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Laser-Assisted Data Acquisition Of Building Geometry

Selection and use of laser meters and data processing software for IV20

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DEPARTMENT OF CIVIL ENGINEERING

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by

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1 Introduction

Energy-efficient building design and operation has been a major focus of the building industry in recent years. The narrow focus on reducing energy consumption often comes at the expense of residential comfort by compromising the indoor environment (Larsen, 2011; Heiselberg *et al.*, 2016).

IV20 is an IE (Indoor Environment) evaluation tool, currently under development at Aalborg University, focussing on the thermal, atmospheric, visual and acoustic potential of a building. The tool is intended to be usable for designers and energy consultants in building design and renovation projects in the early design phases, based on accurate and consistent data (Larsen *et al.*, 2017).

It can be time-consuming and expensive to acquire, model and store data needed for IE evaluations in a building data repository, e.g. a spreadsheet schema or a building information model (BIM). 3D models and building information models can be used for storage and exchange of building data (Christiansson and Svidt, 2011) to reduce manual data input and miscommunications between designers and clients (Petrova *et al.*, 2017; Arayici *et al.*, 2018). However, when building models are based on manual data input, they often lack consistency and reliability (El-Omari and Moselhi, 2011; Gerrish *et al.*, 2016).

Designers working with energy efficiency and the indoor environment (IE) furthermore often lack know-how with respect to the modelling applications, user interfaces (UI), data input and the complexity of building simulation and evaluation applications (Paryudi, 2015; Arayici *et al.*, 2018). In a study by Attia et al., (2012) designers rated "intelligence" and "usability" of building performance simulation (BPS) tools higher than "interoperability" and "accuracy". Tools used for data acquisition must, therefore, as BPS tools have a high degree of intelligence and usability.

In this report, we present a framework for analysis and selection of handheld laser meters and data processing software for geometric building data acquisition, ensuring the intelligence and usability demanded by designers, as well as interoperability and accuracy. The report additionally explores the theoretical background of handheld lasers and data processing software use through a methodology we have names Laser-Assisted Data Acquisition (LADA).

Based on the framework, a handheld laser and two data processing software were selected. These were then tested in four test cases to explore their usability and abilities with respect to data export for IV20. The findings from said test cases are presented in this report as well.

LADA is developed to support the tool selection and data acquisition for IV20 evaluation process. It can, however, in our opinion support selection and use of handheld laser and data processing software for other purposes as well.

2 Laser-Assisted Data Acquisition

Acquisition of geometric building data is possible through multiple methods, both manual and automated. Laser scanning, photogrammetry and laser meter measuring are common tools used in the Danish building industry.

While many studies concentrate on laser scanning and how to generate 3D models from such scanning's (Jung *et al.*, 2014; Barazzetti, 2016; Schnabel *et al.*, 2016; Shanbari *et al.*, 2016; Ottoni, Freddi and Zerbi, 2017), this report focusses on using laser meters for geometric data acquisition accurately and consistently.

A laser meter is usable in different ways. In this study, we focus on using the laser meter as an advanced and more accurate measuring tape, as shown in figure 2.1., with the prospect of generating data models (schematic or graphical) automatically. When measuring external building geometries, the laser meter was placed on a tripod on a fixed location (figure 2.2), measuring distances by using the laser meters point-to-point functionality, capable of triangulation (Leica, 2010).

Figure 2.1 Using the handheld laser as an advanced measuring tape by placing it in on a surface and measuring the distance to the surface opposite the placement surface.

Figure 2.2 Using the handheld laser with a tripod

2.1 Types of building data

In order to perform an Indoor Environmental Evaluation using IV20, multiple types of building data are needed, both geometrically and non- geometrically. In this report, we have identified five categories of data.

1. **Internal Geometries**
   This includes the length, width and height of rooms, windows, door, the windowsills and other internal geometries of a room.

2. **External Geometries**
   This includes the length, width and height of neighbouring buildings. The eaves and balconies of the building being scrutinised for IV20 LADA and the topography and fauna surrounding the building. The acquisition of such external geometry makes it possible to analyse shadowing (own and neighbouring) as well as the view in/ out situation of a building.

3. **Construction Components**
   This includes the parameters of the specific layers in each construction.

4. **Surface Materials**
   This includes all surface materials such as flooring, walls and ceilings.

5. **Locational Data**
   This includes the orientation of the building, GPS position and data regarding wind, noise and pollution maps, etc.

Some of the needed data for IV20 evaluation can be acquired through inspection and use of LADA on-site, whilst some data are collected through relevant databases. The use of such databases is not studied in this report.

When selecting a laser meter and data processing software (software), it is very important to consider which data can be captured and stored through such tools. Not all handheld lasers are capable of doing photo documentation and not all software support documentation of construction components, surface materials, and locational data or include GPS.

When acquiring internal and external geometries, some measurements are crucial , as they allow computation of the measurements not being made on site. Figure 2.3 shows crucial measurements with respect to IV20 evaluation, obtainable using the Leica Disto S910 handheld laser meter[1].

2.2 Exportability, interoperability and usability

When selecting handheld laser and software to facilitate the acquisition of internal and external geometries and other it is important to understanding and difference between usability of the handheld laser and the software, interoperability between the tools and the exportability the tools have.

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[1] The Leica Disto S910 handheld laser meter was used for all initial testing and analysis in the study presented in this report. Further description of the selection process is presented in chapter 3.
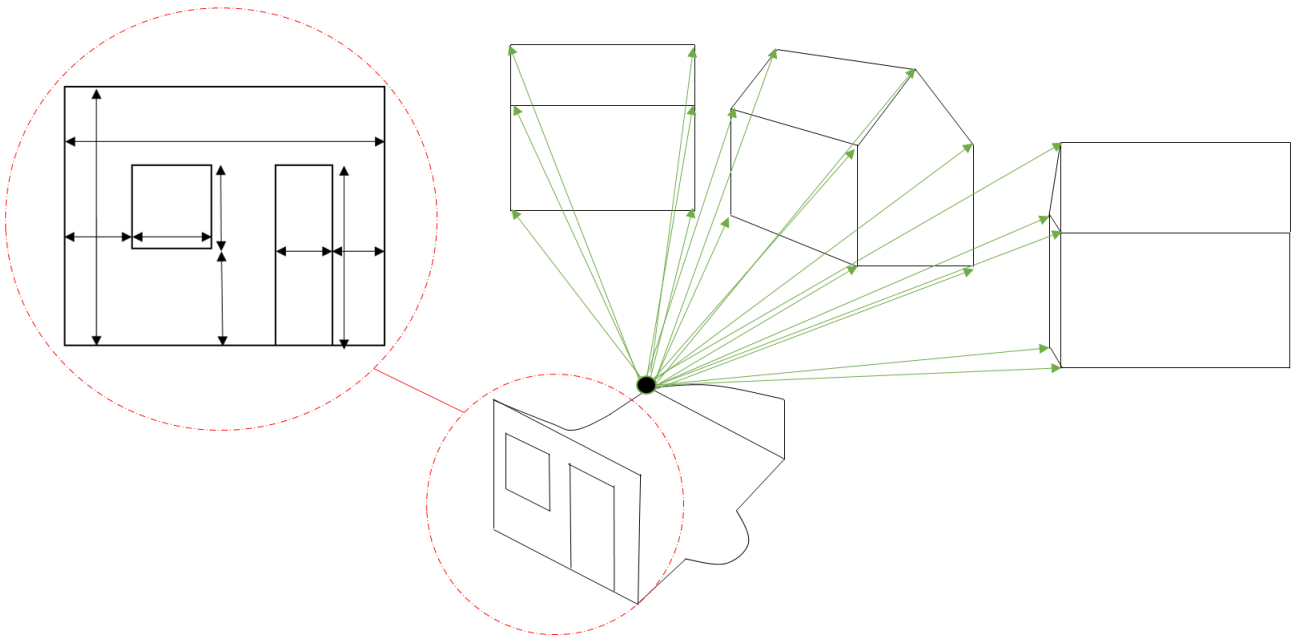
Figure 2.3 Measurements needed to collect to do IV20 evaluation.

2.2.1 Usability

Beyer and Holtzblatt (1997) explain that: "a User Interface (UI) should be designed to stay out of the user's way". It is therefore important to consider the usability of a laser meter and software before tool selection focussing on their UI.

Most work involving information and communication technology (ICT) is supported by a combination of systems, sometimes so complex that no one really understands it (Beyer and Holtzblatt, 1997). Such systems are often filled with confusing elements and complex interfaces which results in poor usability (Markus and Benjamin, 1997; Attia et al., 2012; Haaksma, R., De Jong and Karreman, 2018). Attia et al., (2012) further notes that a Graphical User Interface (GUI) should be adaptive and flexible to improve usability and allow for simple and basic data entry choices for non-specialists and detailed data entries for specialists.

Products designed with the user in mind are generally easy and enjoyable to use (Rogers, Sharp and Preece, 2015). Selection and use of a handheld laser in combination with software must, therefore, be designed with the users in mind. As people without expert experience in use of lasers and software are the intended users with respect to the study presented in this report, simple and intuitive UI's are preferred.

2.2.2 Interoperability

Another important element regarding the use of multiple technologies, such as a handheld laser and software, is interoperability. Improved interoperability can address many early design issues on a building project, and create a smoother transition between design stages and make life easier for all project involved parties (Østergård, Jensen and Maagaard, 2016), a swift transfer of data from the handheld laser to the software is desired in LADA.

2.2.3 Exportability

The use of 3D modelling and building information modelling has increased over the past two decades (Schlueter and Thesseling, 2009; Arayici *et al.*, 2011). This has resulted in many using the Industry Foundation Classes (.IFC) (Arayici *et al.*, 2018; Farghaly *et al.*, 2018) and The Green Building Extensible Mark-up Language .gbXML, together with other open or proprietary formats to store and exchange building data. Using .gbXML and building information modelling (BIM) native formats like .IFC to facilitate data exchange does, however not necessarily ensure a data exchange free of issues (Choi *et al.*, 2016; Gerrish *et al.*, 2016; Arayici *et al.*, 2018).

When using LADA for IV20, exportability is essential, as LADA data are futile if they cannot be exported to IV20 swiftly in a usable format. It would additionally be pointless to use LADA (an automated process) to acquire and structure data, and then transfer the data into IV20 manually.

In chapter 3, we propose a framework for the selection of tools needed for LADA providing the data needed for IV20 evaluation in addition to facilitating usability, interoperability and exportability.

3 Tool selection for Laser-Assisted Data Acquisition

A selection framework was developed to aid selection ofa handheld laser and data processing software (software) for Laser-Assisted Data Acquisition (LADA),

As introduced in chapter 2, usability, interoperability and exportability are some of the key criteria to consider when selecting tools. Connect-ability, and the price of the tools are two additional criteria, which are very important to consider when selecting tools as well.

In order to rate usability, interoperability, exportability, connect-ability and price, user needs and the requirements of the system data acquired through LADA must be specified. In this report, the IV20 evaluation tool was used as test case.

The handheld lasers analysed in the framework presented in this chapter were selected based on an extensive search and analyses of functionalities handheld lasers. The software was selected based on downloads in Google Play and the App Store. In order to test the software with respect to usability, all software analysed in the framework were downloaded onto an iPad Air 2 Wi-Fi tablet. It was then used in unison with the selected handheld laser.

In the following, each criterion is explained in context to firstly, the laser meter and secondly, the software.

3.1 Laser meter criterions explained

Exportability is the ability a laser meter has to exchange data in various formats. The more formats the laser meter is capable of exporting, the more applications will be able to use said data without conversion or manipulation.

Connect-ability is concerned with how a laser meter connects to software or hardware through e.g. WIFI, Cable or Bluetooth.

Interoperability is the ability a laser meter has to transfer measurements to the software.

Usability is the parameter concerned with the ease of use the laser meter has. The usability parameter is a subjective criterion, as knowhow and understanding an UI is very person dependent (Haaksma et al., 2018).

The usability is defined by a tool's abilities with respect to the setup of the tool; the connect-ability regarding both data exchange and maintenance of connection to other tools. We suggest rating the usability based on pre-specified questions on a scale from 0 to 9, valuing each question 1/3.

$$X = \frac{Q^a + Q^b + Q^c}{3}$$

Where X is the rating, Q^a is the question: "*How easy it is to set up the system*?" Q^b is the question: "*How easy is connecting the laser and the software and export data from the software to another program or repository?*" and Q^c is the questions: "*How easy is it to maintain the connection between laser meter and the software?*"

Translation of the three questions into ratings makes comparing tools easier, which aids the selection process. The higher the rating of a laser's usability, the more usable it is likely to be.

The final parameter to consider is the price of a laser meter. Often, "you will get what you pay for". However, the quality of "what you get" is revealed through analysis of the four other parameters analysed in the framework. We, therefore, recommend looking at the exportability, connection, interoperability and usability firstly, and not to let the price dictate which handheld laser is chosen.

Figure 3.1 shows the selection framework for handheld lasers. When filling out the framework to analyse different handheld lasers, looking only at the handheld laser's abilities in exportability, connection and interoperability, it was clear only one laser meter was able to provide the necessary data for IV20 evaluation.

Tool name	Exportability	Connection	Interoperability	Price	Usability
Leica S910	DXF, .DWG, .TXT, .CSV, .JPG	Bluetooth, WIFI and Cable	Disto ™ Sketch, Floor Planning, Site Draw Lite, Measure Mobility 3, Orthograph I, Magicplan.	1341,50 €	5+8+9 /3 = 7,33
Stanley TLM 99S	.DXF	Bluetooth	Stanley Floor Planner	131,94 €	NAV/
Bosch GLM50C	NAV/	Bluetooth	Bosch Measuring Master	103,55 €	NAV/
Dewalt DW065E	NAV/	Dewalt DW065E	NAV/	36,83 €	NAV/

Figure 3.1 Example of LADA- framework for Laser meter selection

The selection framework also works for the selection of the software. However, small adjustments must be made, as the definition of exportability, connection, interoperability and usability is different for the software as explained in the following section.

3.2 Data processing software criterions explained

Exportability is the ability the software has to exchange data in various formats, after receiving initial data from a laser meter. The more formats exportable, the more abilities the users have using the data.

Connect-ability is the parameter concerned with the software ability to connect to other hardware or software through e.g. WIFI, Bluetooth or cable.

Interoperability is the ability the software has to transfer data directly to other software. Most laser meters have their own software. However, the ability to work with software from different vendors makes it easier to manipulate data into the exact information needed in order to do IV20 evaluation.

Usability is the parameter concerned with how user-friendly the UI is.

How easy the software is to use defines the usability, which is why analysis of each tool is necessary. We again suggest rating the answers of the questions on a scale from 0 to 9, valuing each question 1/3.

$$X = \frac{Q^a + Q^b + Q^c}{3}$$

Where X is the rating, Q^a is the question: "*How easy it is to set up the system?*" Q^b is the question: "*How easy is connecting the laser and the software and export data from the software to another program or repositorie*s?" and Q^c is the questions: "*How easy is it to draw/ model and enriching the model with building component and material data*"?

The final parameter to consider is the **price** of the software. It is again important to consider how the software fulfils the other four criteria before looking at the price.

Figure 3.2 shows an example of how the framework was used for selection. The first two types of software in the framework are developed by laser meter vendors. Accordingly, the software only works with laser meters of the same brand. The advantage of such tools is that they can be downloaded and used free of charge when purchasing a laser meter. However, the usability of the vendor made software in the example in figure 2 are low, because they are not equipped to export data directly to other software or repositories and because they have low performance with respect to creating and enriching captured data.

Tool name	Exportability	Connection	Interoperability	Price	Usability
Stanley Floor Planner	.JPG, .PDF	Mail	Stanley Tools Only	Free	8+2+2 / 3 = 4,00
Disto™ Sketch	.PDF	Mail	Leica Tools Only	Free	8+2+4 / 3 = 4,67
Orthograph I	.PNG, .PDF, .XLSX, .ICF., .DXF	Mail/ Website Repository	Leica Disto Tools D110, D910, D510, S910, D1, D2. Bosch Tools GLM 50C, GLM 100C Stabila Tools LD S20, :S, 250BT	44,99 €	7+7+5 /3 = 6,33
Magicplan	.PNG, .JPG, .PDF, .CSV, .SVG., .DXF	.Mail/ Website Repository	Leica Disto Tools D110, D910, D810, S910, 510, E7500i. Bosch Tools GLM 50C, GLM 100C Stabila Tools 250BT, WDM 8-14 Stanley Lasers TLM99S, TLM99si, TLM660.	16,67 €	8+2+9 /3 = 6,33

Figure 3.2 Example of LADA- framework for Data processing Software selection

Enrichment of captured data includes adding metadata to geometries. This could e.g. be the ability to link information about construction components or surface materials to a geometric 2D model in the software.

In the framework, it is evident that Orthograph and Magicplan are both applications with high exportability; connect-ability, interoperability and usability, as well as allowing enrichment of the captured data. The two applications nevertheless differentiate in the number of laser meters they support, which formats they can export and their price. Regarding exportability, Magicplan does not export the Industry Foundation Classes (.IFC) format, which makes the application less feasible to use in situations where 3D models of geometries are needed.

It is noticeable that even though the usability ratings of the two applications are the same, Q^a, Q^b and Q^c differentiate significantly. Most noticeable is the difference between the setup of the systems, with Orthograph being relatively easy to set up and maintain connection with between handheld laser and software. Magicplan does in adverse do better when it comes to modelling geometries and enriching it. In summary, even though the usability ratings are the same, the applications do differentiate greatly in use.

Based on the results of the framework, Orthograph and Magicplan were selected for further testing, to establish which of the two were best suited for use for IV20 evaluation.

3.2 Results

By introducing a framework for the selection of LADA tools, based on specific data needs focussing on the IV20 evaluation tool, a laser meter and data processing software were selected. By siding exportability, connect-ability, interoperability, price and usability, an analysis of functionality and use of the tools in combination were established and the Leica S910 handheld laser was selected, as well as Orthograph and Magicplan as data processing software for testing in the case study.

Some of the criteria in the framework are based on subjective values. The framework does, however, consider such subjectivity by people selecting tools for LADA, through calculating an average usability score based on relevant questions regarding usability rated on a scale from 0 to 9.

Price does reflect the functionality of both laser meter and data processing software. The framework makes it possible to select a combined set of a handheld laser and software based on the actual needs of the end-user.

4 Measuring and modelling using Data Processing Software

This chapter introduces and examines the Data Processing Software (software), Orthograph and Magicplan, used with a Leica Disto S910 handheld laser meter on an iPad Air 2 Wi-Fi tablet. The Laser meter and the software were connected through Bluetooth. All descriptions and measurements in this chapter are based on using the laser meter as an advanced measuring tape as described in chapter 2, focussing on the use of LADA for IV20 evaluation. The presentation of the tools are based on *use* of the software, and not the information given by the vendors.

4.1 Description of Orthograph

The User Interface (UI) in Orthograph is straightforward and easy to use. Connecting a laser meter to Orthograph through Bluetooth is also quite easy to do and when the connection is established, the connection in the tests, presented in this report, proved to be very reliable.

Two modelling functionalities divide the interfaces, as shown in figure 4.1. The 2D interface allows sketching and accurate drawing of geometry based on measurements received from the handheld laser, and insertion of geometrical components. The 3D interface allows visualisation of the 2D drawing and makes it possible to do walkthroughs and use various 3D functionalities (gyroscope, azimuth and altitude).

