BIM SPEED

# Application for crowdsourcing of inhabitant's input

## Deliverable Report D1.5

Deliverable Report: D1.5, issue date on 1 August 2021

BIM-SPEED
Harmonised Building Information Speedway for Energy-Efficient Renovation

This research project has received funding from the European Union's Programme H2020-NMBP-EEB-2018 under Grant Agreement no 820553.

# Application for crowdsourcing of inhabitants input

## Deliverable Report D1.5

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## Colophon



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# Change log

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# Publishable executive summary

***Overview***

Deep renovation of buildings is key to meet the EU's energy efficiency target[1]. To propose and develop optimized renovation solutions, a good understanding of the as-is situation of a building is required. This often leads to collecting large amount of data at the beginning of a renovation process, which is a very time-consuming process. This large amount of gathered raw data is not always collected in a structured way and utilized for further analyses. On the other hand, the full picture of energy efficient buildings not only concerns the use of energy but also the comfort of users, their preferences, and their priorities. Therefore, the objective of the work package 1 of BIM-SPEED project is to collect and understand the required data from existing buildings by developing a series of use cases 1) to enable the users to specify their main goal of the refurbishment project 2) to characterize the related business processes as use cases, and 3) to identify the relevant methods, software, tools and devices to be utilized in the process. To this end, within this work package, several tasks are dedicated to distinguishing and collect different types of data from existing buildings with respect to the characterized use cases. Task 1.5, which is the focus of this deliverable, is geared towards data collection from inhabitants. Inhabitants' inputs are crucial to complement a set of analyses and simulation results modeling the as-is situation of a building, particularly concerning comfort. In this respect, a user-friendly application is developed to collect such input from inhabitants. This has been achieved by firstly identifying the use cases that require inhabitants' inputs for further analyses, simulations, validations, or calibrations. After the identification of relevant use cases, a set of questions has been gathered and implemented in a user-friendly app taking privacy and data protection protocols into consideration. The main objective of developing this app is to optimize and digitize the process of data collection and data analysis from the inhabitants. Moreover, a simple BIM model has been integrated in the application to facilitate the spatial communication and interaction with the inhabitants as well as the storage of responses in relation to each spatial component in question.

Watch this video to learn how to use the app.

Access the app here.

Download the installation manual here.

# List of acronyms and abbreviations

**DoA:** Description of Action
**BEM**: Building Energy Model
**BIM**: Building Information Modelling
**WP**: Working package
**EEB**: Energy Efficient Buildings
**KPI**: Key Performance Indicator
**MET**: Metabolic Equivalent of Task
**WP**: Work Package
**MET**: Metabolic Equivalent of Task
**KPI**: Key Performance Indicator
**EC**: European Commission
**UC**: Use case
**IEQ**: Indoor Environment Quality
**GUID**: Global Unique Identifier
**API**: Application Programming Interface

# Definitions

**SaaS**: Software as a Service is a software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted.
**SQL**: Structured Query Language is a domain-specific language used in programming
**REST WebService**: Representational state transfer is a software architectural style that defines a set of constraints to be used for creating Web services
**.Net framework:** is a software framework developed by Microsoft that runs primarily on Microsoft Windows
**Xamarin.Forms**: is an open source cross-platform framework for building native UIs for iOS, Android, and Windows from a single, shared C# codebase.

# Contents

# List of Figures & Tables

# 1. Introduction

## 1.1 Outline of this deliverable

This document describes the deliverable **D1.5 "Application for crowdsourcing of inhabitants input"**. The type of this report is "**Other**: Software, technical diagram, etc." (the code used by EC for this type of deliverable). In this context, the deliverable of type "other" is not meant to be an elaborate report, yet this accompanying document is to facilitate the use of the developed mobile app, titled "BIM_SPEED inhabitants app" which is the final result of task 1.5 "Inhabitants input and information crowdsourcing". The app can be downloaded from generic application stores such as the Apple AppStore. This report summarizes the conceptual framework of the work and its implementation as a user-friendly application. It starts with BIM-SPEED underlying objectives and the role of work package 1 in the data acquisition. Then it explains and outlines the conceptual framework and the methodology used in relation to the identified use cases where inhabitants' input is required. Furthermore, section 3 describes the implementation and the development of the proposed methods as a user-friendly app and finally it ends with ethical and privacy considerations, in specific the measures taken for safe handling of privacy-sensitive data.

## 1.2 Research objectives

The main aim of the BIM-SPEED project is to improve the energy efficiency of the existing buildings by means of BIM to reduce the planning, execution, engineering time and costs of renovation projects. This will be achieved by developing required protocols and technologies for providing a cloud-based and affordable BIM platform that can interoperate with a set of BIM tools to be utilized in all cycles of the renovation processes; namely **as-built data collection**, renovation design, engineering, renovation work execution, and maintenance. In this context, the main objective of work package 1 is to reduce time, cost, and complexity in the deployment of tools and techniques (methods/procedures/protocols) for **data acquisition** in residential renovation projects. In other words, this working package deals with acquiring data form existing buildings. More specifically within this work-package, five tasks are dedicated to collect different types of data from an existing building (Figure 1). Task 1.5, which is the focus of this deliverable, is geared towards collecting inhabitants' input from an existing building to complement the required input for further analyses and simulations, especially in relation to comfort. This task utilizes the concept of crowdsourcing to collect relevant and useful data from inhabitants. As shown in Figure 2, there are several types of crowdsourcing with different levels of intellectual challenges for the participants[2]; from the highest-level applications such as crowd innovation, and crowd voting, all the way down to micro editorial tasks and crowd data collection. In the context of this project, our focus is specifically on **crowd data collection**.

