a cost estimation software package from scratch nor does it make sense to add (open standard) BIM support to some cost estimation software packages that do not have such connections at this moment.

7.2 Planning / Scheduling Software

Available software for planning and scheduling can be found easily, however adding the requirement for supporting BIM reduces the choices considerably. Where cost calculation software for the building and construction sector clearly embraced BIM and open standards in this area like IFC the scheduling software with such integration is very limited. We actually found only one solution Synchro Pro that really was able to integrate open standard IFC into their scheduling application.

Like with Cost Calculation it does not make sense to create a new software solution for planning/scheduling. Even a plugin to support BIM in applications like Microsoft Project seems to be a complicated and time consuming path with minimal benefits for INSITER. With new extensions of scheduling available within the latest version of open standard IFC it is also to be expected integration of BIM in scheduling applications will become more widely available in the next few years.



7.3 Visualization

Where applications for defining schedules and applying actual cost calculations are available on the market tools to visualize the combined data are limited. There are several BIM server related solutions from larger vendors like Autodesk and Nemetchek on the market in this area like BIM+ and BIM 360 Glue. They are however open in a limited way and still are missing the functionality to show integrated Cost and Scheduling data on any platform taking into account that the same solution also needs to support self-instruction and self-inspection tooling as well as a connection towards the augmented reality functionality.

The requirements boil down to developing a front end solution on the BIM server to visualize this data integrated with the 3D BIM model. This can be an extension of the current available plug-ins to visualize 3D on top of the selected Open Source BIM server.

For more information on the Open Source BIM server and also competitive solutions like BIM+ and BIM 360 Glue it is good to read D4.3 where a review of different BIM servers is included.

7.4 Standardization

Apply extensions to the latest IFC standards and creation of a trust worthiness feedback on quantity values of geometry of objects in an IFC based BIM file.

In the area of planning and scheduling the connection with BIM and open standards like IFC is available but only with a small set of applications and in a limited way. The support for scheduling within the latest standard IFC4 ADD1 is however considerably more detailed than what was possible in IFC2x3 and using the latest version of open standard IFC for supporting scheduling in a BIM context seems advisable when used to store scheduling information. Although one application was found with integrated support of planning/scheduling and BIM, especially via open standard IFC, it is still far from embedded in the market. It is expected that the market will develop tools in this area of combined BIM and scheduling.

7.5 Self-Instruction and Self-Inspection

In this paragraph the connection to Self-Instruction and Self-Inspection is given. Although the results of this deliverable and therefore also the following deliverable in Task 3.1 are based on the requirements coming from INSITER the focus is on Cost Estimation and Scheduling. To ensure that the results from Task 3.1 are not only covering the found requirements and the task description but also the greater vision of INSITER this paragraph describes the relation between self-inspection and self-instruction and the main subjects Cost Estimation and Scheduling and illustrates as a proof of concept how this will work in the software that will be operational for INSITER.

7.5.1 Self-Instruction

On the part of Self-Instruction software it is expected that Task 4.2 will develop a tool to support self-instruction models based on BIM data interacting with the end-user in a web-enabled manner. For both cost and scheduling it is possible to



be tightly integrated with BIM as is described in this deliverable. In cooperation between task 4.2 and task 3.1 it is therefore important to enable visualization of this information available in BIM through this software as foreseen in task 4.2. The 3D/4D coordination system that will be developed as part of D3.2 will contain a part that does exactly that, this part will become an independent part (available as library/DLL) that can be reused in the software developed in task 4.2. Another strong link between the same tasks lies in the fact that self-instruction itself is a workflow and therefore has the exact same characteristics as a schedule of a building process itself. Given that both scheduling in task 3.1 and the self-instruction workflow in task 4.2 need to be supported it is important to align this work both content wise as well as from a software development point-of-view.