With respect to geometries and generation of building data, the application functions in the same way as most building modelling applications. Limitations, however, occur when modelling multiple storeys, as it is not possible to indicate slap thickness or materials. Modelling of roofing and external geometries is furthermore not possible in a feasible manner.

When doing registration and modelling of small buildings and apartments, Orthograph works quite reliably. When the building unit exceeds 75 m^2, the performance ability of the tablet nevertheless becomes vital. The tablet used for testing was relatively powerful, yet not powerful enough during all tests, making it recommendable to use a tablet with more power when modelling more than 75 m^2. System "crashes" occurring
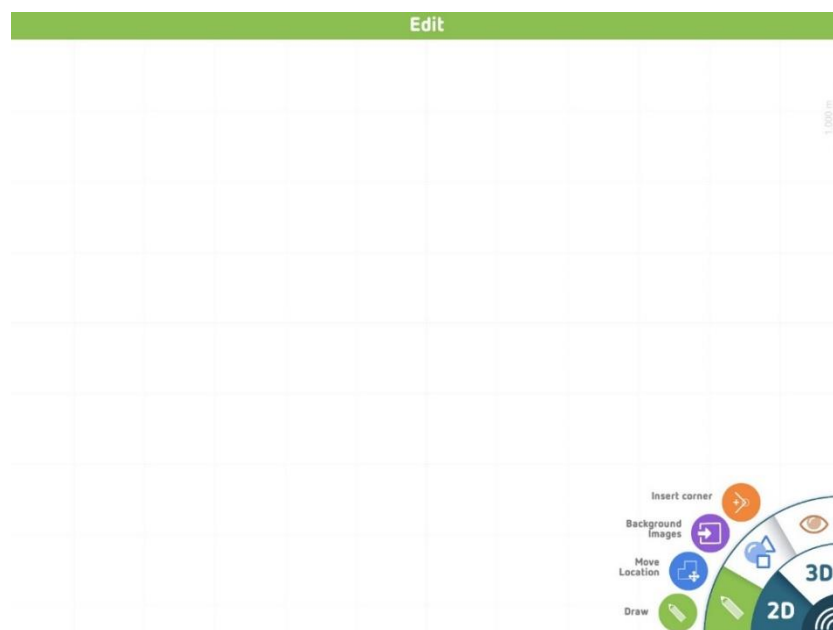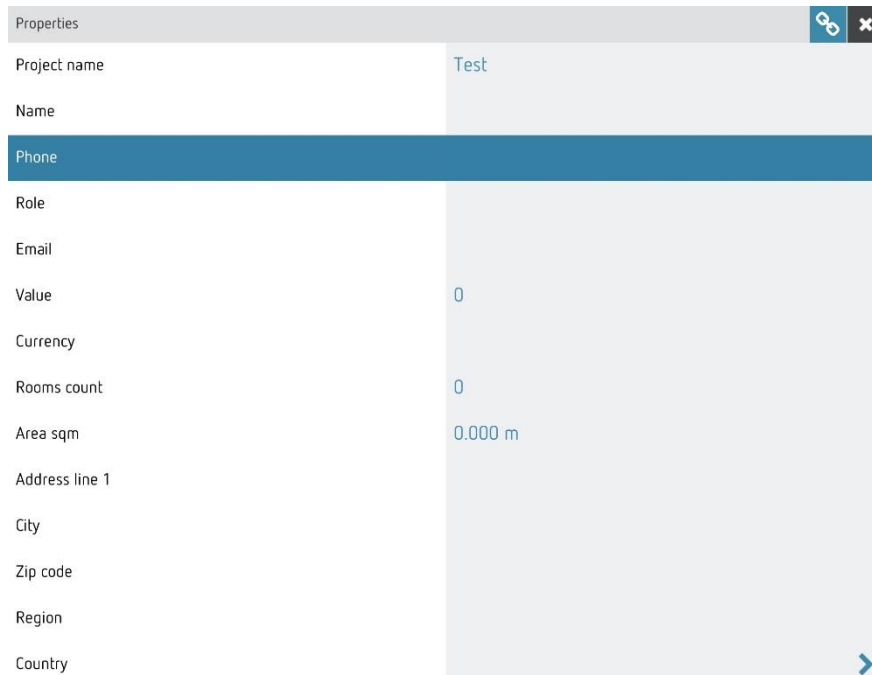

Figure 4.1 Orthograph 2D UI

while using Orthograph was in most cases resolved by rebooting Orthograph. If that was not enough, a reboot of the tablet usually solved the problem.

4.2 Modelling in Orthograph

In the menu: "Properties", project, quantities take-off from the model, location of the building, orientation and multiple other information are handled, as shown in figure 4.2.

Figure 4.2 The Orthograph

The more specific the capture of project information is, the easier it is to attain accurate project data later on in the IV20 evaluation process. It is recommendable to do such registration before beginning the LADA process.

Orthograph data are exportable in various formats. The more information captured in Orthograph, the more detailed the reports are. What separates Orthograph from other software, is its ability to export the Industry Foundation Classes (IFC). IFC is an open exchange format used in the building industry (Arayici *et al.*, 2018). The format makes it possible to exchange information models created in e.g. Revit, ArchiCad or Microstation, and provide the building blocks for interoperability and building information modelling (BIM) through its non-proprietary data schema (Venugopal *et al.*, 2012).

During the test of software, it became clear that modelling one room at the time and composing the various room for a final floorplan is the recommended way of model geometries in Orthograph. Another important factor when modelling in Orthograph is to not anchor or lock measurements. Anchoring a measurement happens automatically when inserting objects (windows and doors) into a wall. Anchoring can however be reversed using the "Measure tool" as shown in figure 4.3. If the geometry of a room is changed whilst geometries are anchored, the orientation and the corner angles the rooms automatically changes, which in many situations cannot be re-corrected.

When using Orthograph, one might be inclined to model the doors shared by two rooms, twice. This will,, however, make the door opening area count twice as well in the data export, and is thusly not recommended.
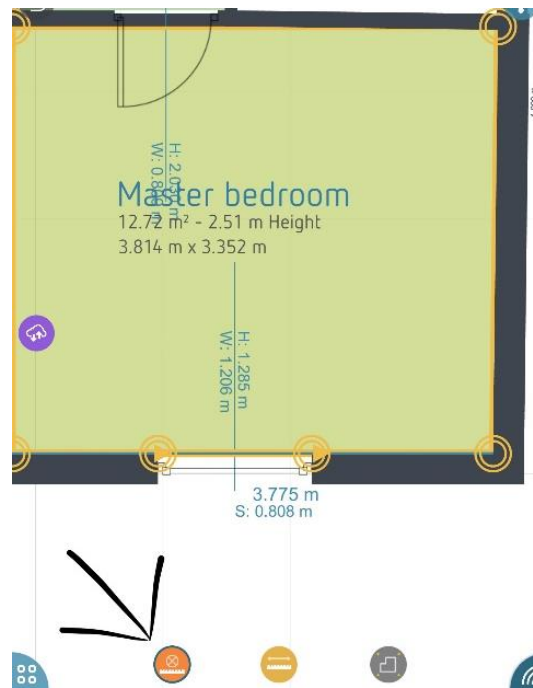
When exporting files from Orthograph, it is important to quality control the model, and make sure that the geometry of a building is enclosed. This is necessary to ensure accuracy in the geometric data e.g. room, wall and surface areas etc.

4.2.1 Orthograph export

Orthograph data can be exported in multiple formats, as shown I figure 4.4. In the following the export formats are described, to give an overview of the possibilities they provide, and in order to conclude the usability of Orthograph data for IV20 evaluation.

Export formats
DXF
PNG
PDF
IFC
ORT

Figure 4.4 Export formats from Orthograph

.DXF: Drawing Exchange Format was developed by Autodesk to heighten interopera-bility. .DXF consists of coordinates, points, lines and text.

20

The .DXF export from Orthograph contains floorplan(s) and measurements of doors, windows, walls and square meters of the rooms (Autodesk, 2007).
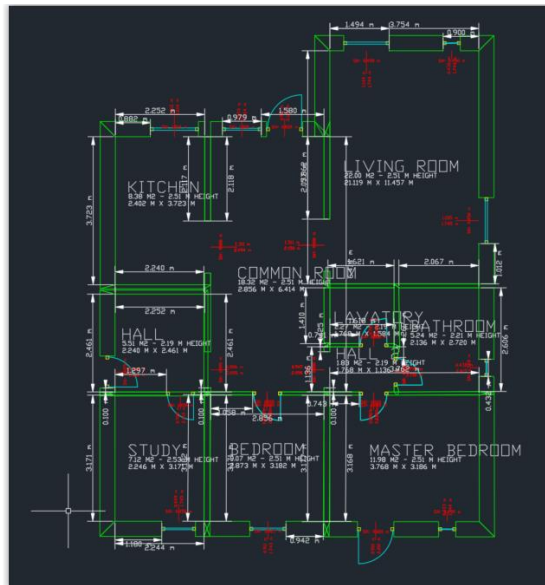
Figure 4.5 .DXF data viewed in Autodesk AutoCAD

.PNG   Portable Network Graphics is a raster graphic file format supporting lossless data compression (Wikipedia, 2018a).

Figure 4.6 .PGN export.

.PDF   Portable Document Format developed by Adobe Systems Inc. is made for ex-change and view of electronic documents, represent text and graphics in a res-olution-independent manner and to optimize documents for (web) viewing and enhanced with interactive features (Ag, 2005).

The .PDF export from Orthograph consists of both plan drawings and building unit/ room in-formation.

Orthograph can export two types of .PDF report. A floorplan report and a detailed floor plan report. Both types their own specific limitations[2]. The basic report contains all rooms of the model and basic information such as lengths, widths, heights and square meters of a room. Building component data are not presented in the document. In the detailed floor plan report, most data is present, however not all rooms are, which makes the use of this type of reporting unfeasible.

.IFC   Industry foundation classes stores building data in a neutral non- proprietary data schema, making it possible to transfer data between multiple applications (Venugopal *et al.*, 2012; Niu and Leicht, 2016).

The visual quality of an .IFC file exported from Orthograph depends on which viewer is used. In figure 4.7 an .IFC file is viewed in Autodesk Revit.
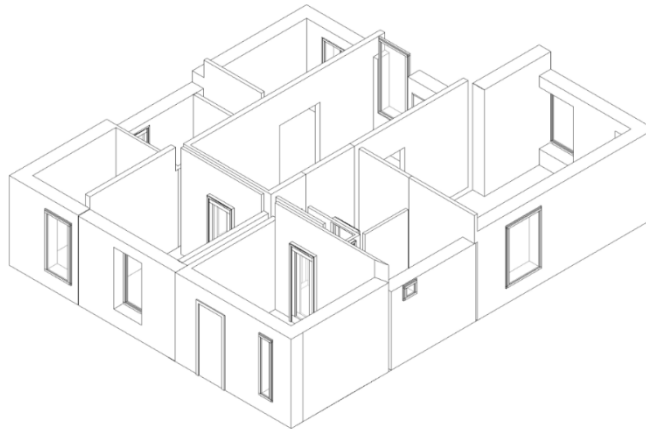
Figure 4.7 .IFC export viewed in Autodesk Revit.

.ORT   This format is the proprietary format used by the data processing format and not exchangeable for use in IV20. It does, however, make it possible to ex-change data with other Orthograph users.

4.3 Description of Magicplan

Magicplan is a 2D modelling application usable in unison with a handheld laser meter as data processing software (software).

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[2] The two report types can be found in appendix B1 and B2.

Compared to Orthograph, connecting the handheld laser to Magicplan software proved to be quite trouble-some in some of the testings in the study presented in this report.

The following description, however, ensures connection between handheld laser and Magicplan if connecting using the description provided by the vendor does not suffice.

1) The Magicplan Application must be "turned on" on the handheld device.
2) Delete the Leica Disto unit on the iPad under Bluetooth/ my units.
3) Pair Handheld laser and Application through Magicplan, as shown in figure 4.8.

If the third step does not work, the following steps will make it possible to pair the laser meter to the application.

a) open Functions, on the Leica Laser Meter
b) open Sittings
c) open Bluetooth
d) open Bluetooth settings
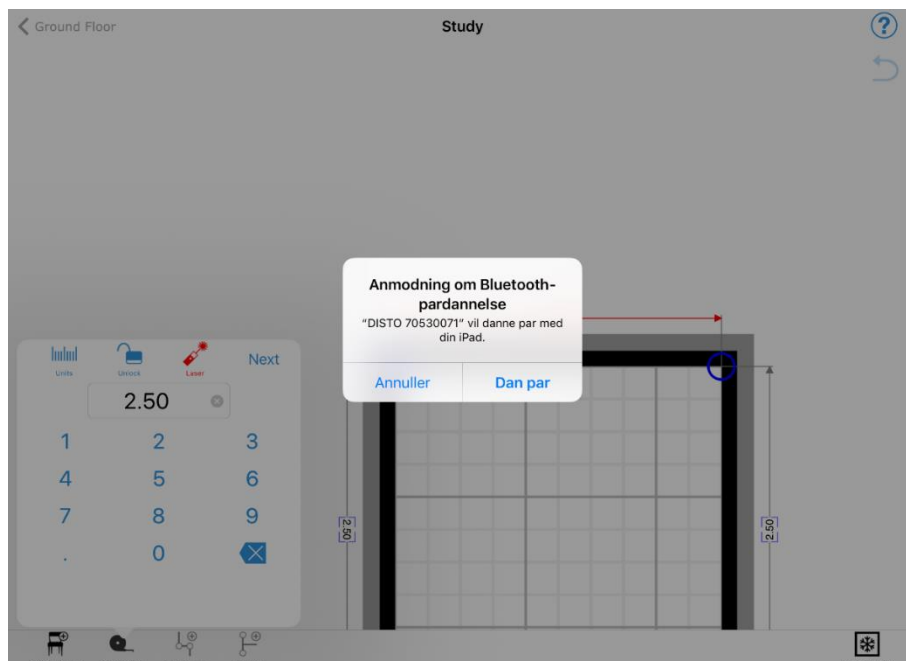
Figure 4.8 Request for Bluetooth paring

Even after extensive testing, it is still not clear why the handheld laser and software sometimes have prob-lems connecting. However, when the laser meter and Magicplan were connected (paired), the connection was stable in all tests, until reboot of either device. In some situations, pairing can fail if the distance between laser meter and the handheld device become too great (estimated 20 m), or if the battery level is low on of the used devices.

4.4 Modelling in Magicplan

Magicplan is very easy to use and more intuitive compared to Orthograph with respect to modelling geome-tries based on data received from the handheld laser. As shown in figure 4.9 certain initial steps are needed before modelling in Magicplan can begin.

We propose always starting with a square room, in the right category, as viewed in figure 4.9. When room type is selected, additional corners and shapes can be joined the geometry if needed. The pairing of the handheld laser and the software can occur both before and after the room type is selected.
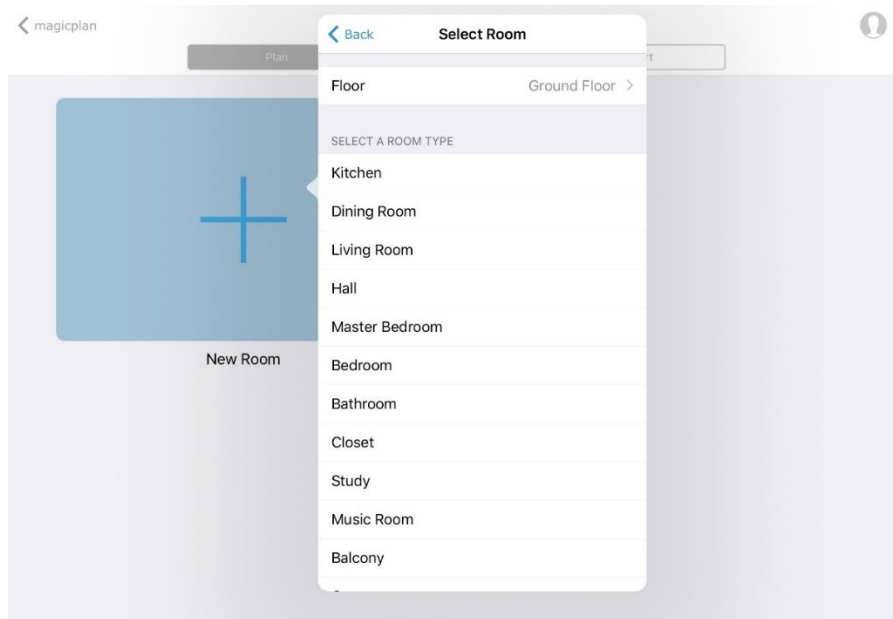
Figure 4.9 Room type selection menu in Magicplan

The use of Magicplan presents some of the same issues as Orthograph, especially the function of automatically anchoring or locking geometries. It is however easy to un-anchor each measurement in Magicplan, as the lock function is linked to the building components (door, window, and wall) and not to each specific measurement, as in the case with Orthograph. The locking function was easy to access and use and is located in the UI in a similar position as the anchoring function in Orthograph (see figure 4.3). Generally, Magicplan proved to be a user-friendly and easy-to-use software.
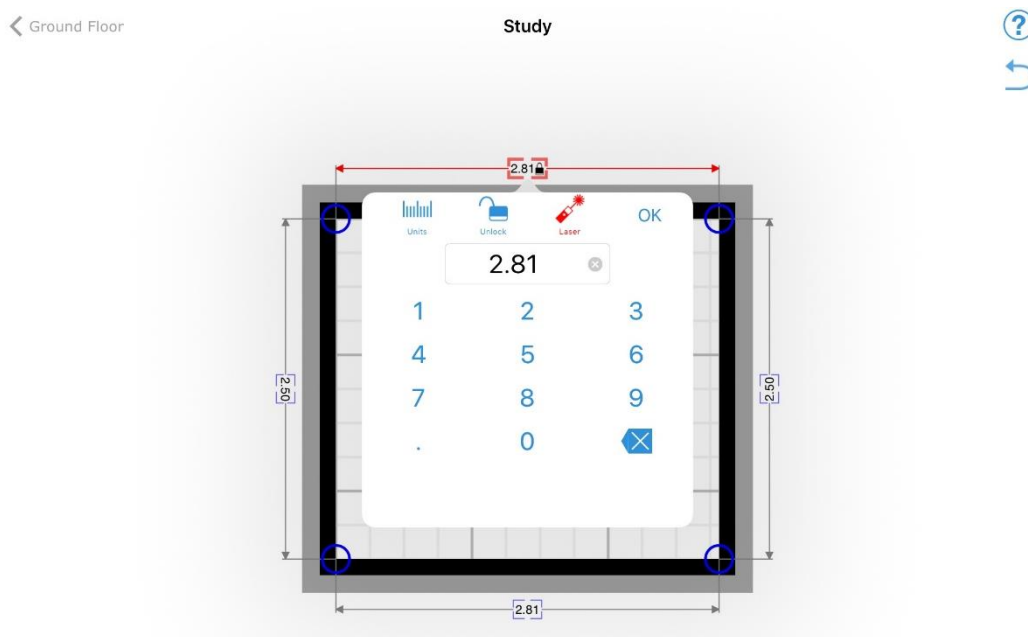
Figure 4.10 The lock/ unlock function in Magicplan
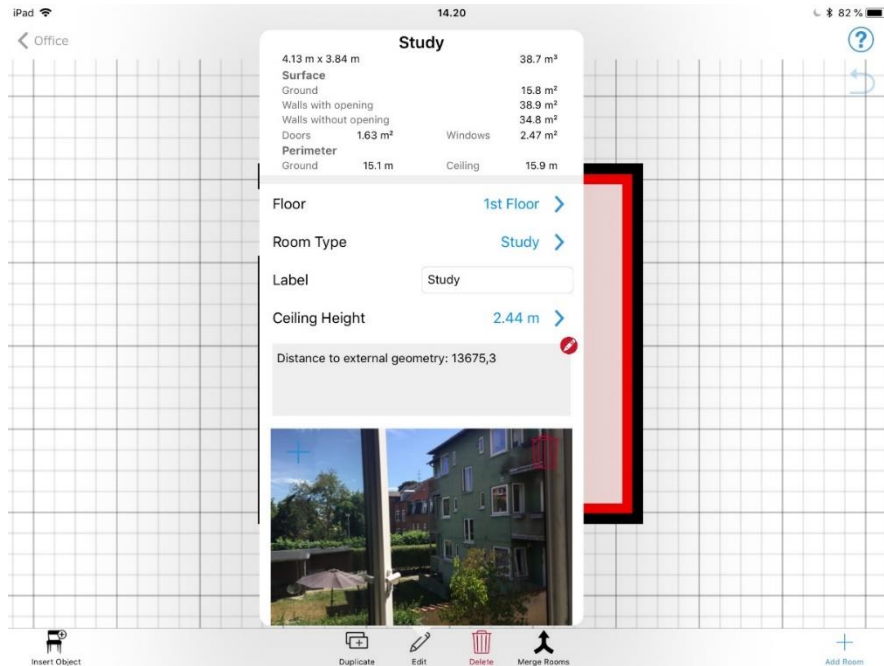
Figure 4.11 Report function in Magicplan