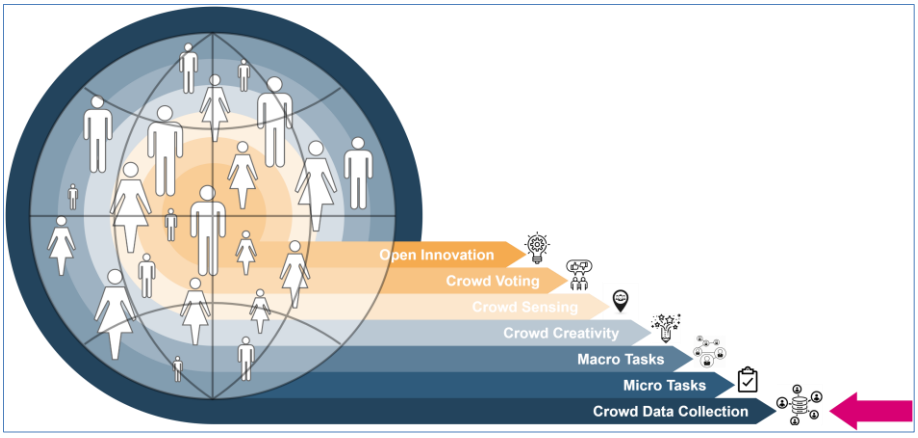



Figure 2: Different levels of crowd scouring

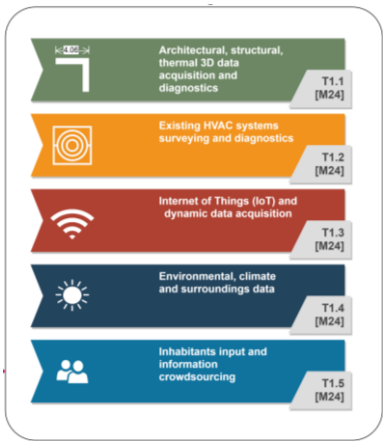


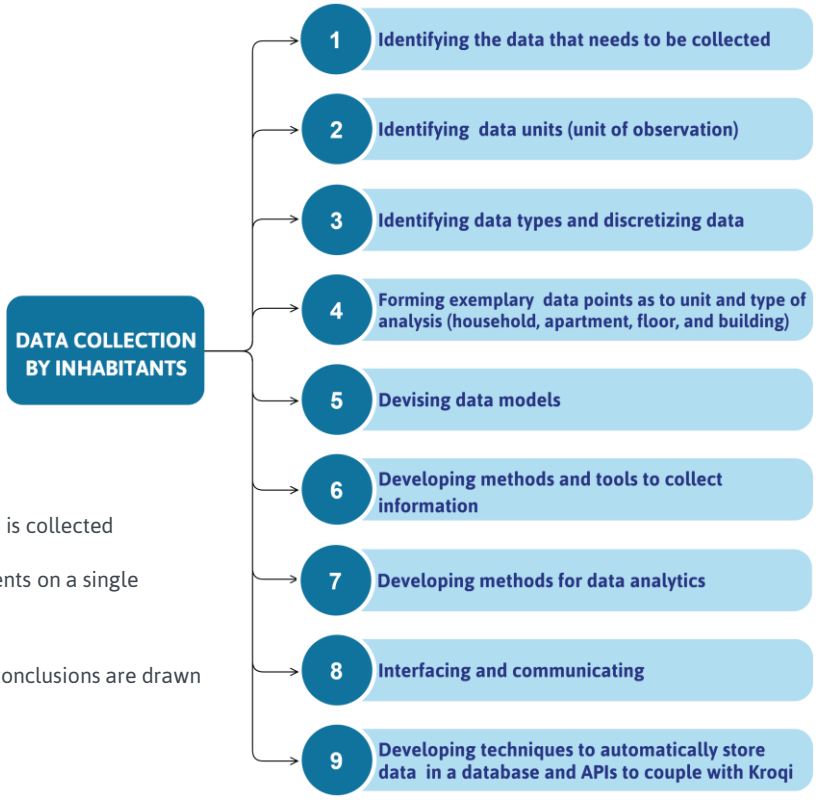

Figure 1: WP1 structure; collecting and understanding BIM data from existing buildings

# 2. Conceptual Framework

## 2.1 Methodology & work break-down structure

Inputs from the inhabitants are essential to detect the changes and weaknesses of an existing building as well as to develop optimal renovation strategies. To collect such inputs, within the context of task 1.5, a user-friendly application has been developed. The underpinning conceptual framework behind the development of the app is shown in Figure 3. The proposed framework consists of the following steps:

1. deciding on 'what data' we are going to collect;
2. deciding on the spatial/topical level at which we are collecting the data;
3. identifying and deciding on the data types;
4. forming data points for further explorations and comparisons; specifically determining what measurements are to be recorded for each unit of observation;
5. designing and deciding on relevant data models;
6. making the means to collect the data;
7. developing methods for data analytics, (or database queries in particular);
8. designing a user interface, based on the use-cases involving the participants; and finally;
9. developing procedures for automatically storing the collected data in a structured database.




**Unit of Observation**: The level at which data is collected

**Data point:** A set of one or more measurements on a single member of unit of observation

**Unit of analysis:** The level (a case) at which conclusions are drawn

Figure 3: Work Break-Down Structure

## 2.2 Data collection with respect to the identified use cases

One of the primary questions pertains to the identification of the data that needs to be collected from inhabitants: '**what data are we going to collect?** In general, we have identified several categories of information dealing with objective and subjective matters relevant to the business of deep renovation:

1) information that can be used to detect defects about building systems and services;
2) information which can be used to model the as-is situation;
3) information about the perceived comfort;
4) Information about wishes, needs and preferred renovation scenario.

This information can be collected at different levels (unit of observation). The unit of observation can differ from the most public unit (building level) to the most private unit (a component within the apartment, e.g. a kitchen). The matrix presented in Figure 4, shows the inter-relation between the units of observation (the level at which the data is collected) and the potential data which can be collected.