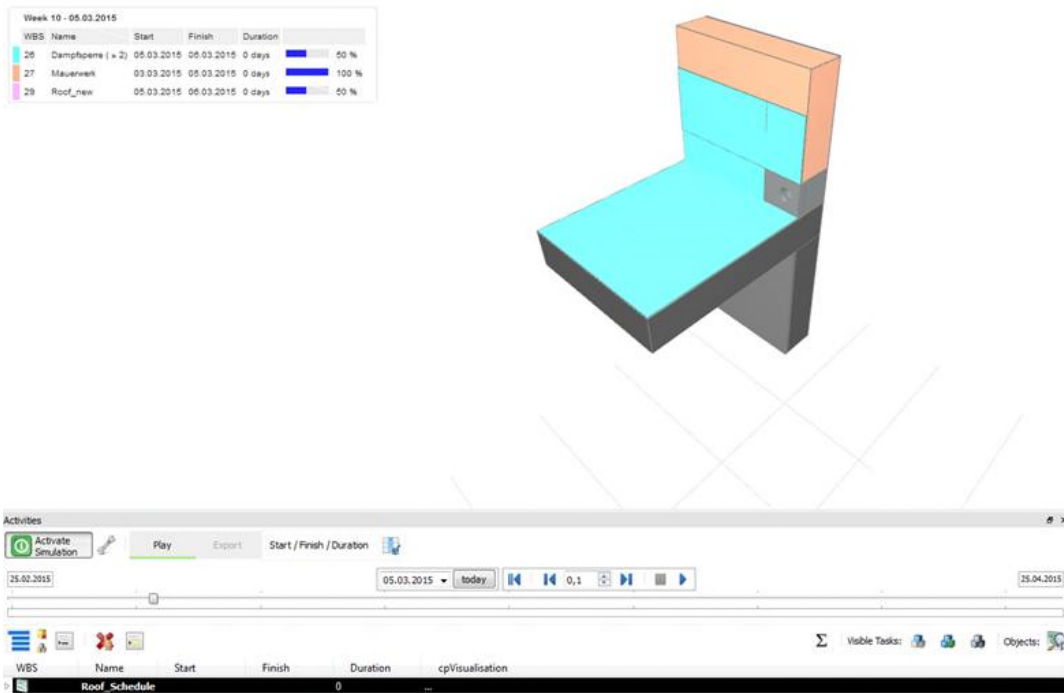


FIGURE 6

This is a screenshot of a planning integrated with BIM that can interactively viewed by an end-user. The end result of task 4.2 will be a prototype that enables exactly this, however in a web enabled environment and as a generic solution on top of BIM information. It is clear that self-instruction content can greatly benefit from this generic BIM connection, suddenly several existing commercial tools (as discussed in this deliverable) can be used to create self-instruction content.

7.5.2 Self-Inspection

On the part of Self-Inspection the relation with cost and scheduling is even stronger and more complex. Every deviation found during the self-inspection process will potentially lead to deviation (most probably increase) of cost but can also lead to a updated schedule, especially when a part is on the critical path time-wise the results from self-inspection can influence the overall schedule of the project. The other way around the self-inspection itself is depending on the process (i.e. a construction not created cannot be inspected yet) and as self-inspection results potentially can lead to delays of the complete project the schedule of these inspections need to be scheduled carefully to minimize potential project delays based on (unexpected/unwanted) results of these inspections.



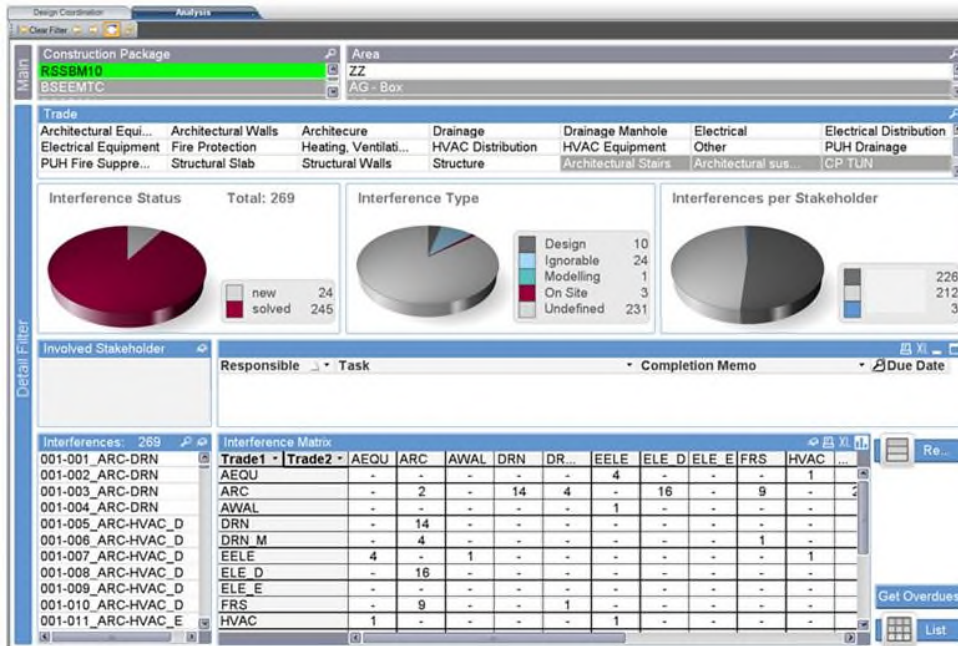


FIGURE 7

In the picture above a dashboard is shown giving an overview of interferences within a certain project. Although the visualization of the dash board itself is part of task 3.2, the driving knowledge behind could very well be cost and planning data. Having this dash board functionality as part of INSITER can visualize consequences due to deviations found in self-inspections of changes in cost and planning in a fast and clear manner.