When using Magicplan, only a limited amount of project properties needs to be filled out compared to using Orthograph. Essential project data nevertheless needs to be filled in, which can then be shown in the "Report" function, as shown in figure 4.11. This report contains all geometric data of rooms which are included in the exports from the software using the export menu. In addition to geometrical data, it is possible to add photo documentation of shadowing objects and distances to such[3] in the report.
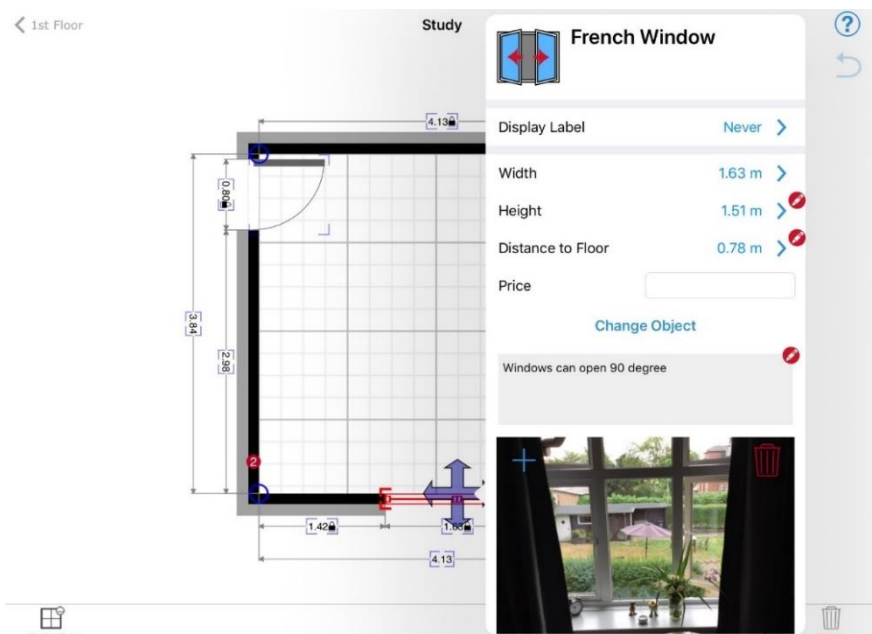
Figure 4.12 Magicplan report function in the application UI

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[3] Distance data must be written into the report manually using "edit" in the report menu.

Windows, doors, walls etc. modelled in Magicplan, can additionally have appended notes and photos, as shown in figure 4.12.

In addition to being able to publish geometry, notes and photos captured using LADA; Magicplan makes it possible to submit address and photos of the location being scrutinised. When an address is entered, Magicplan provided the GPS-coordinates of the location, based on Google maps, as shown in figure 4.13. The function only works when Magicplan has a connection to the internet. When exported in one of the many formats Magicplan offers, coordinates are only present in the .CSV export. This functionality is not available in Orthograph.

Office
Thomas Manns Vej 23, Aalborg, Denmark 9220

Statistics

16 m²
1 Floor
0 Bedroom
0 Bathroom

1st Floor

3.84
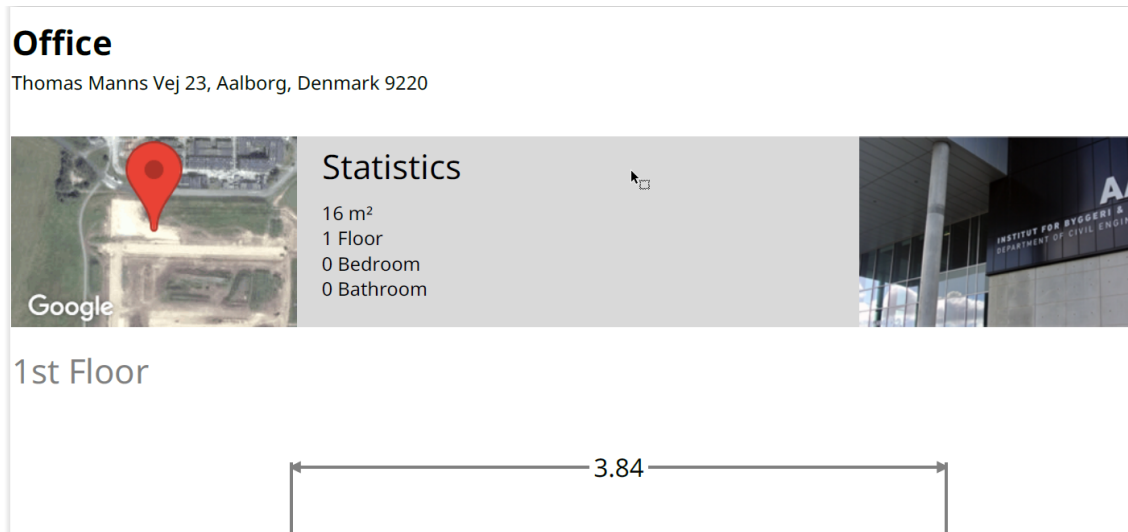
Figure 4.13 Address and photo documentation of building. Photo of building belongs to © civil.aau.dk. The map showed in the figure was printed from Magicplan using © Google Maps.

4.4.1 Magicplan export

Geometries and building data are exportable in the formats shown in figure 4.14. In the following report section, the formats exportable from Magicplan are explained[4].

Exportability
.PDF
.SVG
.DXF
.PNG
.JPG
.CSV

Figure 4.14 Export formats from Magicplan

---

[4]For explanation of the formats .DXF, .PNG, .PDF and IFC see chapter 4.2.1.

.SVG: Scalable Vector Graphics is a format derived from XML, used for defining vector graphics. The format is often used in unison with HTML, as it does not need to be loaded as a separate file. It further allows for the dynamic image- generation (Wikipedia, 2018b).

.JPG/ JPEG: Joint Photographic Experts Group is an adjustable "lossless" compression format for digital photography (Pennebaker and Mitchell, 1992; Lane, 1999).

CSV: Comma-Separated Values is a text file that uses a comma to separate values. It can store large amounts of numbers and text and consists of one or more fields, separated by commas. The files are easily editable using spreadsheet applications like Microsoft Excel (Smith, 2018) (CSVReader, 2018) (*Super-CSV*, 2018).

As presented in this chapter, both Orthograph and Magicplan presents with advantages and disadvantages with respect to Laser-Assisted Data Acquisition. Orthograph is easy to set up and allows export of 3D models in the Industry Foundation Classes (.IFC) format. Magicplan, on the other hand, is easy and intuitive to use and is able to export the .CSV format, which can include both geometric data and GPS-coordinates.

In the following chapter, the case study locations used for testing of software are presented.

5 Case study locations

In this chapter, the buildings and apartments used in the case study are presented. Hardware and software testing was done in five different locations. The tools selected based on the framework presented in chapter 3, were used on all test cases.

Some test case demands were set.

- Firstly, test areas must include both new and old buildings allowing testing in more buildings with a greater amount of scenarios.

- Secondly, the geometry of the buildings and rooms had to be different from case to case with at least some differences. This demand was set in order to secure a wider range of testing of both hardware/ software and how to use them.

- Thirdly, the buildings and rooms had to be real case scenarios for building energy design and/ or IE industry (or a close representation).

Three test persons were chosen to test the LADA process involved tools. The test persons had different competences with respect to the use of technology, knowledge of energy design and the indoor environment and use of the IV20 evaluation tool. All test persons participated in two tests or more, to achieve a better understanding of use and limitations of LADA and the tools involved.

5.1 Test case one: The office

Located in Randers, Denmark. The test case was a room in the size of 16.21 m^2, built-in 1904. The test area was selected to test the laser meter and the software use, in a limited area with low geometric complexity and thereby a low volume of data to manage. The test area was also used to test registration of shadowing objects and how to capture such[5].
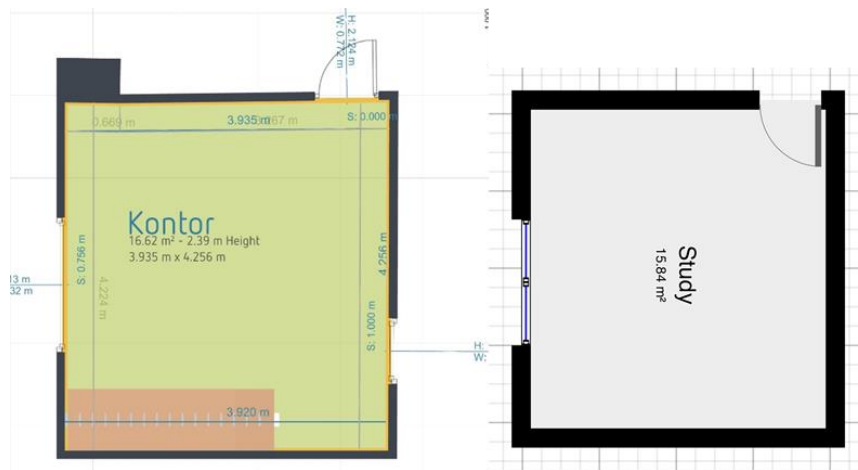
Figure 5.1 Left: Floorplan of office modelled in and exported from Orthograph. Right: Floorplan of office modelled in an exported from Magicplan.

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[5] In order to keep the test building anonymous, the address of the Department of Civil Engineering at Aalborg University address was used in the data export and not the real address of the test building and photos of the Department of Civil Engineering was used instead of photos of the test building.

5.1.2 Test case two: The clinic

Located in Randers, Denmark. The test case was a one storey building in the size of 67m^2, built-in 1967. The building was previously an orthodontist clinic but is expected to be converted into a two-bedroom house as reflected in figure 5.2. The building was tested to understand the laser meter and the software in a multi-roomed building with low geometric complexity.

The building was measured and modelled in both Orthograph and Magicplan, which made it possible to identify different aspects of measuring both positively and negatively.
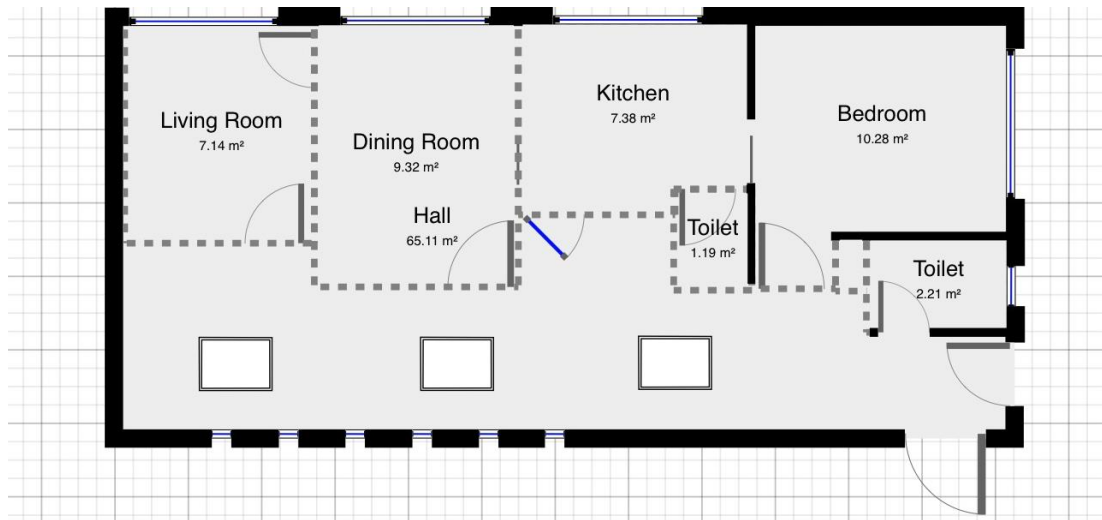
Figure 5.2 Floor plan of test case 2 modelled in and exported from Magicplan

5.1.3 Test case three: The apartments

Located in Nørre Tranders, Denmark. Two test cases were selected. Both were apartment units of 83 m^2 build in 1986. The test apartments were selected in order to test multi-roomed apartment units with high geometric complexity. The apartments were measured and modelled using both Orthograph and Magicplan. The exported dataset from the software was afterwards used to test out use and limitations with respect to the IV20 tool.
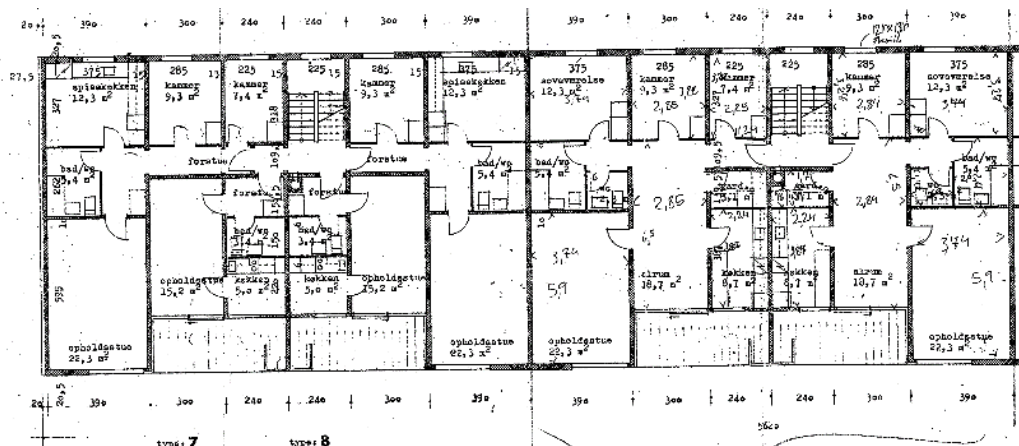
Figure 5.3 Floor plans for test cases three and four - supplied by the building's FM- organization
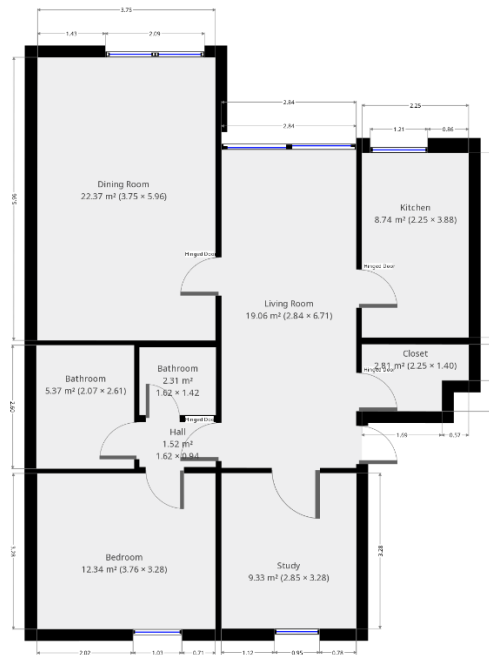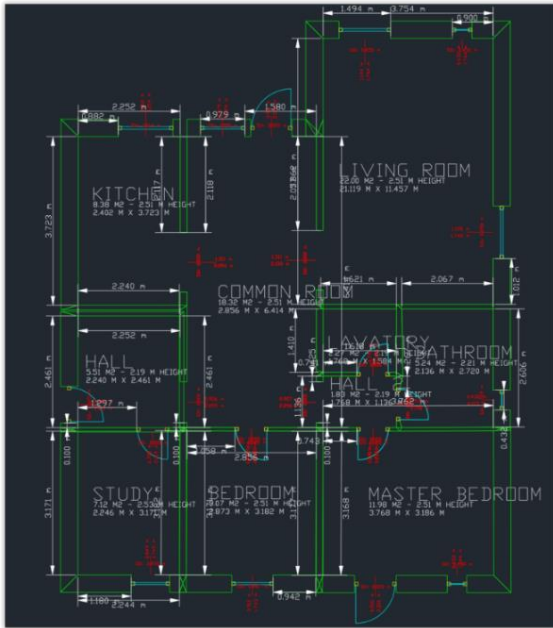
Figure 5.4 The floorplan to the left: Orthograph generated drawing of one of the two apartment units, exported to .DXF and view in Autodesk AutoCAD. The floorplan to the right the other apartment unit's floorplan modelled in Magicplan and exported in the .PNG format.

5.1.4 Test case four: The Apartment in Frederikshavn

Located in Frederikshavn, Denmark. The test case was an apartment unit of 74 m^2 build in 1949. The test apartment was selected in order to test multi-room apartment units with high geometric complexity. Only Magicplan was tested in the apartment to validate the software's usability and functionality with respect to IV20.

Figure 5.6 The test case floor plan modelled in Magicplan.

6 Results and Discussion

This chapter presents the results captured during testing of Orthograph and Magicplan as data processing software for LADA in the case studies presented in chapter 5. All results are discussed promptly after the introduction.

Based on the selected framework for handheld lasers, it became clear that the only laser capable of providing the data needed for LADA with respect to the IV20 tool is the Leica Disto S910 (handheld laser). This was, therefore, the only handheld laser tested in the study presented in this report.

The handheld laser was purchased by the Department of Civil Engineering at Aalborg University, before any analysis of its functionalities or usability was done, and was thusly used for initial testing in the study. The purchase was made with the assumption that the higher the price and the better the functions available. Fortunately, this assumption was validated. When used in unison with the data processing software Orthograph and Magicplan high functionality was experienced. Only Magicplan had connection problems, as the handheld laser would not connect without initial adjustments to the properties of the tablet the software was installed on.

Even though only Orthograph and Magicplan were found usable for LADA with respect to IV20, the handheld laser can connect to many other software. LADA can therefore also be used for other types of laser-assisted data acquisitions, as it allows capturing of a wide variety of data usable in most design and evaluation projects of existing buildings.