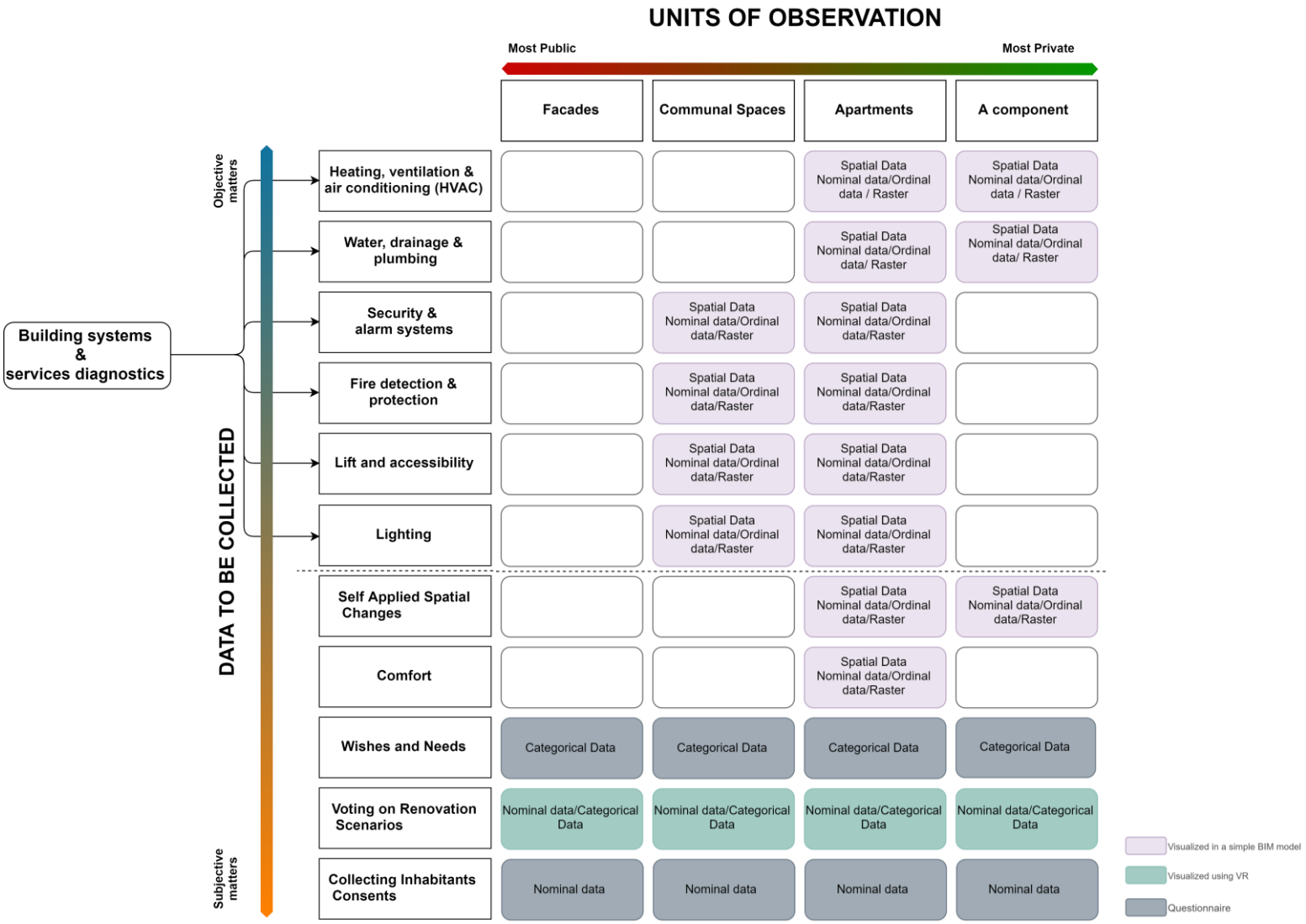



Figure 4: Inter-relation between the unit of observation and the potential data, which can be collected

After defining the conceptual framework and outlining the general approach, we depicted the inter-relations between different work-packages and the corresponding tasks so as to have an insight on the data needed from inhabitants for simulation and calibration methods highlighting the requirements and the accuracy levels needed as shown in Figure 5. Additionally, with the assistance of the use cases' toolkit (developed in Task 1.1 and reported in deliverable 1.1), we have filtered all established BIM_SPEED use cases, particularly those which require inhabitants' inputs in order to perform specific assessment and thus to serve specific renovation goals. Some of the use cases that require inhabitants' inputs are shown in Figure 7. Next to the identification of the use cases, we have classified the potential privacy concerns with respect to the data to be collected form inhabitants (green: potential, red: definite).