8. Development plan (input for next deliverables)

The requirements are found in Chapter 2 and clustered in Chapter 3. Chapter 4 introduces more contexts from the Description of Action and sets the context for the review of state-of-the-art software. Chapter 5 describes the actual review executed of state-of-the-art software where Chapter 6 places this all developments in context of the BIM architecture as is defined in Deliverable 4.3. The previous Chapter gives an overview and finally this Chapter will describe what is feasible in the context of INSITER, what the scope should be for Task 3.1 for the following 18 months and D3.2. This Chapter will conclude with clear decisions and conclusions.

8.1 Feasibility analysis

8.1.1 Feasibility analysis Cost Calculation related requirements

Cost calculation related requirements were

- BIM support
- Calculation of components object based + aggregated calculations

We have seen that many Cost Calculation applications have BIM support, actually many of them have already integrated IFC support and a well-developed internal object based setup. The market is fragmented and also several software products meant for a local market have support for BIM and IFC.

For this discipline there is no reason within INSITER to reinvent the wheel, the advice is to use an existing solution preferable already known by professional and in line with modern BIM based state-of-the-art solutions as found. In the area of standardization there are possibilities to improve use of IFC and add a precision factor to the quantity take-off values based on calculated properties by the original CAD application and as derived from the defined by the geometry. Also visualization of the results in a web based view on the results can be an effective part of INSITER and Task 3.1.

8.1.2 Feasibility analysis Process related requirements

Process related requirements

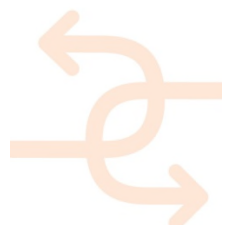
- Process definition support
- Microsoft Project / Primavera format support

The number of applications supporting both Scheduling/Planning and BIM is limited. Still development of a competing application within the context of INSITER is not useful, even when this can be done by further improving existing applications. Extensions could for example be using the API of Microsoft Project and creating a plug-in, however this would still require a lot of effort and not even come close to other existing solutions in the market. Use existing software on the market, for example Synchro Pro or iTWO 5D is therefore also here the advice. Looking at the new IFC4 standard it is expected that within limited time more scheduling applications will have better BIM and IFC support.

8.1.3 Feasibility analysis Visualization related requirements

Visualization related requirements

- Support for Visualizing combined knowledge in a 4D view
- Enabling visualization of 4D view on any modern device



Optimal solution:

A coordinated 3D/4D/5D front-end available for all parties is still missing. Based on the BIM server storing the BIM data with integrated 3D geometry and scheduling and cost/quantity take-off data it is expected it is possible to create such a front-end making use of modern Web Technology. A HTML5/WebGL could enable access to available integrated data and act as the front-end of the 3D / 4D Coordination System. There are several WebGL based IFC/BIM viewers available that come with source code; such a solution could be extended to enable 4D presentation in the already developed IFC/BIM visualization.

8.2 Scope

In this paragraph we will discuss the scope of the work as defined as we can foresee it at this moment.

8.2.1 Scope Cost calculation related requirements

Tools are already available, the scope if these requirements focus on integrating the results from the applications into the databases of INSITER. Looking at the databases, the capabilities of the reviewed applications and the open standard to be use for exchanging information it is expected this connection can be created within Task 3.1.

8.2.2 Scope Process related requirements

Tools are already available, the scope if these requirements focus on integrating the results from the applications into the databases of INSITER. Looking at the databases, the capabilities of the reviewed applications and the open standard to be use for exchanging information it is expected this connection can be created within Task 3.1.

8.2.3 Scope Visualization related requirements

The optimal solution seems possible and feasible; apply the adjustment to one of the already existing WebGL viewer examples of 3D BIM/IFC data. Still this is expected to be the most complex (and most valuable) task to fulfil for Task 3.1.

8.3 Decisions and conclusions

Conclusion on if such software component is beneficial and if the development plan of the complete project makes sense to develop in a commercial environment.