The most important feature of data processing software is that it is able to receive data from a handheld laser and model geometries bad on said data, which has already been addressed in chapter 4. The software must, however, be able to translate the data into an exportable format usable for IV20.
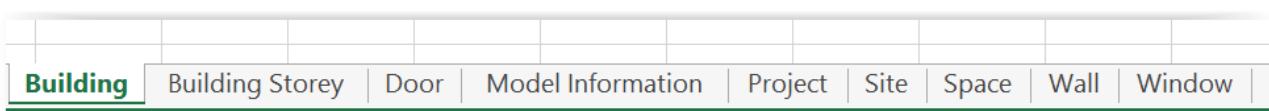
The test software is in the following section evaluated based on exportability and the quality of it.

6.1 Evaluation of Orthograph

Modelling in Orthograph can be done in both the 2D and 3D user interface (UI), when modelling based on data from a handheld laser, it is recommended to use the 2D UI. Controlling the 3D and having sufficient quality control of the model during LADA, is however difficult, as heights of e.g. walls is not seen in the 2D view unless the parameters of the specific wall are selected and reviewed.

When geometries of a building are modelled in Orthograph can be exported as both 2D and 3D. Especially the 3D model is of interest, as it can be exported in the .IFC format, making the model interoperable with various design applications such as Autodesk REVIT, ArchiCad and Bentley Microstation.

Using the .IFC file can, however, be difficult, as the data cannot be exported directly from a design application as a data schema. SimpleBIM® however, makes it is possible to export the .IFC file to .XLSX (Excel format)

Figure 6.1 Category list from SimpleBIM generated .XLSX- file.

31

	BO	BP	BQ	BR	BS	BT
ing Storey	Name (material)		Layer Assignment Name	GlobalId		
Floor	Background-Air Space-Foreground-Rigid Insulation-Batt Insulation			0a13DFED2e164442d9CCba		
Floor	Background-Air Space-Foreground-Rigid Insulation-Batt Insulation			5fceeC3B03Af320f0947Fb		
Floor	Background-Air Space-Foreground-Rigid Insulation-Batt Insulation			84813CBa8790aee4b7C0Eb		
Floor	Background-Air Space-Foreground-Rigid Insulation-Batt Insulation			0c12041DdfE794E92d9C5B		
Floor	Background-Air Space-Foreground-Rigid Insulation-Batt Insulation			B812C9E1D94A8B8cC0BCac		
Floor	Background-Air Space-Foreground-Rigid Insulation-Batt Insulation			8cEac7EFCDf4BB7dbA8962		
Floor	Background-Air Space-Foreground-Rigid Insulation-Batt Insulation			187ba88FaC6CdeF26a8029		
Floor	Background-Air Space-Foreground-Rigid Insulation-Batt Insulation			760BBc3ED0E141eF7aEAcD		
Floor	Background-Air Space-Foreground-Rigid Insulation-Batt Insulation			F0BFa0BEBCb1e6229d138F		

Figure 6.2 The GlobalId of a window equivalent of the ifcGUID in Revit

providing a schema for data storing, reading and manipulation of data. The schema generated using SimpleBIM® is divided into 9 data categories containing data on doors, spaces, walls and windows as shown in figure 4.9. The data can nevertheless be hard to use for IV20, as the object tags in the data schema are randomly generated, and referrers to the .IFC Global Unique Identifier (GUID), as shown in figure 6.2.

However, the ID has no indication of which specific object it represents, making it very hard to use. When viewing the data schema and the model in a design application or IFC viewer simultaneously, the connection between ID and object can be made, as shown in figure 6.3. Such process nevertheless makes attaining IV20 usable data from the .IFC file very demanding and proved to be inefficient during testing.
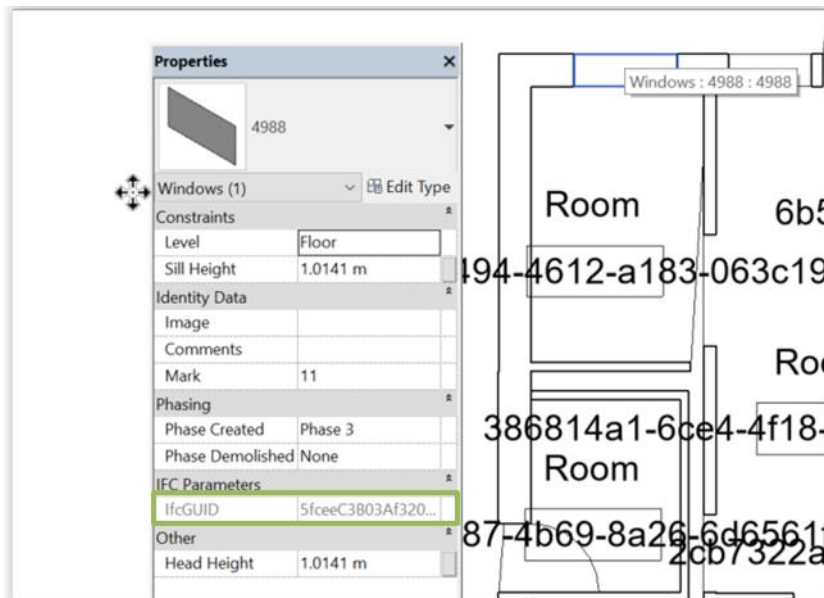
Figure 6.3 Excel sheet with list of windows and their GlobalId

A positive feature of the .IFC file generated from Orthograph and the .XLSX file generated through SimpleBIM® is that parameters of constructions are included under "Name (material)". The use of this data is nevertheless limited as the data are placed in the schema based on the GUID. Data is however stored in the model, without the use of a note function, as is the case with Magicplan. Measurement tag is however not included in the .IFC export.
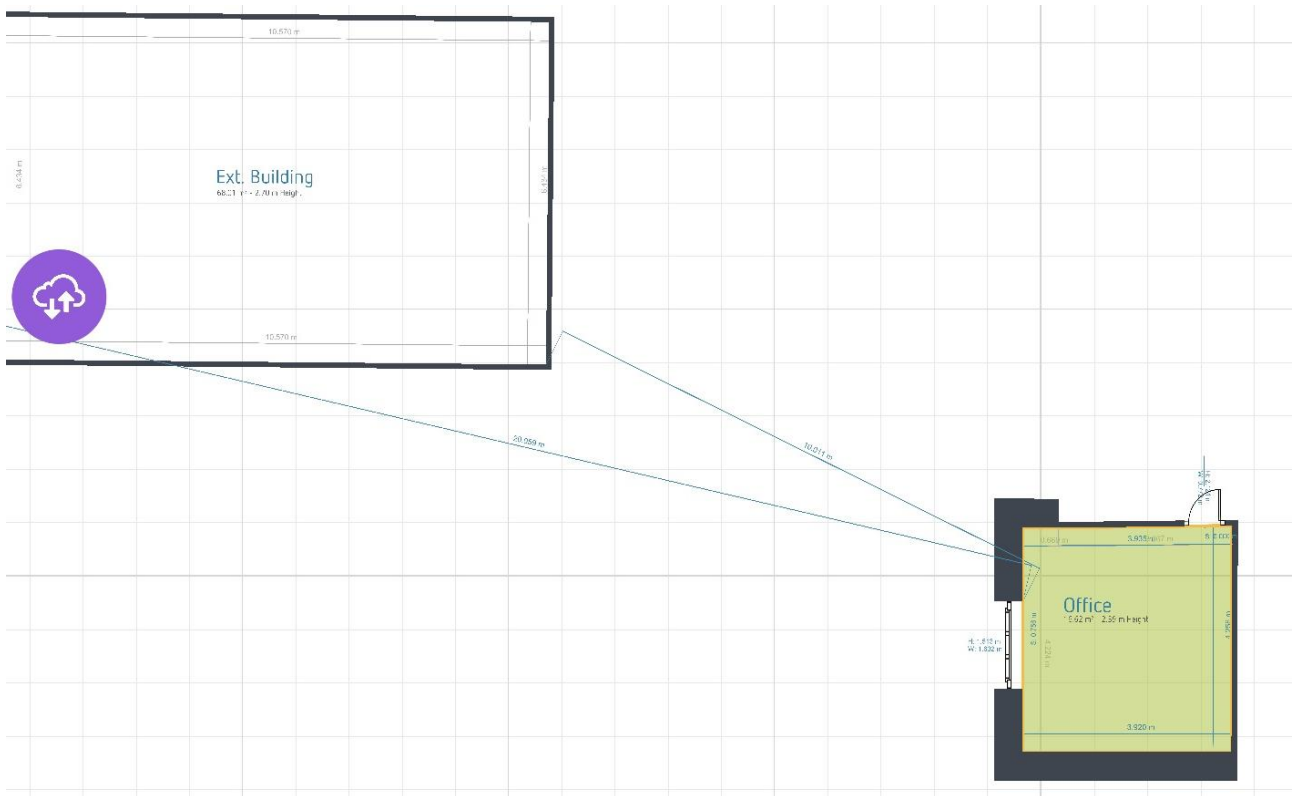
Figure 6.4 External building placed next to test area based on distance measured from window

6.1.1 External geometries

Using Orthograph and a handheld laser for measuring distances and modelling of external geometries can be difficult to do, as corners of building components and objects are the only usable fix-points in Orthograph. Measuring distances to neighbouring buildings can prove impossible, as shown in figure 6.4. During the case study, the distance from one of the test cases was set from the corner of a window to the corner of the neighbouring building. The distance was however in the real building measured from the middle of the window to the corner of the building. Attaching the measurement to the real measuring point was nevertheless not possible. Additionally, if the measuring point set by Orthograph was used to measure from in the real building, it would not have been possible to measure the distance at all, as the neighbouring building cannot be seen from said point.

Only corners of wall, windows and doors can have attached measurements, and even though possible, this is not easy to accomplish. Orthograph is therefore not recommended for LADA with respect to external geometry.

Orthograph can export data in various formats, as introduced in chapter 4. When exporting the .PDF reports available in the software, not all rooms were present. In the .DXF file, the building's geometry was limited, and data regarding the location of the building, external objects and the documentation attained during acquisition was furthermore not included in any of the exports from Orthograph.

Measuring and modelling of case study one, The Office, took 20 minutes, including external objects, whilst measuring and modelling of case study three 3 took 45 minutes, not including registration of external objects.

As shown in table 1, exports from Orthograph contain many data across five different formats. Much of the data are nevertheless incomplete or in a quality making it insufficient for use in IV20 evaluation.

	.PDF	.IFC	.DXF	Schema (.XLSX/ .CSV)	.PNG/ .J-PEG
Room statistics	÷	■	■	■	■
Wall data	÷		■	■	
Window data	÷	÷	■	■	
Door data	÷	÷	■	■	
Location data					
Notes and photos					
External object data					
External object data photo documentation					

Table 1 Data included in Orthograph export in various formats. The yellow colour affirms that the data is in the export. If supported by the ÷ symbol, the data was incomplete.

6.2 Evaluation of Magicplan

Modelling in Magicplan is done in a 2D UI, which is quite easy and intuitive to use. As with Orthograph, there are multiple export possibilities in Magicplan, each for specific purposes, as shown in figure 6.5. Even though some of the export formats are the same in the various options, the content of each export is not the same.
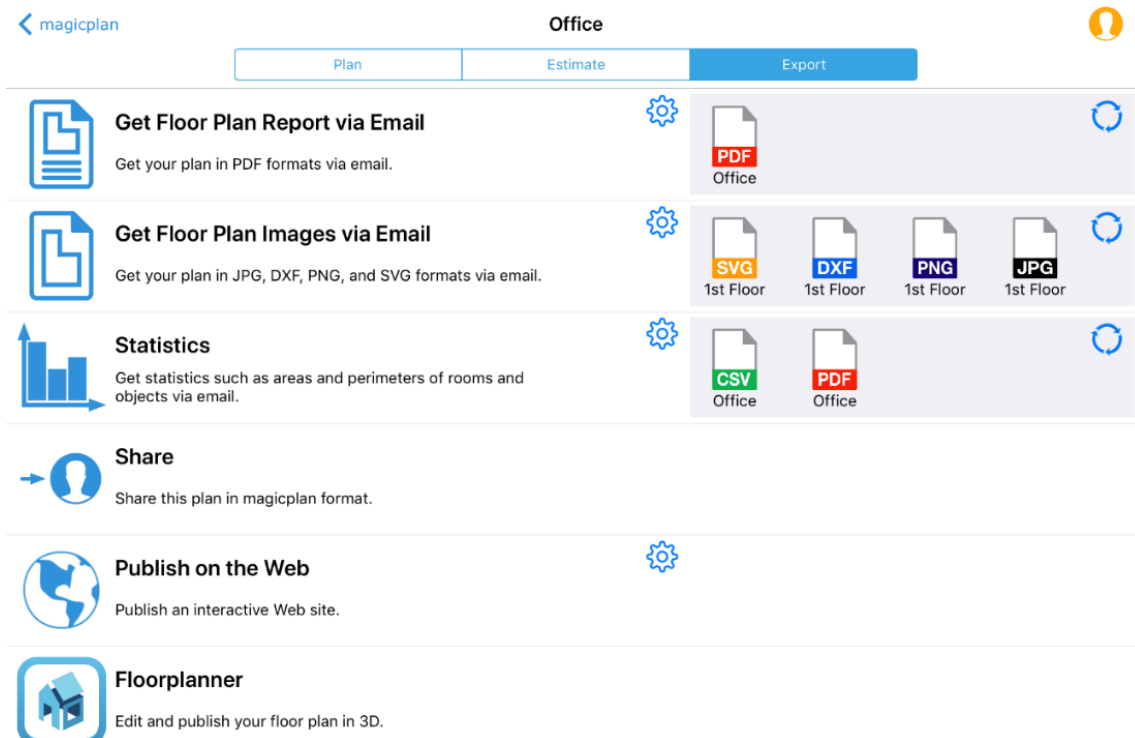
Figure 6.5 Export options in Magicplan

- The first export option: "Get Floor Plan Report via Email", provides a PDF- report sent by mail. This PDF-report contains a floor plan, information regarding measurements and building components, in addition to notes and photos[6].

- The second export option: "Get Floor Plan Images via Email" includes .SVG, .DXF, .PNG, and .JPG.

  The photo formats: .SVG, .PNG and .JPG has no use in IV20 as they only contain an image of the floorplan without any form of extractable data. The photo documentation captured in the software, linked to the building objects in the model is not exported in the photo- export.

  The .DXF format holds the geometric 2D model modelled in Magicplan, however without any views of measurements and notes attached, making this output less efficient to use, compared to the .DXF output attainable from Orthograph. Photo documentation capturing in the software linked to the building objects in the model are also not exported in the .DXF format.

- The third export from Magicplan called "Statistics", allows for export of .CSV and .PDF. The .PDF-export attainable using the export option, however, only includes numbers and text from the Magicplan model and no photos or notes are included in the export, as shown in figure 6.6. The .PDF export is therefore not feasible to use if more than the geometric data are needed.

Statistics

Summary

Floors	1	Bedroom	0	Windows	1	Ground surface with all walls	20.07 m²	Exterior Perimeter	17.93 m
Rooms	1	Bathroom	0	Doors	1	Ground surface with interior walls	15.84 m²		

	Volume	Ground surface without walls	Walls with opening	Walls without opening	Ground Perimeter	Ceiling Perimeter	SurfaceOfWindows	SurfaceOfDoors
TOTAL	39 m³	15.84 m²	38.87 m²	34.77 m²	15.13 m	15.93 m	2.47 m²	1.63 m²

Figure 6.6 .PDF statistics report from Magicplan

.CSV is also included in the "Statistics" export, which is a data schema with comma-separated values, as shown in figure 6.7. In order to make the .CSV schema usable for IV20, it is necessary to update the data structure[7].

PLAN ATTRIBUTES							
Ground surface with all walls: m²,20.07,							
Ground surface with interior walls: m²,15.84,							
Ground surface without walls: m²,15.84,							
Volume: m³,39,							
Perimeter: m,17.93,							
Floor,1,							
Room,1,							

Figure 6.7 .CSV schema opened in Microsoft Excel

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[6] The Floor Plan Report in .PDF from test case 1, is attached as appendix C1.

[7] In the Laser Assisted Data Acquisition of Building Geometry for IV20- User Manual by, Wyke et al. (2019), it is further explained how .CSV data from Magicplan are re-structured for IV20.
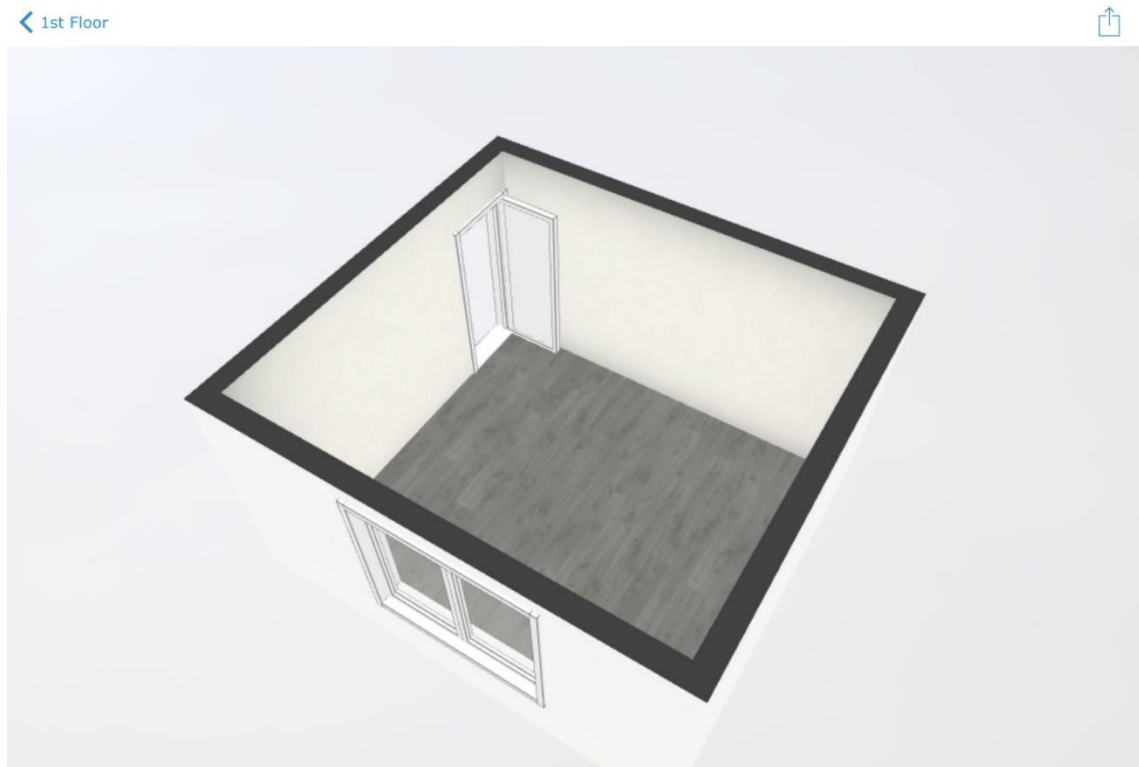
Figure 6.8 3D view of test case one in Magicplan

The final the export- options from Magicplan is an export to the online editor "Floorplanner". This is an internet-based UI allowing manipulation of geometry, making it possible to specify object materials and surfaces. The Floorplanner application was not further examined in the case studies, as the exportable formats from Floorplanner are not useable for IV20 evaluation.

Even though Magicplan cannot export any 3D formats, the UI of the application allows for 3D viewing of the geometry, with a high level of development (LOD), as shown in figure 6.8. The 3D model is usable for visual and quality control and presentation of the building geometry. It can nevertheless not be exported in an IV20 implementable format.