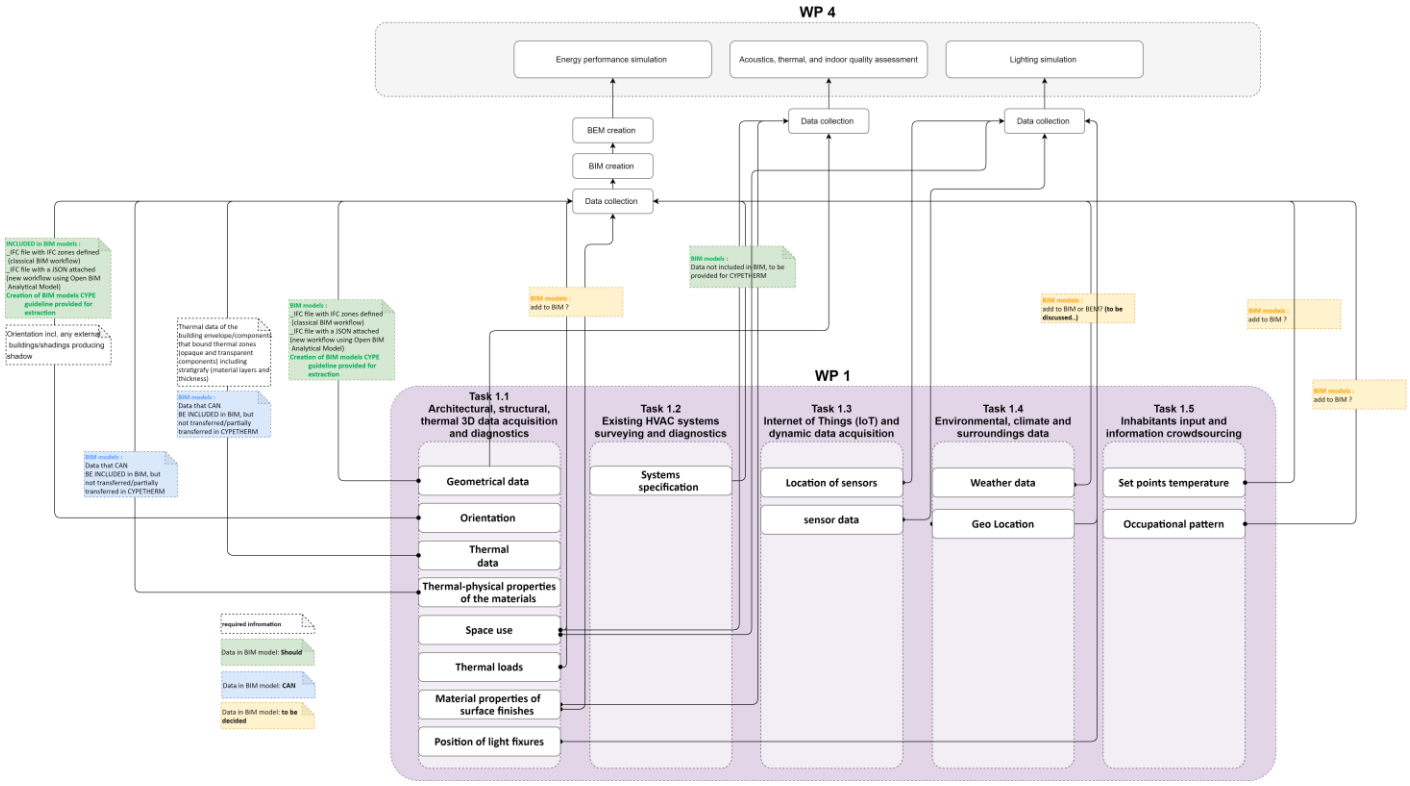



Figure 5: Shows the inter-relation between the required data for calibration and simulation models

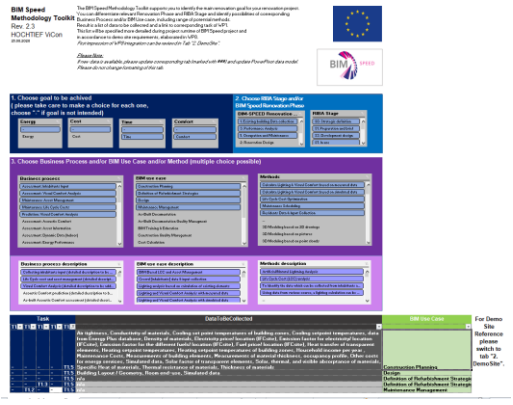


Figure 6: BI-System for managing data developed in Task 1.1 (Architectural, structural, thermal 3D data acquisition and diagnostics)

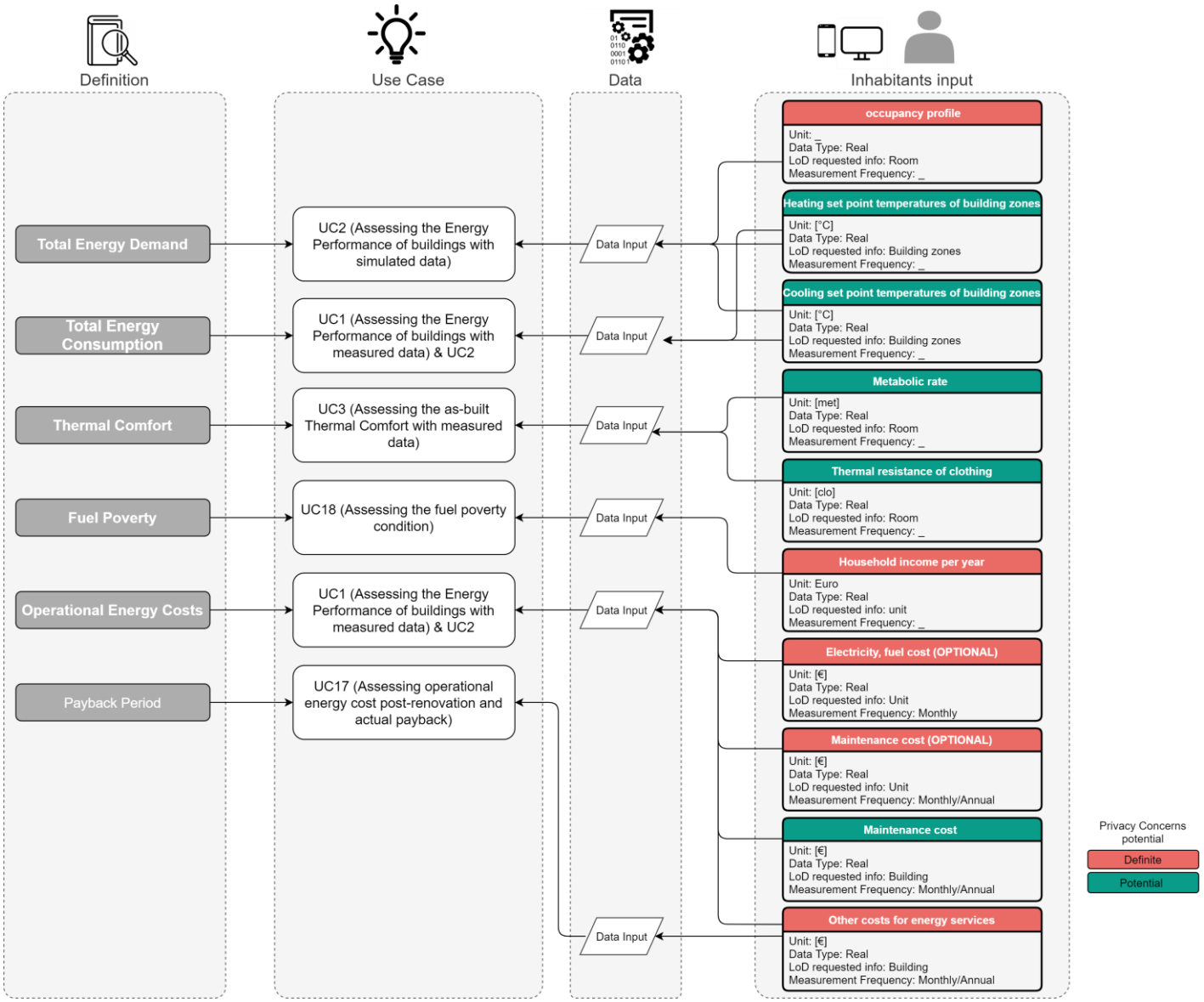



Figure 7: the use-cases that require inhabitants' input for performing a specific assessment

## 2.3 Questionnaire in relation to each use case

Following the identification of relevant use cases [that require inhabitants' input], a series of questions were collected, and their corresponding unit of observation were identified. The responses from the inhabitants will be used by each identified use case to perform a certain assessment or analyses.