In conclusion for the work in the next 18 months in Task 3.1 we should focus on:

- Create an integrated Cost, Planning/Scheduling BIM viewer on top of the BIM data, i.e. an extension of the current 3D Web GL based visualization solution on top of the BIM server.
- Create a proposal for an extension on top of IFC that shows quantity take-off results and adds an 'trust' value to the numbers based on calculated values from the CAD systems in combination with derived values from the actually presented geometry. This development could be a further refinement of Qtie from Building SMART or at least take the basic principles form QTie as a starting point.



- Connecting actual applications with the BIM components and storage within INSITER, i.e. the three databases:
 - Open Source BIM server (based on the Berkley database)
 - PostGreSQL database
 - Microsoft SharePoint file server
- 3D / 4D Coordination System
- Tracking of design, fabrication and delivery status

This deliverable also returns valuable feedback on some pro's and con's for IFC 2x3 TC1 versus IFC4 ADD1. The selection of open standard format itself is left to WP4 to decide.

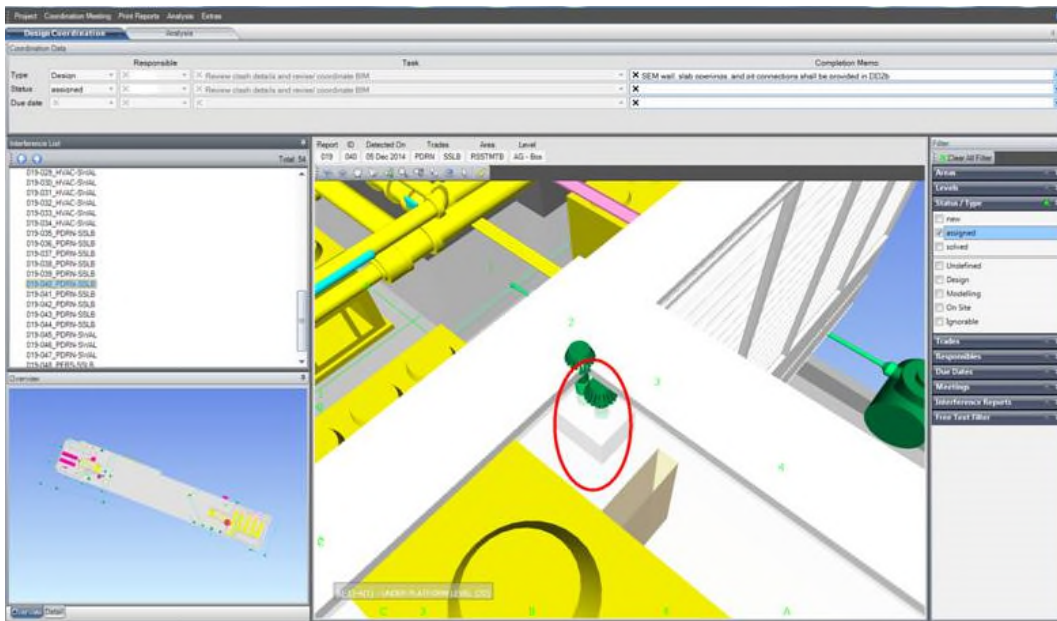
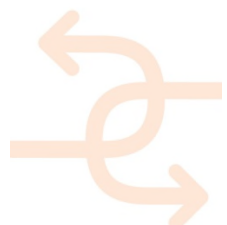


FIGURE 8

Above picture shows an example of a 3D design coordination system as it is used by some advanced building and construction companies nowadays. The same solution, however working on the real BIM data from INSITER and combined with cost estimation and scheduling information is what the prototype in task 3.1 is expected to deliver. Together with the results from task 3.2 and the other software delivered in WP2 and WP4 the coordination system enables also interactive access to the self-instruction and self-inspection solutions.



9. References

[Solibri Model Checker - Solibri / Nemetchek]

Rule Based Model Checking application

<http://www.solibri.com/products/solibri-model-checker/>

[DesiteMD - CEAPoint]

Integrated BIM visualization + script based model checking

<http://www.ceapoint.com/>

[ISY Calcus - NorConsult / NOIS]

Calculus BIM based Cost application

<https://www.nois.no/nedlasting/isy-calcus/>

[CostX - Exactal]

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Synchro Pro BIM based scheduling application

<https://synchroltd.com/synchro-pro/>

[MS Project - Microsoft]

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References to deliverables from other work packages:

- INSITER D1.1 Best practices and existing shortcomings.
- INSITER D3.3 Functional Requirements and integration architecture of applications for building quality and energy assessments.
- INSITER D4.1 BIM (aggregate models and whole models) of new and existing buildings including the construction sites.
- INSITER D4.3 Framework for BIM, hardware and software data interoperability.