6.2.1 External Geometries

Measuring and modelling external geometries based on LADA is not feasible to do in Magicplan. A land surveying function was added to the application in the summer of 2018. In the testing presented in this paper, the feature did not allow for the modelling of neighbouring buildings. Flora and other smaller shadowing objects can, however, be modelled using the surveying function. Export from Magicplan does nevertheless not include surveying data at this time.

As presented in chapter four, the use of notes and photo documentation of external geometries such as shadowing buildings or flora can realise the need for data. The amount of data acquired through that method is however highly dependent on the person making the acquisition, as that person is in charge of gathering all measurement and distance as well as documenting objects, without support of a model, indicating what is missing and what is not.

As with Orthograph, Magicplan does not allow modelling of floor slap or roofing.

6.3 Direct comparison of the software

Both Orthograph and Magicplan fulfils many of the demands for IV20 evaluation. However, as the tests of the applications showed, Magicplan succeeded in delivering the most of the necessary data for IV20 evaluation. As shown in figure 6.9, Orthograph (yellow) has the capability to deliver .PDF, .IFC, .DXF, .PNG/ .J-PEG. The .IFC further made it possible to extract a data schema of the geometric model data, using SimpleBIM®.

The two software tested in the case study primarily differentiated with respect to the quality of data they exported. As shown in figure 6.9 data from Orthograph, regarding geometric parameters and component data was only partial, whereas data exported from Magicplan (blue) included all, or most elements and data. Between the two software, only Orthograph is capable of exporting the .IFC format. The quality of the data exported through .IFC nevertheless made it infeasible to use the application for LADA.

As previously mentioned, most data was present in the data export when using Magicplan. However, in some situations, certain walls could be missing, if they did not host any building components e.g. windows or doors.

	.PDF	.IFC	.DXF	Schema (.XLSX/ .CSV)	.PNG/ .J-PEG
Geometric Parameters (Orthograph)	÷		yellow	yellow	yellow
Geometric Parameters (Magicplan)	blue		blue	blue	blue
Wall data (Orthograph)	÷		yellow	yellow	
Wall data (Magicplan)	blue			blue	
Window data (Orthograph)	÷	yellow	yellow	yellow	
Window data (Magicplan)	blue		blue	blue	
Door data (Orthograph)	÷	yellow	yellow	yellow	
Door data (Magicplan)	blue		blue	blue	
Location data (Orthograph)					
Location data (Magicplan)	blue			blue	
Notes and photos (Orthograph)					
Notes and photos (Magicplan)	blue				
External object data (Orthograph)					
External object data (Magicplan)	blue		blue		
External object data photo documentation (Orthograph)	yellow				
External object data photo documentation (Magicplan)					

Orthograph	yellow
Magicplan	blue

Figure 6.9 Comparison of functions and export abilities of Orthograph and Magicplan.

While testing Magicplan and Orthograph, a non-building-industry experienced test- person (A) was asked to measure and model the second test case (the Clinic). A person (B) from the building industry additionally tested the building. A third test person (C) also participated side by side with the test person B.

As test person A progressed, it became apparent that Magicplan was easier to use than Orthograph, for the test person and that fewer modelling issues arose when using Magicplan. When the building was measured and modelled using Magicplan, the test person further went on to furnish the test area, on own initiative.

This was not the case when the test person used Orthograph. Magicplan's easy to use interface arguably makes it more intuitive to use and motivates use of the application, whilst the many issues involved with modelling in Orthograph in order to be able to export .IFC tones down the user- initiative in use of that application.

Modelling test case one was timed as part of case- study one. Using Orthograph for data processing from the laser meter, took 20 minutes for test person A and 21 minutes for test persons B, resulting in a low- functioning 3D .IFC models with very little data extractable from the file after using SimpleBIM®. Modelling test case one using Magicplan took 11 minutes for test persons A and 4 minutes for test person B, resulting in a high functioning 2D model with ready to use data extracted directly from the application in the .CSV format.

Based on the first test, it was evident that Magicplan is the recommendable tool for LADA for IV20, based on the ease of which the test persons were able to acquire usable data.

Only one person tested the software in test case one three and four. The test person was an industry professional with a high degree of knowledge regarding data acquisition and building information and 3D modelling. However, without initial knowledge on LADA using Orthograph or Magicplan.

In test case 3, the two apartments were measured and modelled using both Orthograph and Magicplan taking respectively 56 minutes and 45 minutes. The final model in Orthograph was exported using the .IFC format and viewed in different viewers. One of the key benefits of having a 3D model in an exportable format is the ability to manipulate it further in a design application. The models exported as part of the testing were nevertheless not of a quality allowing further use.

The .DXF export from Magicplan was part of the testing imported to Autodesk REVIT and was used for modelling a 3D model of one of the test cases. This re-modelling took 10 minutes, ending out in the result shown in figure 6.10.
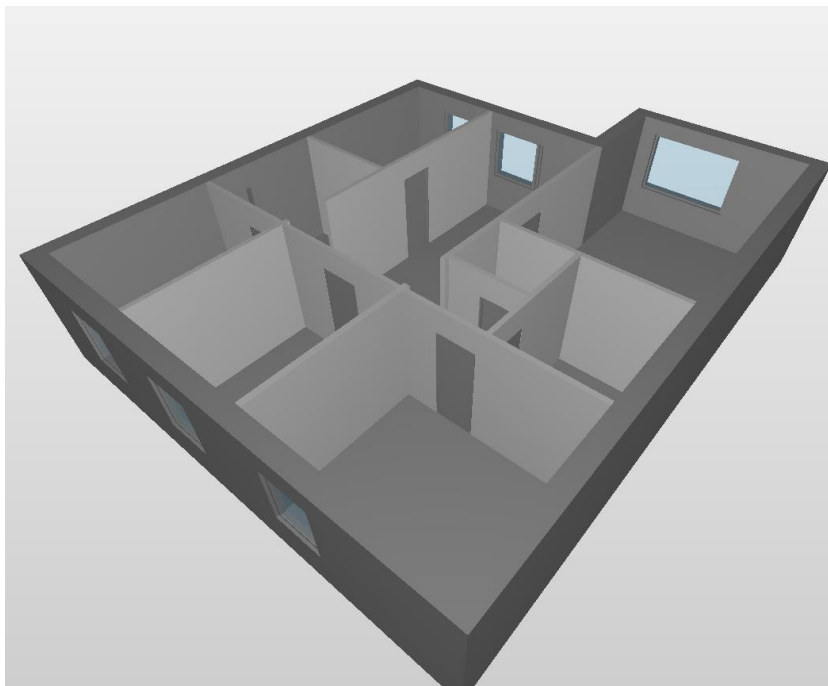
Figure 6.10 3D model based on .DXF export from Magicplan viewed in Solibri Model Viewer.

After the third test case was done, it was decided that Orthograph did not need more testing and that the positive results from Magicplan regarding usability and quality of exported data should be validated in a final test.

Test person B and C performed the final test, now with knowledge on how to use LADA with Magicplan as data processing software, as shown in figure 6.11. The test case was measured and modelled in 36 minutes. The data were exported in .DXF and .CSV. and used successfully for IV20 evaluation.

The final test of Magicplan made it clear that Magicplan is the software most suitable for LADA with respect to IV20 based on its usability, acquisition abilities and export options.
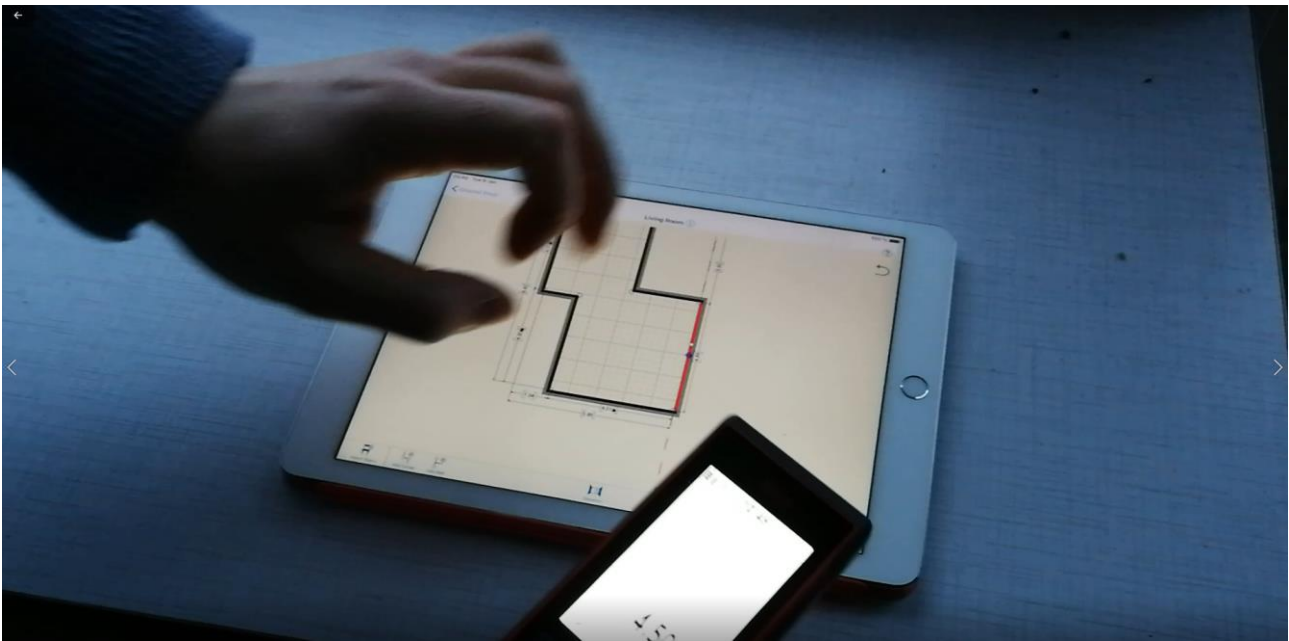
Figure 6.11 Test person doing LADA with Magicplan as data processing software.

7 Conclusion

Both Orthograph and Magicplan are suitable software for Laser-Assisted Data Acquisition for IV20. None of the software fulfils all data demands, but through the analysis and the results presented in this report, a recommendation of software is not possible.

- Magicplan proved to be easy and intuitive to use with respect to geometric modelling.
- The software allows export of 2D drawings of the modelled geometries which can be manipulated into 3D using design applications such as Autodesk REVIT.
- Magicplan allows direct export of data in a structured schema (.CSV) which can be imported the IV20 evaluation tool.
- Magicplan proved through testing to be the tool allowing the fastest LADA process, including geometric modelling.
- Magicplan is cheaper to acquire compared to Orthograph.

To achieve the best Laser-Assisted Data Acquisition with respect to usability, interoperability and exportability using the Leica S910 handheld laser meter, Magicplan must be used as data processing software.

Disclaimer: As the development of both handheld laser technology and data processing software are rapidly evolving the results of this paper might prove inaccurate over time.

7 External data input

In this chapter, a small introduction is given to automation of external data input to the Laser Assisted Data Acquisition Process.

As described in earlier sections of this rapport, it is quite the challenge to do the registration of external geometry (buildings, flora, etc.) However, automated tools exist that can import existing data into building models and evaluation programs, from online databases and repositories.

By using OpenStreetMap (.OSM[8]) it is possible to import the surrounding geometries of the building being renovated. This can be imported e.g. Revit and used together with the .IFC or .DXF file generated through either Orthograph or Magicplan.

As many of the automated tools for external data input involves 3D, Orthograph might be the most feasible tool to use with respect to the following import methods using Dynamo and Grasshopper.

The process of getting .OSM data into Revit is done through the ELK method, viewed in this video by: Timothy Logan: https://vimeo.com/143623515

The same process is performable in Grasshopper for use in Rhino. This is shown in this video by: Timothy Logan: https://vimeo.com/142887447

Another dataset available for IE- simulation and calculation is weather data usable for simulation of sun hours on/ in a building. Through the weather data format .EPW and the import- tool Ladybug, and the analysis engine Radiance, usable in Dynamo through the import tool Honeybee, simulations are made possible (Knudsen, 2018)

The use of said tools for import of external data sets are also usable for generic design exploration, which makes it possible to automate simulation of multiple design options (Knudsen, 2018), this is though not further examined in this report.

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[8] An .OSM file- point is a point with an ID associated with it.

Acknowledgements

Appendix list

A1   Orthograph modelling flow

B1   Orthograph data .PDF report

B2   Orthograph data .PDF specified report

C1   Magicplan Floorplan report

References

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A1 Orthograph modelling flow

Connect lasermeter to Orthograph → Sketch wall → Lock/ Anchor measurement of wall

Sketch wall:
- Measure length
- Measure Heigth
- Measure Width
- Data through Bluetooth

Open room location info manager menu:
- Select floor colour
- Select room category
- Select floor level
- Select base level
- Select "generel" wal thickness
- Select "generel" ceiling height
- Select "generel" suspended ceiling height

Close manager → Sketch Window(s)

Sketch Window(s):
- Measure length
- Measure Heigth
- Measure Width
- Measure Sill
- Measure Threshold
- Measure Baselevel
- Data through Bluetooth

Sill, threshold and baselevel are additional data found under properties

Lock/ Anchor measurement of window → Sketch door(s)

Sketch door(s):
- Measure length
- Measure Heigth
- Measure Width
- Measure Sill
- Measure Threshold
- Measure Baselevel
- Measure Reveal depth
- Measure Architrave width
- Measure built-in depth
- Data through Bluetooth

Sill, threshold and baselevel are additional data found under properties

Lock/ Anchor measurement of window → Export format

Export format → Send by e-mail → IFC → Use file

Kitchen

8.38 m² - 2.51 m Height

Living room

22.00 m² - 2.51 m Height

Common room

18.32 m² - 2.51 m Height

Room #1

2.27 m² - 3.00 m Height

Room #1

5.24 m² - 2.19 m Height

Room #1

51 m² - 2.86 m Height

Room #1

1.83 m² - 2.19 m Height

Room #1

7.12 m² - 2.19 m Height

Room #1

9.07 m² - 3.17 m Height

Room #1

11.98 m² - 2.21 m Height

Common room

Common room
18.32 m² - 2.51 m Height

Report Summary

Net area:	18.32 m²
Gross area:	18.56 m²
Net volume:	45.91 m³
Gross volume:	46.51 m³
Perimeter:	18.540 m

Kitchen
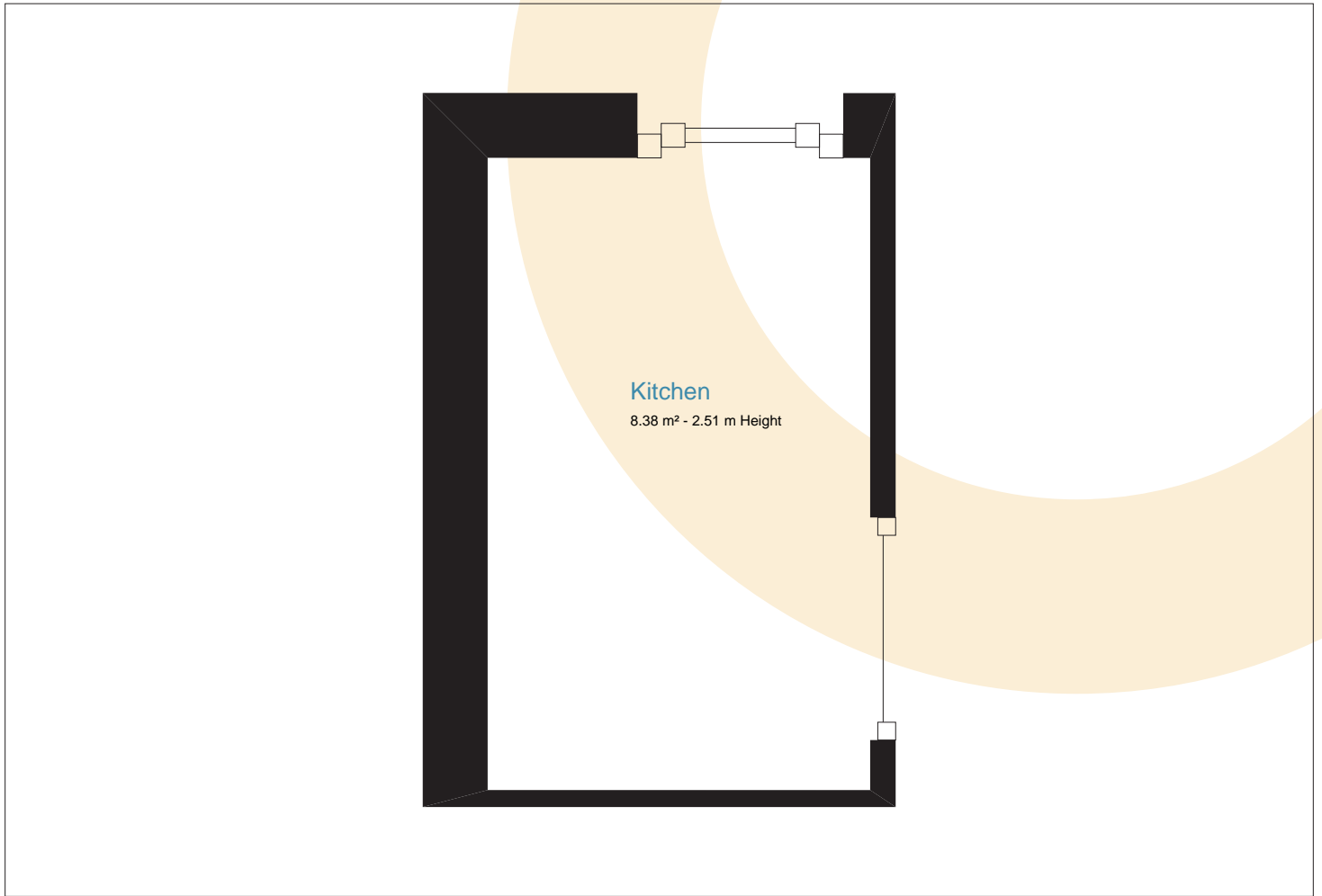
Kitchen
8.38 m² - 2.51 m Height

Report Summary

Net area:	8.38 m²
Gross area:	10.15 m²
Net volume:	21.04 m³
Gross volume:	25.47 m³
Perimeter:	11.949 m