| KPI ID | Definition | Unit | Main Contributor/ Responsible partner | Output Use Case | Output in UseCase | Input in UseCase | BIM use case | Data Input | Cluster/Family | Unit2 | Data Type | Measurement Frequency | LoD requested info for | Data flow | Spalte3 | Data to be collected | specify the question which should be asked from inhabitants | Multiple Choices? (Yes, NO) | In case of multiple choices, please provide the choices |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BS.OEC | Operational Energy Costs | [€/m²year] | CARTIF | UC1 | **UC1** (Assessing the Energy Performance of buildings with measured data) | - | energy performance of buildings - measured data | Electricity bills (OPTIONAL) | Surveys/Inhabitants' input | [€] | Real | Monthly | Unit | Platform | Survey | 1.Electricity bills | a)Do you have the electricity bills information available? If Yes, b)Could you provide a full year of billing? | Yes | a)Includes the information by month selecting: **Period**(from so/dd/mm to so/dd/mm)_**EnergyConsumption**(integer)_**Unit** (kWh/m²/ litros/ kg)_**Price**(€)<br><br>b)Includes the bill in PDF format |
| BS.OEC | Operational Energy Costs | [€/m²year] | CARTIF | UC1 | **UC1** (Assessing the Energy Performance of buildings with measured data) | - | energy performance of buildings - measured data | Fuel bills (OPTIONAL) | Surveys/Inhabitants' input | [€] | Real | Monthly | Unit | Platform | Survey | 2.Fuel bills | a)Do you have the fuel (Natural Gas/ Butane/ LPG/ Biomass/ DHC) bills information available? If Yes, b)Could you provide a full year of billing? | Yes | a)Includes the information by month selecting: **Period**(from so/dd/mm to so/dd/mm)_**EnergyConsumption**(integer)_**Unit** (kWh/m²/ litros/ kg)_**Price**(€)<br><br>b)Includes the bill in PDF format |
| BS.OEC | Operational Energy Costs | [€/m²year] | CARTIF | UC1 | **UC1** (Assessing the Energy Performance of buildings with measured data) | - | energy performance of buildings - measured data | Maintenance Costs (OPTIONAL) | Surveys/Inhabitants' input | [€] | Real | Monthly/Annual | Unit | Platform | Survey | 3.Maintenance Costs | a)Do you have the maintenance cost information available? If Yes, b)Could you provide a full year of maintenance costs? | Yes | Include the value of the maintenance costs (in €month or €/year) |
| BS.OEC | Operational Energy Costs | [€/m²year] | CARTIF | UC1 | **UC1** (Assessing the Energy Performance of buildings with measured data) | - | energy performance of buildings - measured data | Other costs for energy services (OPTIONAL | Surveys/Inhabitants' input | [€] | Real | Monthly/Annual | Unit | Platform | Survey | 4.Other costs for energy services | Do you have any additional energy cost not included in bills (1 and 2) and maintenance cost (3)? | Yes | Include the value of the cost associated to this additional costs (in €month or €/year) |
| BS.OEC | Operational Energy Costs | [€/m²year] | CARTIF | UC1 | **UC1** (Assessing the Energy Performance of buildings with measured data) | - | energy performance of buildings - measured data | Maintenance Costs | Surveys/Inhabitants' input | [€] | Real | Monthly/Annual | Building | Platform | Survey | 3.Maintenance Costs | a)Do you have the maintenance cost information available? If Yes, b)Could you provide a full year of maintenance costs? | Yes | Include the value of the maintenance costs (in €month or €/year) |
| BS.OEC | Operational Energy Costs | [€/m²year] | CARTIF | UC1 | **UC1** (Assessing the Energy Performance of buildings with measured data) | - | energy performance of buildings - measured data | Other costs for energy services | Surveys/Inhabitants' input | [€] | Real | Monthly/Annual | Building | Platform | Survey | 4.Other costs for energy services | Do you have any additional energy cost not included in bills (1 and 2) and maintenance cost (3)? | Yes | Include the value of the cost associated to this additional costs (in €month or €/year) |
| BS.OEC | Operational Energy Costs | [€/m²year] | CARTIF | UC2 | **UC2** (Assessing the Energy Performance of buildings with simulated data) | - | Energy simulation | Maintenance Costs | Surveys/Inhabitants' input | [€] | Real | Monthly/Annual | Building | Platform | Survey | 3.Maintenance Costs | a)Do you have the maintenance cost information available? If Yes, b)Could you provide a full year of maintenance costs? | Yes | Include the value of the maintenance costs (in €month or €/year) |
| BS.OEC | Operational Energy Costs | [€/m²year] | CARTIF | UC2 | **UC2** (Assessing the Energy Performance of buildings with simulated data) | - | Energy simulation | Other costs for energy services | Surveys/Inhabitants' input | [€] | Real | Monthly/Annual | Building | Platform | Survey | 4.Other costs for energy services | Do you have any additional energy cost not included in bills (1 and 2) and maintenance cost (3)? | Yes | Include the value of the cost associated to this additional costs (in €month or €/year) |
| BS.PP | Payback Period | [years] | CARTIF | UC17 | **UC17** (Assessing operational energy cost post-renovation and actual payback) | - | Cost estimation | Discount rate | Surveys/Inhabitants' input | [%] | Real | - | - | Platform | Survey | 5.Discount rate | - | - | - |

Figure 8: set of questions in relation to UC1 (Assessing the Energy Performance of buildings with measured data)

It is important to highlight that a generic approach is used to enable the implementation of different set of questions (related to different use cases) in the app. More specifically, for every relevant use case, developed questions are divided into two categories; non-spatial questions and spatial questions as shown in Figure 9.

1) spatial questions; such questions are pertained to a specific space (e.g. a room). For example, "how do you find the acoustic comfort of this **room**? In this case, all the collected responses should relate to a global unique identifier (GUID) of that specific room for further analyses. This will be achieved by implementing a BIM model in the app, which enables inhabitants to select a specific room or a component while replying to the set of questions.
2) non spatial questions; such questions are not pertained to a specific space. For example," what is your yearly maintenance cost?". An upload functionality will enable a user to provide additional material.

The collected information will be stored structurally in the platform in such a way that it can be used by other tools for further analyses and calculations. The storing mechanism will be explained more in detail in section 0.

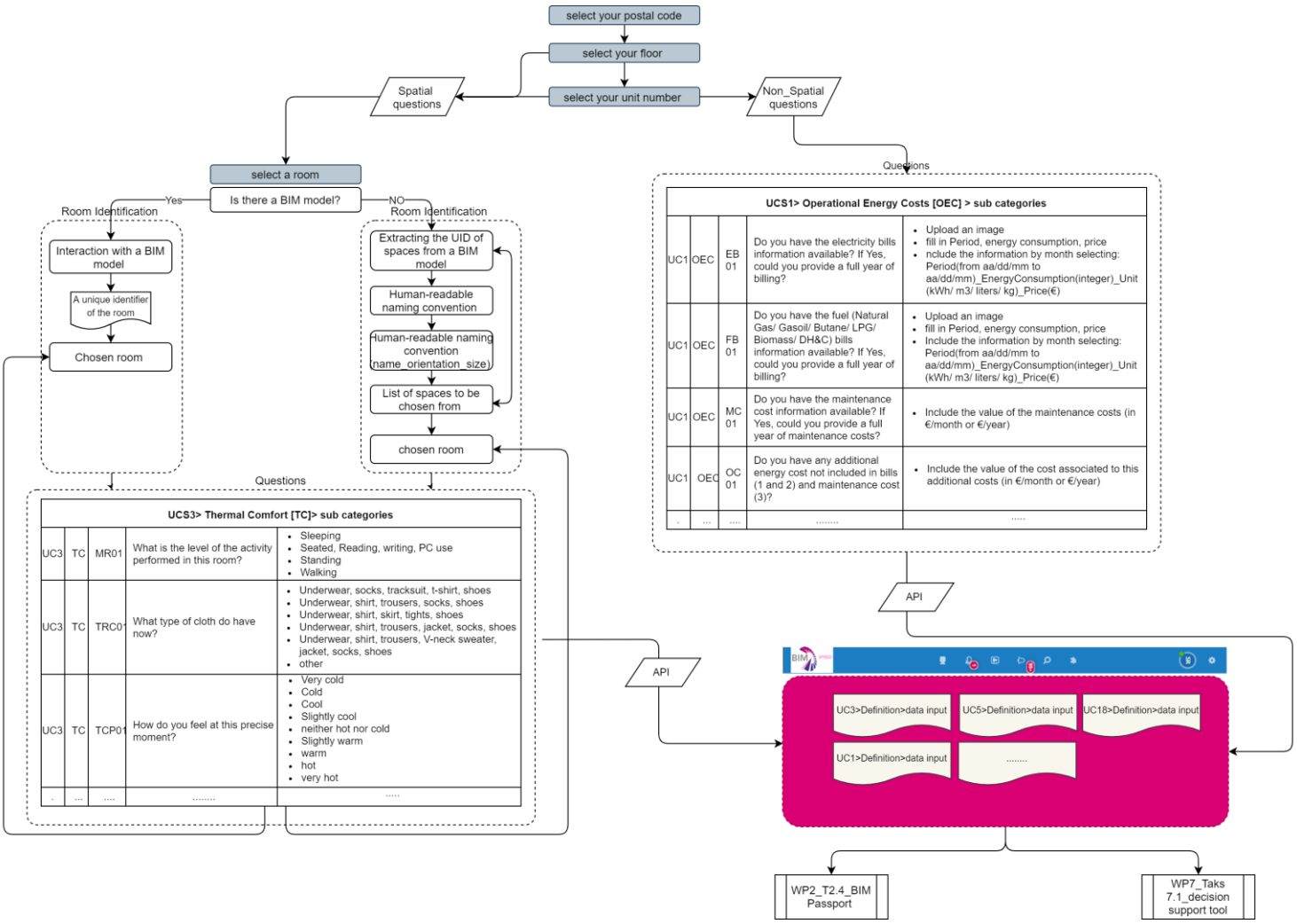



Figure 9: Structuring the spatial and non-spatial information

In APPENDIX 1 – Perceived acoustic and thermal comfort , we explain two identified environmental use cases namely perceived thermal and acoustic comfort, which require inhabitants' input for further assessment and analysis. We describe a set of questions to gather such input from the inhabitants and the evaluation methods. In the next section, we describe the proposed application titled "BIM-SPEED inhabitants app".

## 2.4 Incorporation of collected data in the As-Built BIM passport

As described in Work Package 1, "Collecting and understanding BIM data of existing buildings", there are multiple types of data available for a building, that can be gathered using multiple techniques. The scope of the As-built BIM Passport is to assist building owners in identifying the types of data relevant to perform

the desired renovation solution and to ensure that all the necessary amount of information will be collected. The As-built BIM Passport will be divided into several categories, including general information about the building, status of the 3D model of the building, 1st tier data and 2nd tier data.

The data from each tier will be evaluated based on the quantitative parameter. The difference between the two tiers will be defined by the qualitative parameters, where the 2nd tier will have fewer qualitative parameters (one or none) than the 1st tier (more than 2). All the parameters will be described in the guideline that will accompany the BIM Passport. The data will be rated based on a grade composed of a letter and a number. The letter will define the amount of data available and the number will define the quality.

The 1st tier will include data such as point clouds, 2D drawings, weather information and the 2nd tier will include energy bills and inhabitants input. The inhabitant's input will be store in a specific folder on the BIM SPEED platform and if the data is available, will be used in the BIM Speed use cases presented in 2.3. The first reason that the inhabitant data is included in tier 2 is that the use cases do not depend, entirely, on the existence of this data, but, if available, it gives more useful insight into the building. The second reason is that the inhabitant can decide to answer, or not, the entire questionnaire and some of the answers may be subjective. Since the As-built BIM Passport is still under development, how the categories in which the data is divided can still be changed.

# 3. BIM-SPEED Inhabitants App

The Inhabitants App aims to directly gather data from inhabitants by asking relevant questions such as those indicated in the previous sections. By connecting the answers to elements or spaces in BIM model information is inferred.

## 3.1 Conceptual IT architecture and workflow of BIM-SPEED inhabitants App

The IT architecture for the BIM-Speed Inhabitants App is roughly divided in server-based functionality and mobile device functionality. On the server question lists are imported, configured and made ready for distribution towards the relevant participating inhabitants. The mobile device draws upon the question lists and allows inhabitants to fill in relevant information before sending the results to the server. The server then processes these answers and enables a subsequent upload to the BIM-SPEED platform.