Room #1

Room #1

1.83 m² - 2.19 m Height

Report Summary
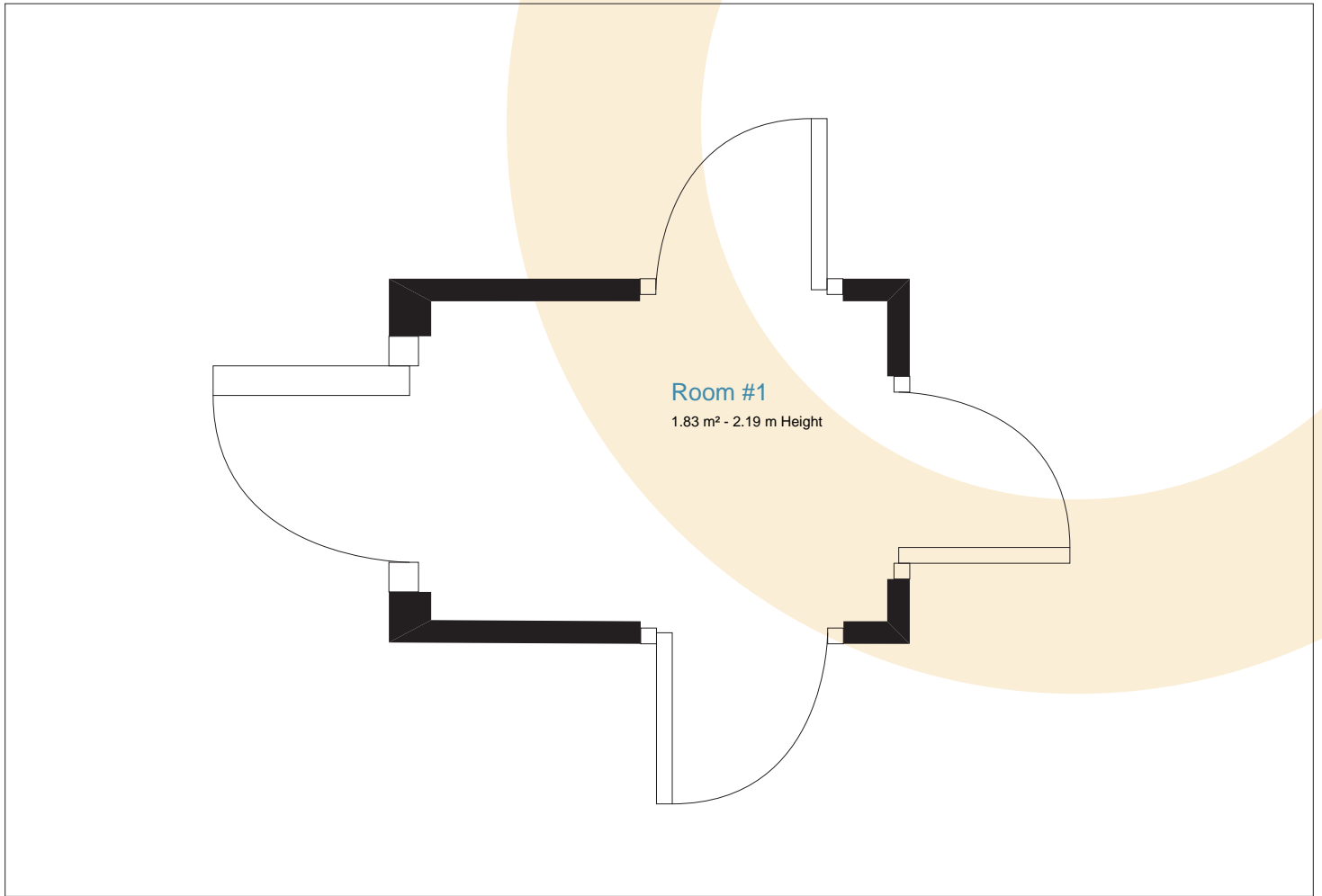
Net area:	1.83 m²
Gross area:	0.00 m²
Net volume:	4.02 m³
Gross volume:	0.00 m³
Perimeter:	5.503 m

Room #1

Room #1
2.27 m² - 3.00 m Height
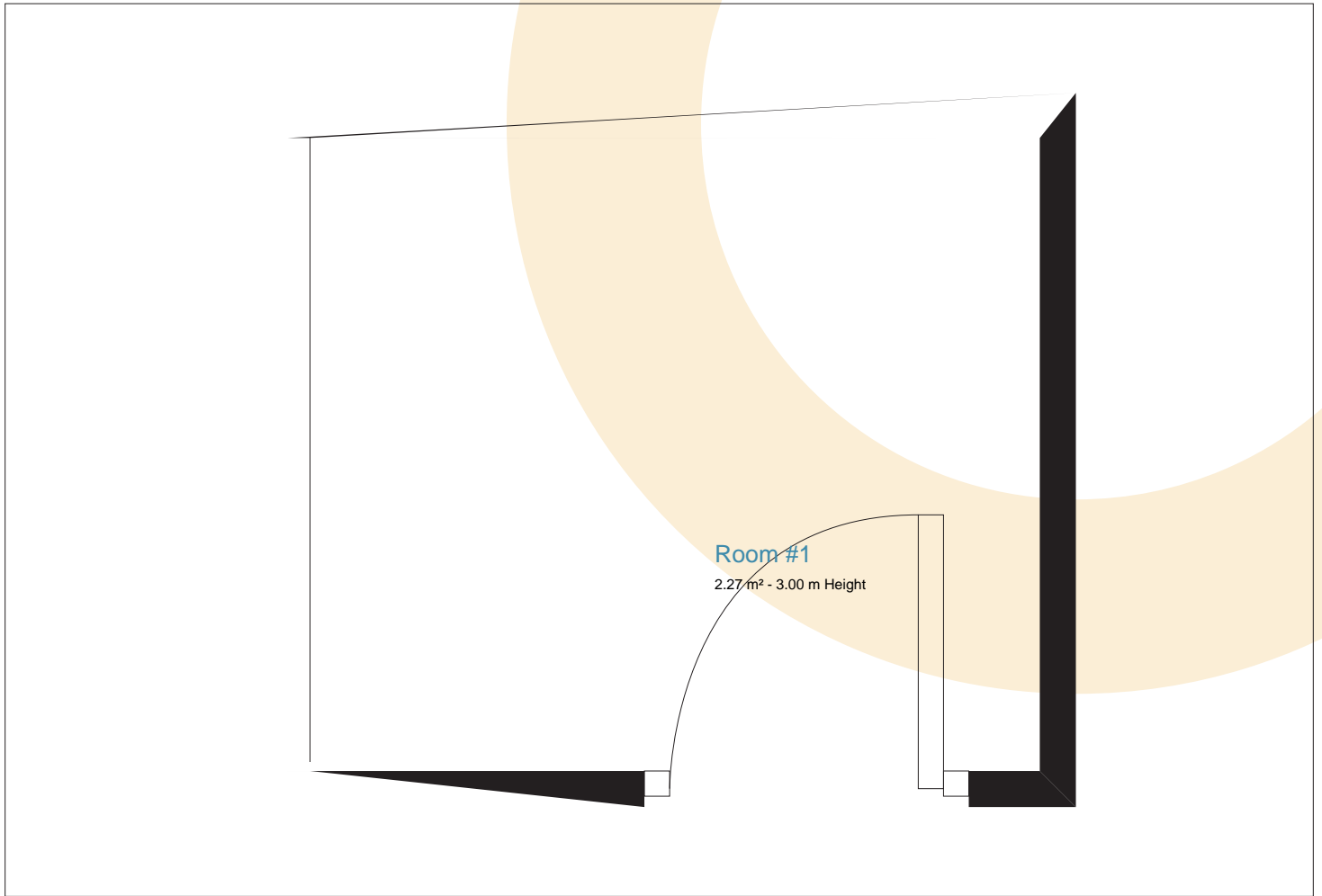
Report Summary

Net area:	2.27 m²
Gross area:	2.39 m²
Net volume:	6.82 m³
Gross volume:	7.18 m³
Perimeter:	6.228 m

Room #1

Room #1
5.24 m² - 2.19 m Height
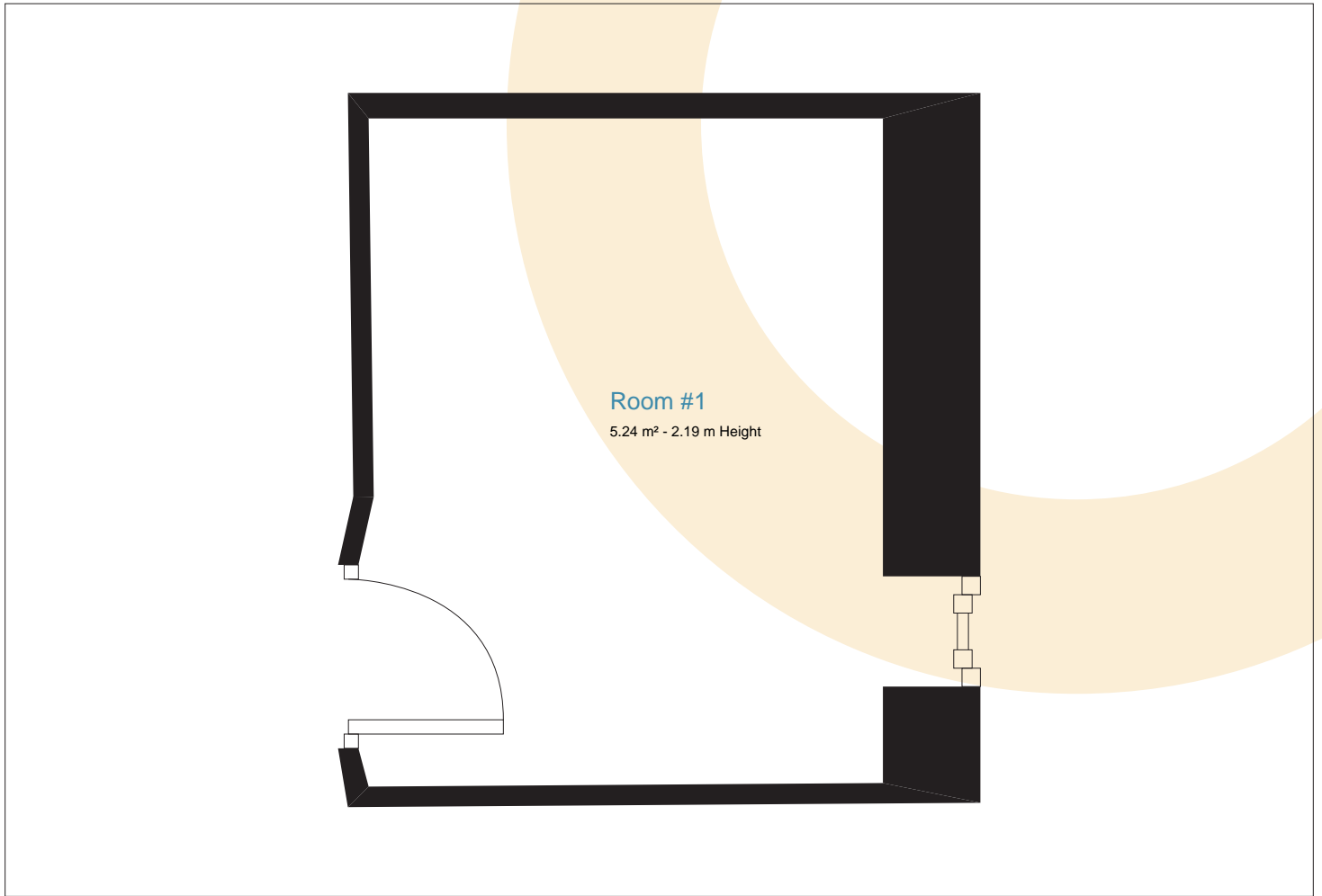
Report Summary

Net area:	5.24 m²
Gross area:	5.77 m²
Net volume:	11.48 m³
Gross volume:	12.63 m³
Perimeter:	9.257 m

Room #1

Room #1
9.07 m² - 3.17 m Height
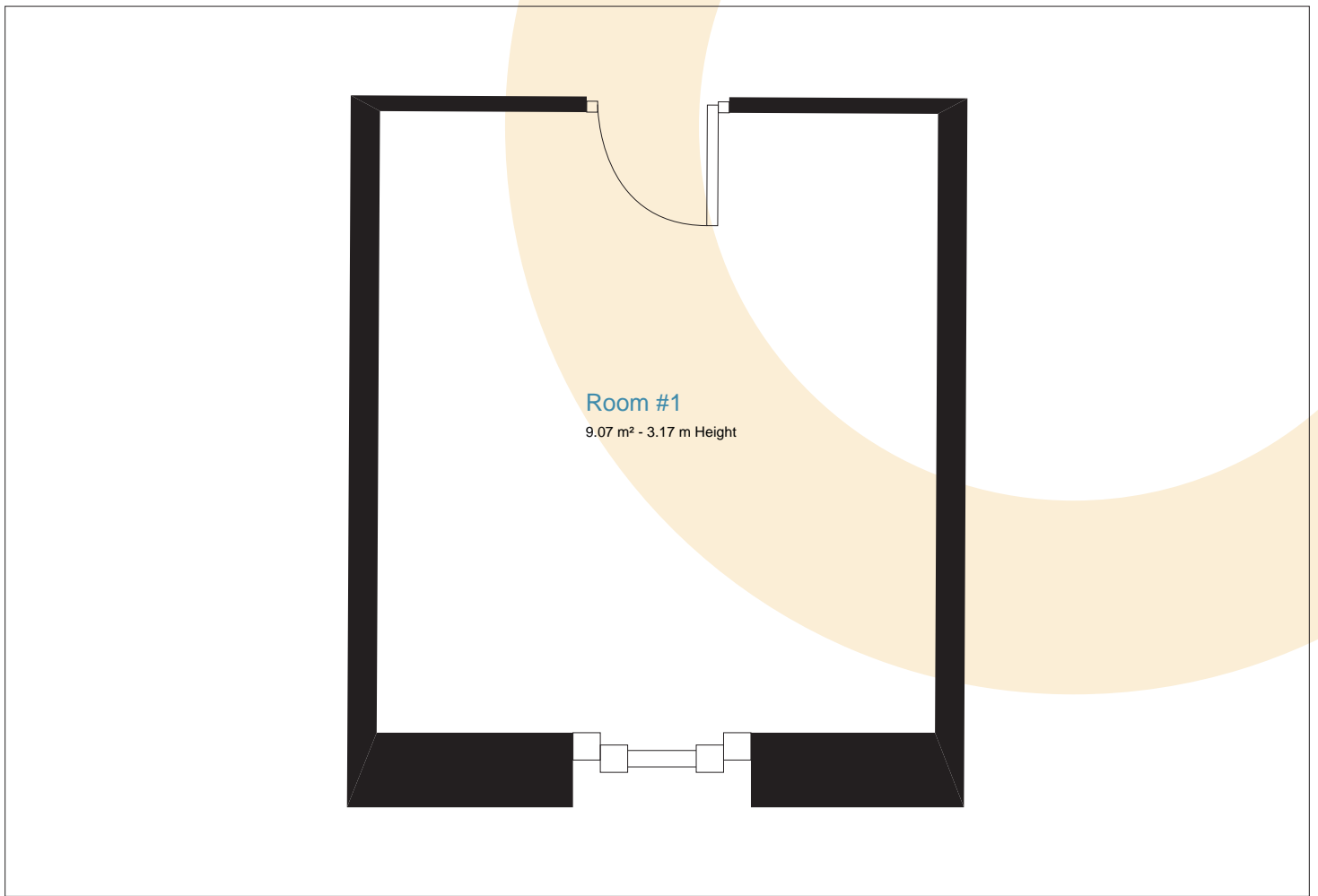
Report Summary

Net area:	9.07 m²
Gross area:	10.09 m²
Net volume:	28.79 m³
Gross volume:	32.04 m³
Perimeter:	12.064 m

Room #1

Room #1
5.51 m² - 2.86 m Height
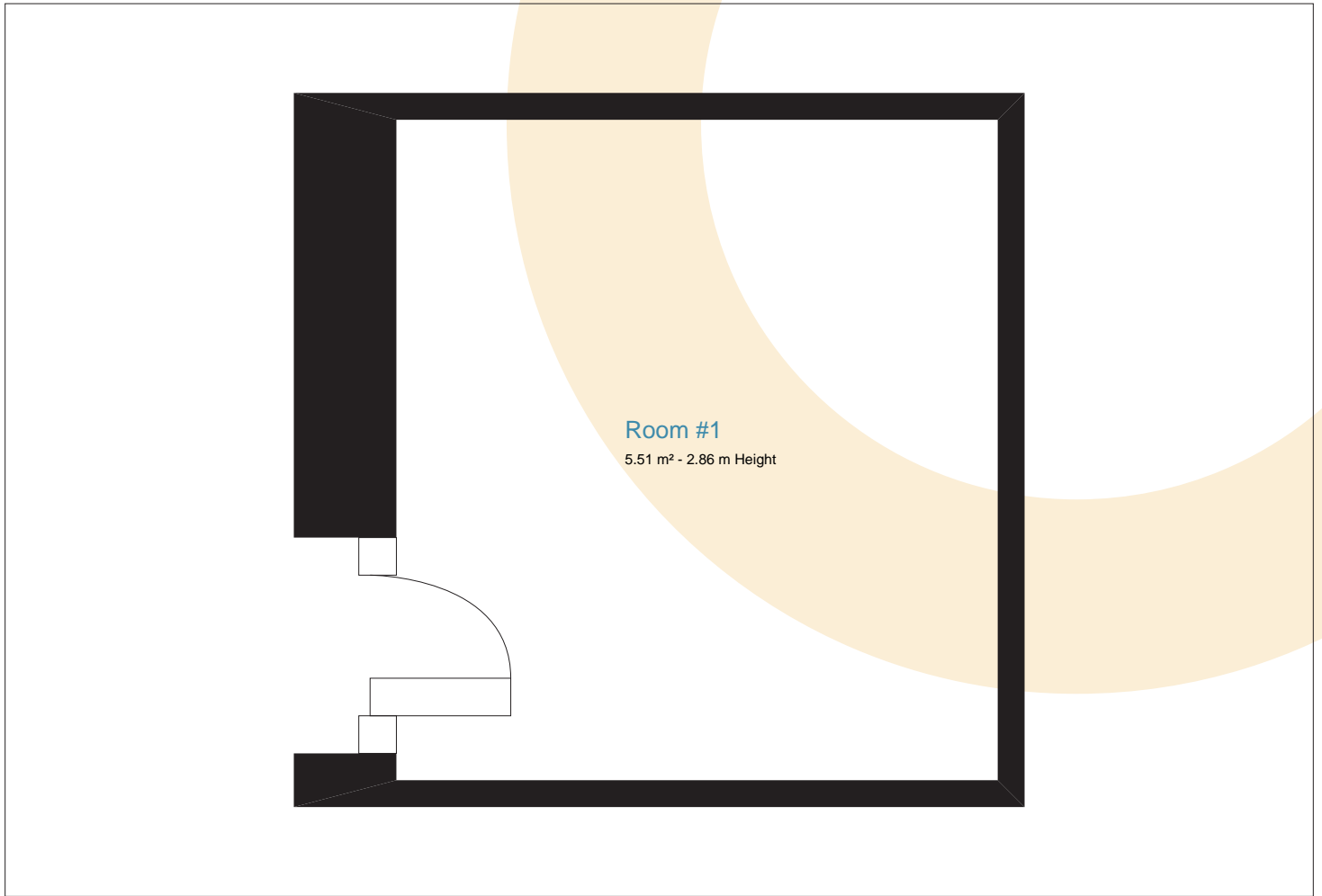
Report Summary

Net area:	5.51 m²
Gross area:	6.26 m²
Net volume:	15.75 m³
Gross volume:	17.90 m³
Perimeter:	9.401 m