More specifically, the Server hosts a (.NET) desktop application, disclosed as Software as a Service (SaaS). Data storage and querying is handled by a server-hosted SQL database. For data exchange with mobile devices the server hosts a REST WebService.

Mobile devices communicate with the webservice for information exchange using internet connectivity. However, required internet connectivity is limited and short term. Normal use of the app requires internet connectivity only for the first login (to verify the user is allowed use of the app) and intentional data exchange, such as checking for updates and submitting completed questionnaire. Beyond these moments, internet connectivity is not required for optimal ease of use. Future developments may include virtual reality and recording features as to the app as shown in Figure 10 but are currently not being used in the prototype version.

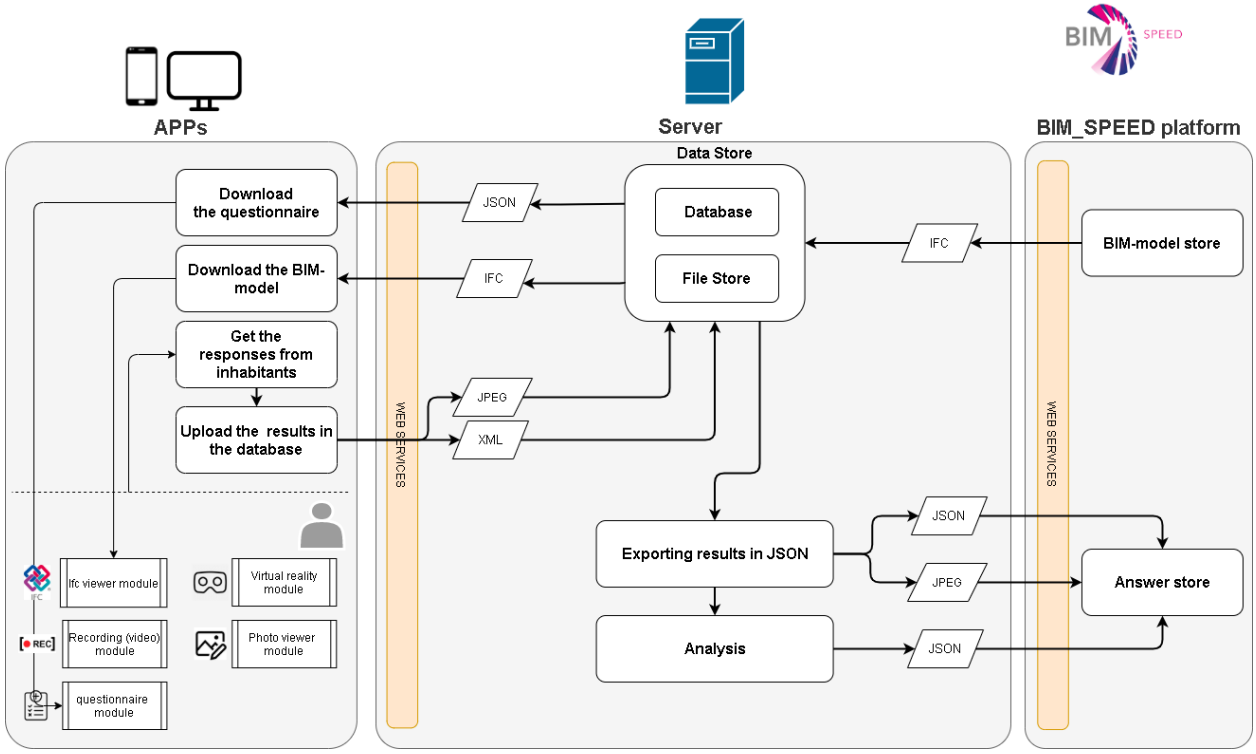



Figure 10: The conceptual IT architecture of the app

## 3.2 Existing tool as the basis for the development

DEMO's software platform RE Suite contains pre-existing architecture for managing question lists and distributing them to mobile devices that allow users to input the requested data. The RE Suite is built on a .NET stack with source code written in C#. As presentation framework the desktop application uses WPF (Windows Presentation Foundation), while the mobile applications use Xamarin.Forms.

Within the RE Suite, the desktop-module RE Survey allows for importing rich question lists from excel templates. This supports both open and multiple-choice questions as well as optional nesting of questions in groups and allows for additional (non-)hierarchical themes. Two exemplary question lists have been created and tested with the tool (see **Error! Reference source not found.**). Within the interface ordering and filtering by different themes, groups, categories, questions, answers, etc. allow for efficient answer analysis. Answer-driven questioning allows irrelevant questions to be hidden when necessary based on previous answers.

| Vragenlijst | thema's | Natural key vraaggr | visibility rule | vraaggroe | vraaggroep volgorde | Natural key vraag 1 | vraagtyp |
|---|---|---|---|---|---|---|---|
| BIMSpeed_test3 | Thermal Comfort>Metabolic Rate | | | | | | |
| BIMSpeed_test3 | Thermal Comfort>Thermal resistance of clothing | | | | | | |
| BIMSpeed_test3 | Thermal Comfort>Thermal comfort perceived | | | | | | |
| BIMSpeed_test3 | Thermal Comfort>Thermal comfort perceived | | | | | | |
| BIMSpeed_test3 | Thermal Comfort>Thermal comfort perceived | | | | | | |
| BIMSpeed_test3 | Thermal Comfort>Thermal comfort perceived | | | | | | |
| BIMSpeed_test3 | Acoustic Comfort>Acoustic comfort perceived | | | | | | |
| BIMSpeed_test3 | Acoustic Comfort>Acoustic comfort perceived | | | | | | |
| BIMSpeed_test3 | Acoustic Comfort>Acoustic comfort perceived | | | | | | |
| BIMSpeed_test3 | Acoustic Comfort>Acoustic comfort perceived | | | | | | |
| BIMSpeed_test3 | Acoustic Comfort>Acoustic comfort perceived | | | | | | |
| BIMSpeed_test3 | Fuel Poverty>Household income per year | | | | | | |
| BIMSpeed_test3 | Total Energy Demand>Heating setpoint temperatures of building zones | | | | | | |
| BIMSpeed_test3 | Total Energy Demand>Occupancy profile | | | | | | |
| BIMSpeed_test3 | Operational Energy Costs>Electricity bills | | | | | | |
| BIMSpeed_test3 | Operational Energy Costs>Electricity bills | | electricity_bill_available=yes | | | electricity_bill_availat | |