Room #1

Room #1

7.12 m² - 2.19 m Height
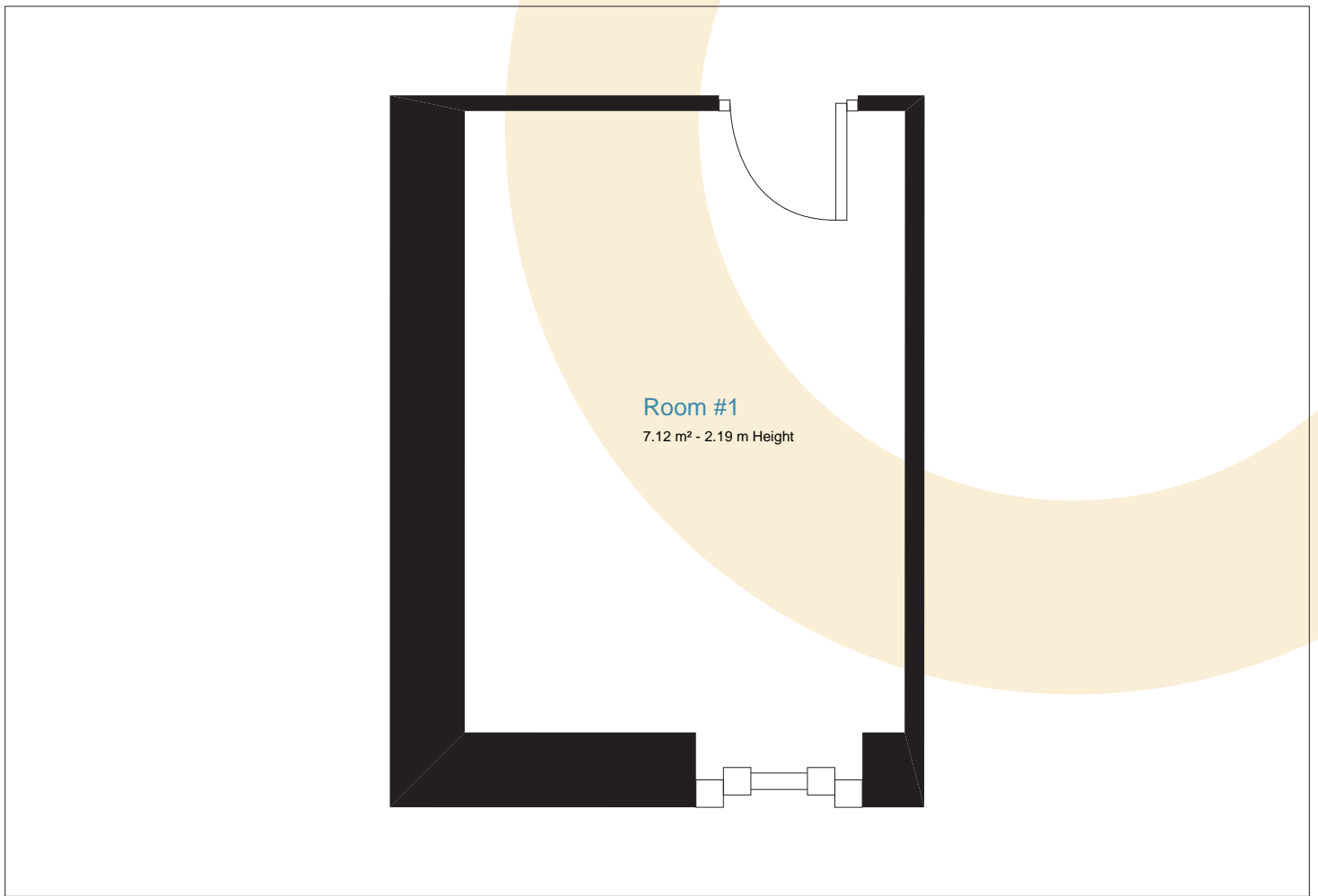
Report Summary

Net area:	7.12 m²
Gross area:	8.76 m²
Net volume:	15.61 m³
Gross volume:	19.21 m³
Perimeter:	10.831 m

Room #1

Room #1
11.98 m² - 2.21 m Height
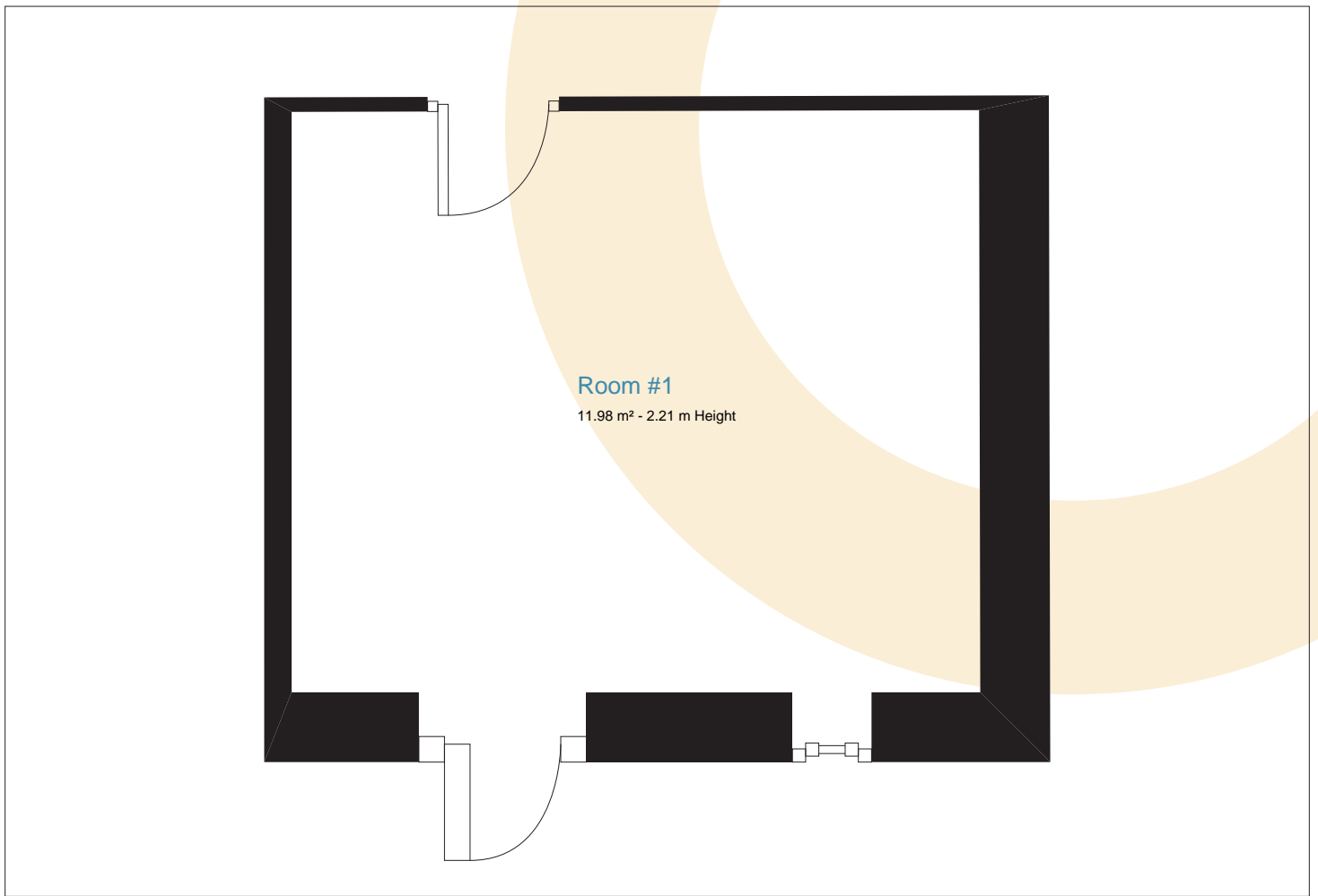
Report Summary

Net area:	11.98 m²
Gross area:	13.79 m²
Net volume:	26.42 m³
Gross volume:	30.43 m³
Perimeter:	13.892 m

Living room

Living room
22.00 m² - 2.51 m Height

Report Summary

Net area:	22.00 m²
Gross area:	32.52 m²
Net volume:	55.15 m³
Gross volume:	81.51 m³
Perimeter:	23.119 m

Case 4

3/August/2018 - Denmark

B2 Orthograph data .PDF specified Report

Kitchen

8.38 m² - 2.51 m Height

Living room

22.00 m² - 2.51 m Height

Common room

18.32 m² - 2.51 m Height

Room #1

2.27 m² - 3.00 m Height

Room #1

5.24 m² - 2.19 m Height

Room #1

.51 m² - 2.86 m Height

Room #1

1.83 m² - 2.19 m Height

Room #1

7.12 m² - 2.19 m Height

Room #1

9.07 m² - 3.17 m Height

Room #1

11.98 m² - 2.21 m Height

Simon Ravn
scr@civil.aau.dk
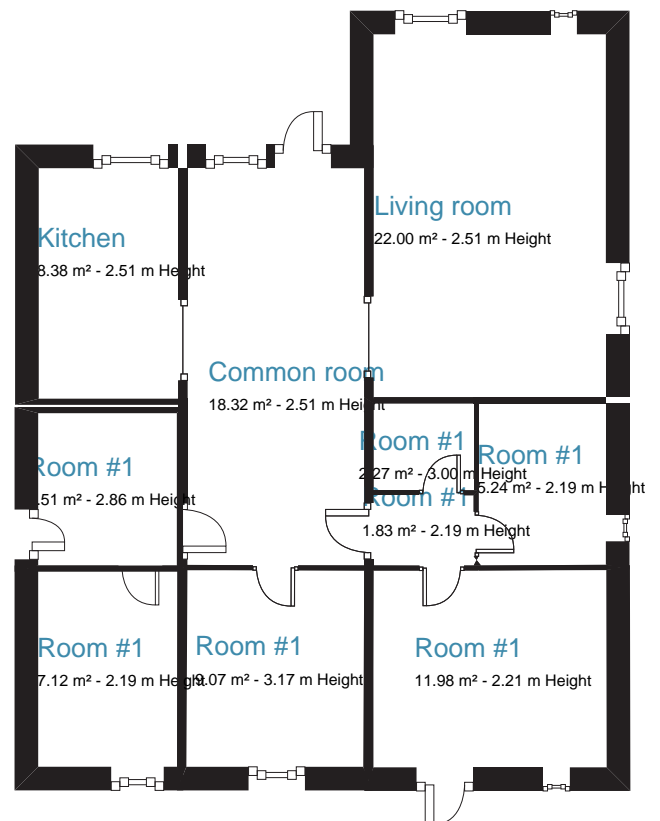
Case 4

3/August/2018 - Denmark

Project properties

Project name: Case 4

Project ID:

Address

Country: Denmark

Town:

County:

Zip code:

Street and number:

Survey data

Surveyor: Simon Ravn

Survey type:

Company name:

Contact details: scr@civil.aau.dk

Date: 3/August/2018

Note:

Report

Net area: 91.73 m²

Gross area: 91.73 m²

Volume: 230.99 m³

Perimeter: 113.740 m

Case 4

3/August/2018 - Denmark

Common room
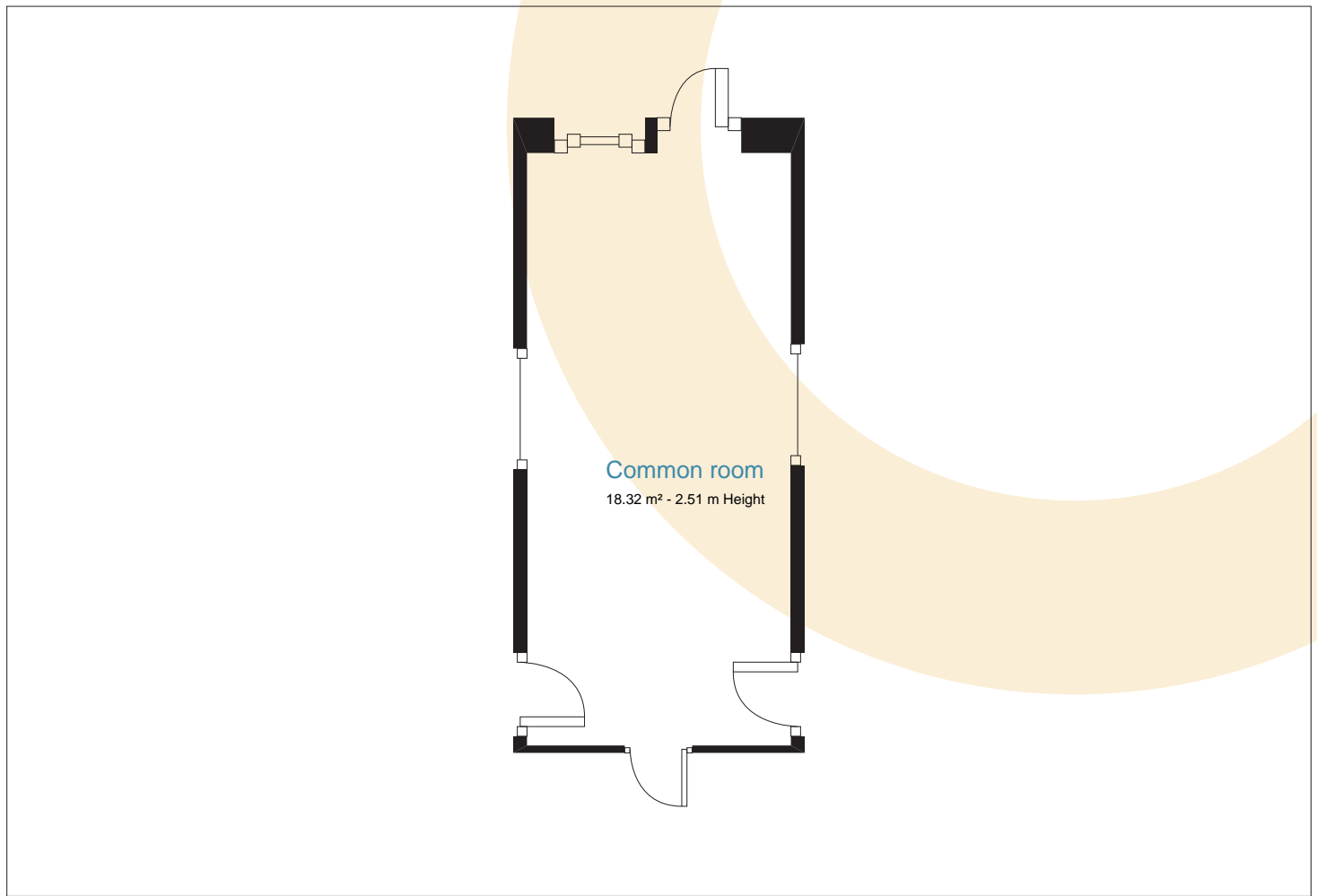
Common room

18.32 m² - 2.51 m Height

Report Summary

Net area:	18.32 m²
Gross area:	18.56 m²
Net volume:	45.91 m³
Gross volume:	46.51 m³
Perimeter:	18.540 m

Simon Ravn
scr@civil.aau.dk

Common room Properties

Floor color:	Yellow
Name:	Common room
Room Categories:	
Floor level:	0
Base level:	0.000 m
Wall thickness:	0.382 m
Ceiling height:	2.506 m
Suspended ceiling height:	2.500 m
Notes:	
Ratio in area calculations:	100.000 m

Common room Report

Type	Room
Name	Common room
Height	2.506 m
Floor covering	N/A
Net area	18.32 m²
Gross area	18.32 m²
Window surface	2.08 m²
Door surface	12.86 m²
Perimeter	18.540 m
Wall perimeter without doors	12.46 m²
Inner wall surface with openings	52.88 m²
Inner wall surface without openings	37.94 m²
Outer wall surface with openings	52.80 m²
Outer wall surface without openings	37.86 m²
Net volume	45.91 m³
Gross volume	45.91 m³

Created via OrthoGraph

Common room Opening Report

Type	Subtype	Width	Height
Door	One wing wooden door	0.729 m	2.150 m
Door	Empty door opening	0.906 m	2.095 m
Door	Empty door opening	1.311 m	2.094 m
Window	Single wooden window	0.979 m	2.124 m
Door	Glazed door	0.911 m	2.122 m
Door	Empty door opening	1.311 m	2.150 m
Door	Empty door opening	0.907 m	2.096 m

Perimeter	Frame length	Sill	Threshold
5.759 m	5.029 m	0.000 m	0.000 m
6.002 m	5.096 m	0.000 m	0.000 m
6.809 m	5.498 m	0.000 m	0.000 m
6.207 m	5.228 m	1.000 m	0.000 m
6.065 m	5.155 m	0.000 m	0.000 m
6.923 m	5.611 m	0.000 m	0.000 m
6.006 m	5.099 m	0.000 m	0.000 m

Reveal	Location 1	Location 2
0.000 m	Common room	Locations
0.000 m	Common room	Locations
0.000 m	Common room	Locations
0.000 m	Common room	Locations
0.000 m	Common room	Locations
0.000 m	Common room	Locations
0.000 m	Common room	Locations

Common room Wall Report

Location	Thickness	Height	Length
Common room	0.080 m	3.000 m	2.856 m
Common room	0.150 m	2.506 m	2.692 m
Common room	0.150 m	3.000 m	3.722 m
Common room	0.382 m	2.506 m	2.856 m
Common room	0.150 m	3.000 m	3.699 m
Common room	0.150 m	3.000 m	1.584 m
Common room	0.150 m	3.000 m	1.131 m

Surface	Volume	Note	Inner Covering
8.57 m²	0.69 m³	N/A	N/A
6.75 m²	1.01 m³	N/A	N/A
11.17 m²	1.68 m³	N/A	N/A
7.16 m²	2.73 m³	N/A	N/A
11.10 m²	1.66 m³	N/A	N/A
4.75 m²	0.71 m³	N/A	N/A
3.39 m²	0.51 m³	N/A	N/A

Outer Covering	Perimeter	Insulation
N/A	5.872 m	N/A
N/A	5.683 m	N/A
N/A	7.745 m	N/A
N/A	6.476 m	N/A
N/A	7.697 m	N/A
N/A	3.468 m	N/A
N/A	2.563 m	N/A
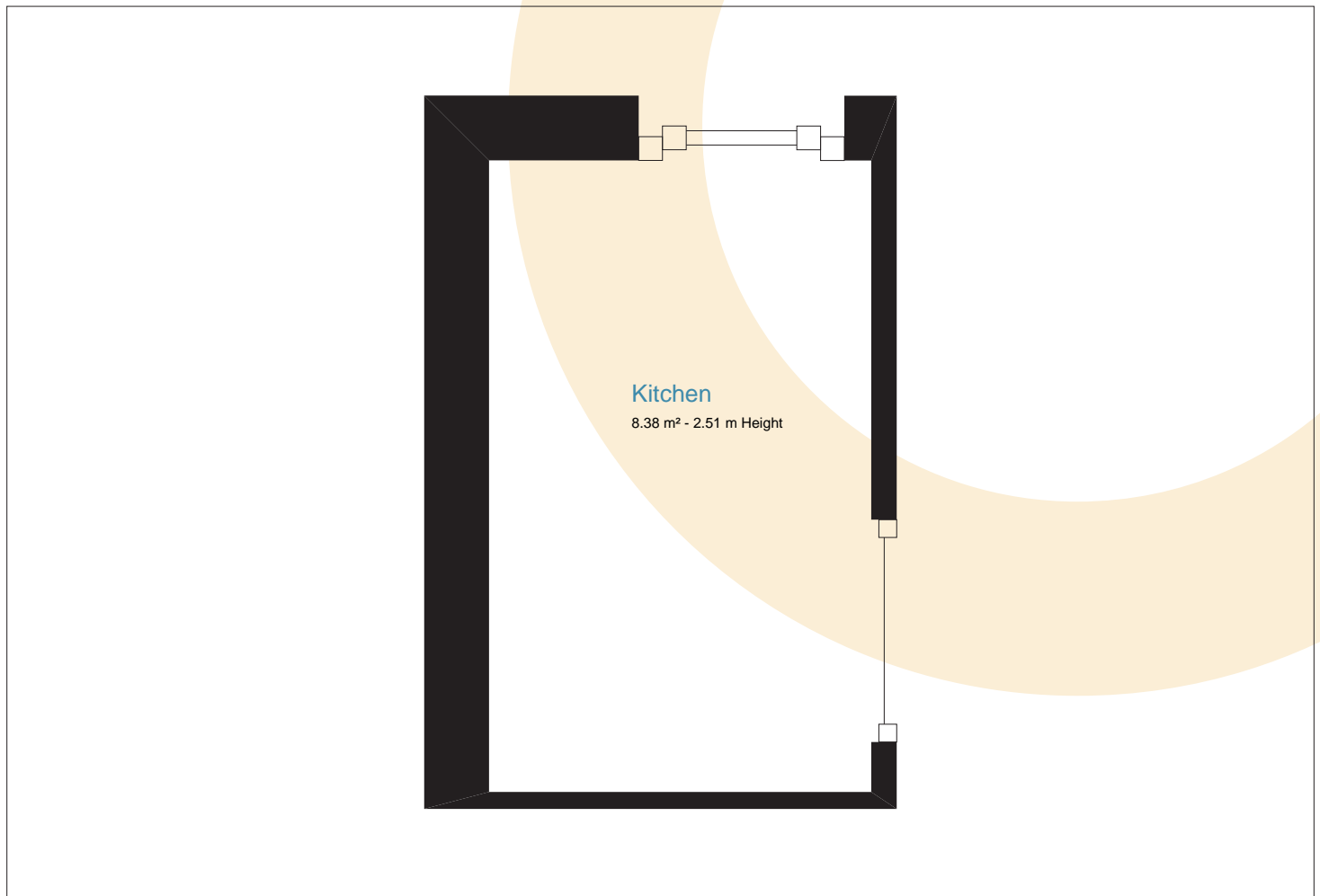
Kitchen

Kitchen
8.38 m² - 2.51 m Height

Report Summary

Net area:	8.38 m²
Gross area:	10.15 m²
Net volume:	21.04 m³
Gross volume:	25.47 m³
Perimeter:	11.949 m

Simon Ravn
scr@civil.aau.dk

Kitchen Properties

Floor color:	Yellow
Name:	Kitchen
Room Categories:	
Floor level:	0
Base level:	0.000 m
Wall thickness:	0.100 m
Ceiling height:	2.509 m
Suspended ceiling height:	2.500 m
Notes:	
Ratio in area calculations:	100.000 m

Kitchen Report

Type	Room
Name	Kitchen
Height	2.509 m
Floor covering	N/A
Net area	8.38 m²
Gross area	8.38 m²
Window surface	1.47 m²
Door surface	2.74 m²
Perimeter	11.949 m
Wall perimeter without doors	10.64 m²
Inner wall surface with openings	31.80 m²
Inner wall surface without openings	27.59 m²
Outer wall surface with openings	34.93 m²
Outer wall surface without openings	30.71 m²
Net volume	21.04 m³
Gross volume	21.04 m³

Kitchen Opening Report

Type	Subtype	Width	Height
Window	Double wooden window	1.212 m	1.214 m
Door	Empty door opening	1.311 m	2.094 m

Perimeter	Frame length	Sill	Threshold
4.851 m	3.639 m	1.014 m	0.000 m
6.809 m	5.498 m	0.000 m	0.000 m

Reveal	Location 1	Location 2
0.000 m	Kitchen	Locations
0.000 m	Common room	Locations

Kitchen Wall Report

Location	Thickness	Height	Length
Kitchen	0.382 m	2.508 m	3.723 m
Kitchen	0.382 m	2.508 m	2.252 m
Kitchen	0.150 m	3.000 m	3.722 m
Kitchen	0.100 m	2.509 m	2.252 m

Surface	Volume	Note	Inner Covering
9.34 m²	3.57 m³	N/A	N/A
5.65 m²	2.16 m³	N/A	N/A
11.17 m²	1.68 m³	N/A	N/A
5.65 m²	0.57 m³	N/A	N/A

Outer Covering	Perimeter	Insulation
N/A	8.210 m	N/A
N/A	5.268 m	N/A
N/A	7.745 m	N/A
N/A	4.704 m	N/A

Room #1

Room #1

1.83 m² - 2.19 m Height

Report Summary

Net area:	1.83 m²
Gross area:	0.00 m²
Net volume:	4.02 m³
Gross volume:	0.00 m³
Perimeter:	5.503 m

Room #1 Properties

Floor color:	Default
Name:	Room #1
Room Categories:	
Floor level:	0
Base level:	0.000 m
Wall thickness:	0.100 m
Ceiling height:	2.191 m
Suspended ceiling height:	2.500 m
Notes:	
Ratio in area calculations:	100.000 m

Room #1 Report

Type	Room
Name	Room #1
Height	2.191 m
Floor covering	N/A
Net area	1.83 m²
Gross area	1.83 m²
Window surface	0.00 m²
Door surface	6.54 m²
Perimeter	5.503 m
Wall perimeter without doors	2.44 m²
Inner wall surface with openings	14.28 m²
Inner wall surface without openings	7.74 m²
Outer wall surface with openings	14.63 m²
Outer wall surface without openings	8.09 m²
Net volume	4.02 m³
Gross volume	4.02 m³

Room #1 Opening Report

Type	Subtype	Width	Height
Door	One wing wooden door	0.719 m	2.150 m
Door	One wing wooden door	0.719 m	2.150 m
Door	Empty door opening	0.907 m	2.096 m
Door	One wing wooden door	0.719 m	2.150 m

Perimeter	Frame length	Sill	Threshold
5.739 m	5.019 m	0.000 m	0.000 m
5.739 m	5.019 m	0.000 m	0.000 m
6.006 m	5.099 m	0.000 m	0.000 m
5.739 m	5.019 m	0.000 m	0.000 m

Reveal	Location 1	Location 2
0.000 m	Room #1	Locations
0.000 m	Room #1	Locations
0.000 m	Common room	Locations
0.000 m	Room #1	Locations

Room #1 Wall Report

Location	Thickness	Height	Length
Room #1	0.080 m	2.190 m	1.136 m
Room #1	0.080 m	3.000 m	1.618 m
Room #1	0.150 m	3.000 m	1.131 m
Room #1	0.080 m	2.190 m	1.618 m

Surface	Volume	Note	Inner Covering
2.49 m²	0.20 m³	N/A	N/A
4.85 m²	0.39 m³	N/A	N/A
3.39 m²	0.51 m³	N/A	N/A
3.54 m²	0.28 m³	N/A	N/A

Outer Covering	Perimeter	Insulation
N/A	2.431 m	N/A
N/A	3.396 m	N/A
N/A	2.563 m	N/A
N/A	3.396 m	N/A

Case 4

3/August/2018 - Denmark

Room #1
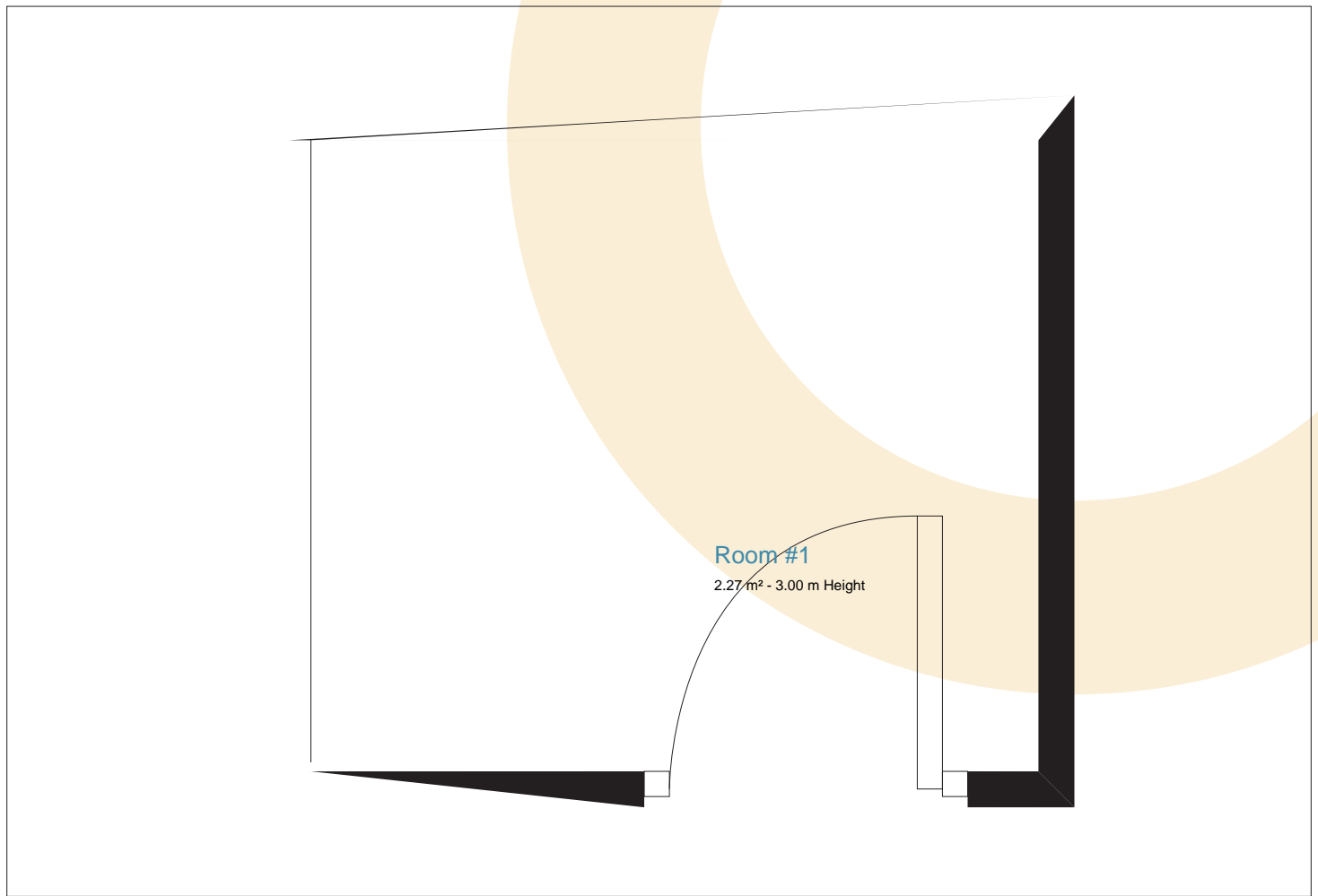
Room #1
2.27 m² - 3.00 m Height

Report Summary

Net area:	2.27 m²
Gross area:	2.39 m²
Net volume:	6.82 m³
Gross volume:	7.18 m³
Perimeter:	6.228 m

Room #1 Properties

Floor color:	Default
Name:	Room #1
Room Categories:	
Floor level:	0
Base level:	0.000 m
Wall thickness:	0.100 m
Ceiling height:	3.000 m
Suspended ceiling height:	2.500 m
Notes:	
Ratio in area calculations:	100.000 m
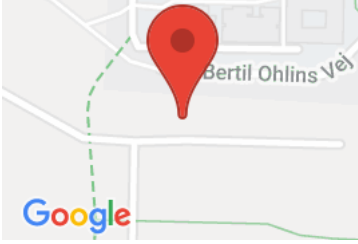
Room #1 Report

Type	Room
Name	Room #1
Height	3.000 m
Floor covering	N/A
Net area	2.27 m²
Gross area	2.27 m²
Window surface	0.00 m²
Door surface	1.55 m²
Perimeter	3.072 m
Wall perimeter without doors	2.35 m²
Inner wall surface with openings	6.73 m²
Inner wall surface without openings	5.18 m²
Outer wall surface with openings	6.79 m²
Outer wall surface without openings	5.25 m²
Net volume	6.82 m³
Gross volume	6.82 m³

Office

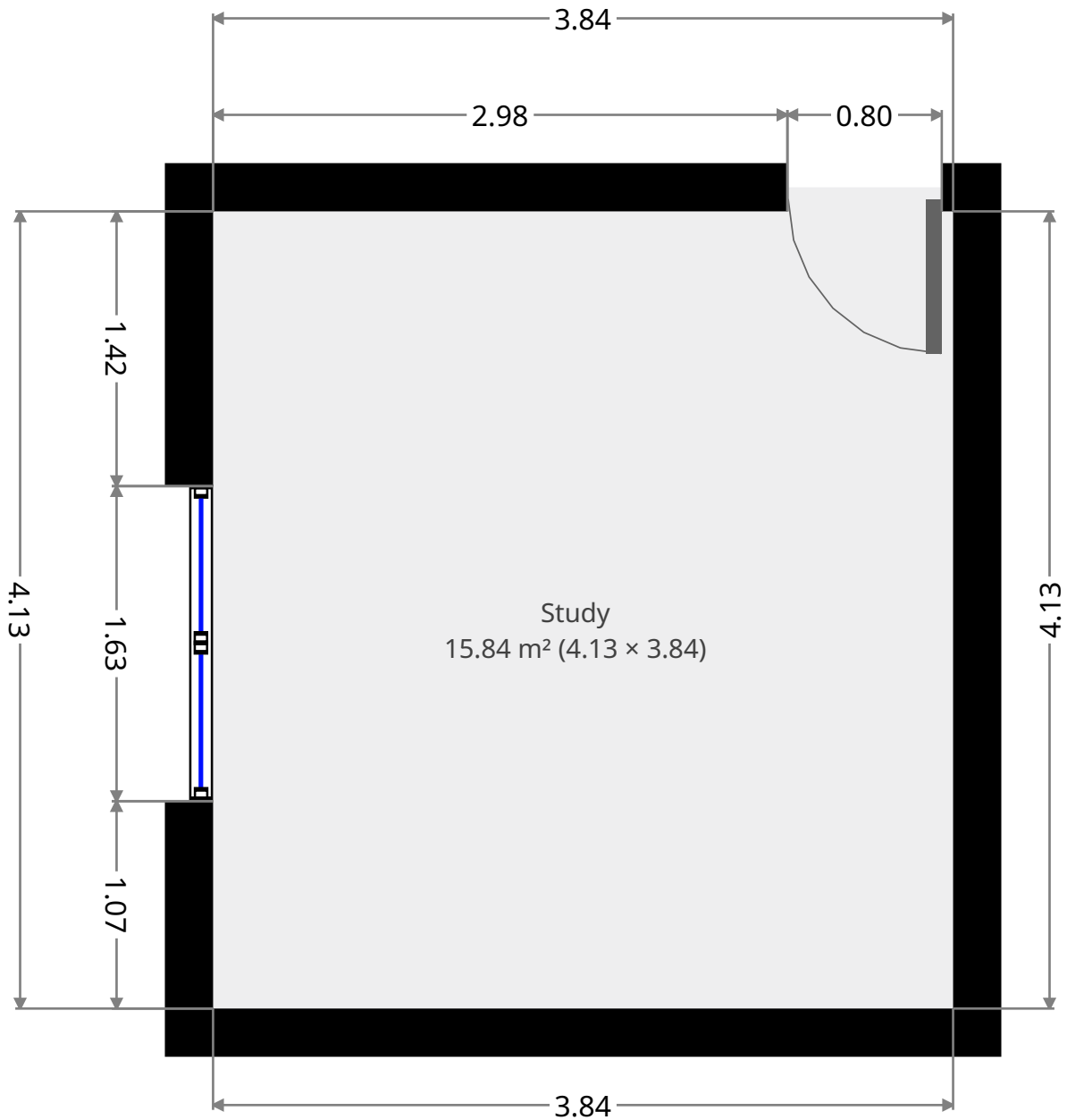Thomas Manns Vej 23, Aalborg, Denmark 9220
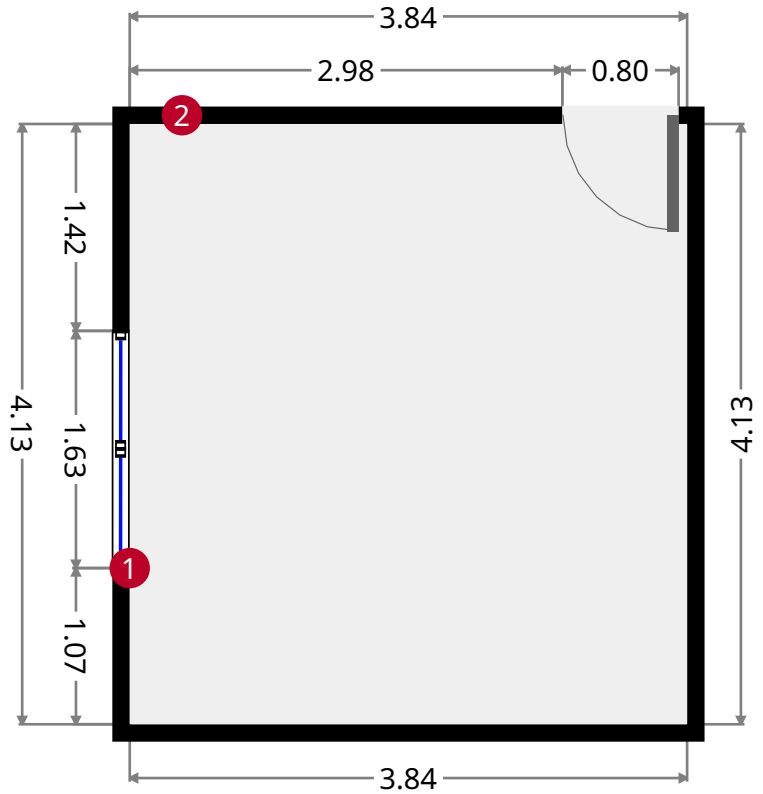
Statistics

16 m²
1 Floor
0 Bedroom
0 Bathroom

1st Floor

3.84

2.98   0.80

1.42

4.13

1.63

Study
15.84 m² (4.13 × 3.84)

4.13

1.07

3.84

0.0   0.5   1.0   1.5m
1:35

Office

Thomas Manns Vej 23, Aalborg, Denmark 9220

Study

Width:	3.84 m
Length:	4.13 m
Area	15.84 m²
Perimeter	15.93 m

3.84

2.98   0.80

2

1.42

4.13

1.63

4.13

1

1.07

3.84
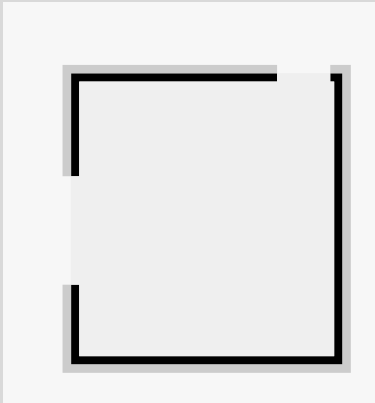
Study

Distance to external geometry: 13675,3

0.0   0.5   1.0   1.5   2.0   2.5m

1:52

Office

Thomas Manns Vej 23, Aalborg, Denmark 9220

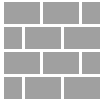**1** French Window

Windows can open 90 degree

- Height: 1.51 m

- Distance to Floor: 0.78 m

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2 Wall   - Thickness: 390 mm.

Office

Thomas Manns Vej 23, Aalborg, Denmark 9220

Plan

https://www.civil.aau.dk/

- Date: 2018-07-30