| vraagtype | Vraag 1 | Antwoordopties 1 | Standaardantwoord | Maatregelen |
|---|---|---|---|---|
| 0 | What is the level of activity performed in this room? | Sleeping;Seated, Reading, writing, PC use;Standing;Walking | | |
| 0 | What clothes are you wearing during the test? (Mark the most appropriate solution.) | Underwear, socks, tracksuit, t-shirt, shoes;Underwear, shirt, trousers, socks, shoes;Underwear, shirt, skirt, tights, shoes;Underwear, shirt, trousers, jacket, socks, shoes;Underwear, shirt, trousers, V-neck sweater, jacket, socks, shoes;Other | | |
| 0 | How do you feel at this precise moment? (mark the most appropriate box) | Very cold;Cold;Cool;Slightly cool;Neither hot nor cold;Slightly warm;Warm;Hot:Very hot; | | |
| 0 | At this moment, how is your comfort level? | Comfortable;Slightly uncomfortable;Uncomfortable;Very uncomfortable | | |
| 0 | At this moment, would you prefer to be ...? | Much cooler;Cooler;Slightly cooler;Without change;Slightly warmer;Warmer;Much warmer | | |
| 0 | Is this environment, in your opinion ...? | Perfectly bearable;Slightly difficult to bear;Fairly difficult to bear;Unbearable | | |
| 0 | Thinking about the period in which you have lived/worked/frequented this area until now, how do you find the acoustic comfort of the room? | High level;Good level;Acceptable level;Bad level;Very bad level | | |
| 0 | Thinking about the period in which you have lived/worked/frequented this area until now, how do you perceive the noise generated from external noise sources (road traffic, railway traffic, industrial activities, etc.) when you are inside the room with closed windows? | Very high;High;Acceptable;Low;Very low | | |
| 0 | How much do you think that building envelope interventions (e.g. increasing wall and windows sound insulation) are necessary in order to improve your acoustic comfort inside building? | Absolutely required;Required;Suggested;Not required;Totally useless | | |
| 0 | Is the noise generated from external noise sources the main source of sound that interfered with your activities inside building? | Extremely yes;Mainly yes;Acceptable level;Bad level | | |
| 0 | How sensitive are you to noise in general? | Very sensitive;Sensitive;Normal sensitive;Low sensitive;Unsesitive | | |
| 1 | Which is your household income per year? | | | |
| 1 | What is the cooling tempeature in this room? | | | |
| 1 | How many people use this room? What is the occpancy hours? | | | |
| 0 | Do you have the electricity bills information available? | yes;no | | |
| 1 | Could you provide a full year of billing? | | | |

Figure 11: Structured excel template which will be interpreted by the app

RE Survey's mobile counterpart is RE OnSite, a modular iPad app that downloads the relevant question lists from the server and guides the user through answering. Answers can be enriched with observations in the form of photos and/or descriptive text.The RE Suite contains a BIM-viewer capable of displaying IFC -models and interacting on an element/space basis. RE OnSite contains an alpha-version basis for a similar BIM-viewer without space-based functionality. Both BIM-viewers are unconnected to question lists.

## 3.3 BIM-SPEED adaptations

The pre-existing architecture was geared towards real-estate inspectors who answer templated question lists for multiple assets. This differs from the BIM-SPEED use case where inhabitants will answer a single question list for a single asset. For ease of use, the Inhabitants App was optimised to remove needless complexity.

Previously inspectors had time to become familiar with use of the software through frequent use. As such the interface was somewhat simplistic. A crowdsourcing app requires that there are as few barriers as possible to keep users engaged. As such, the interface was completely reworked to offer the required ease of use.

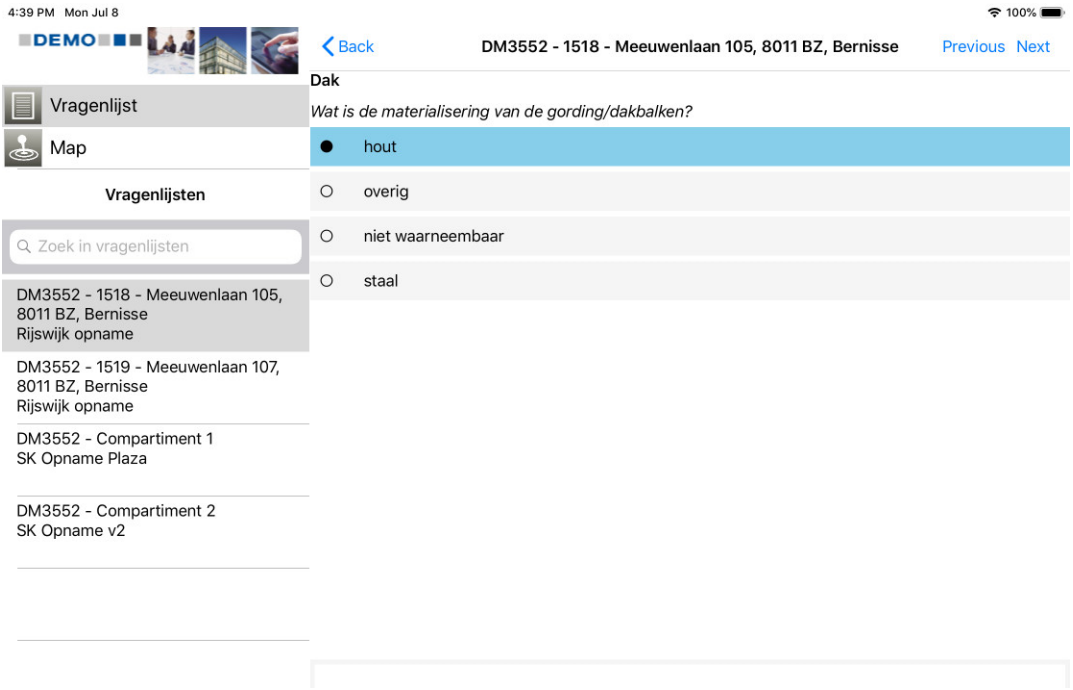



Figure 12: Old interface of RE OnSite

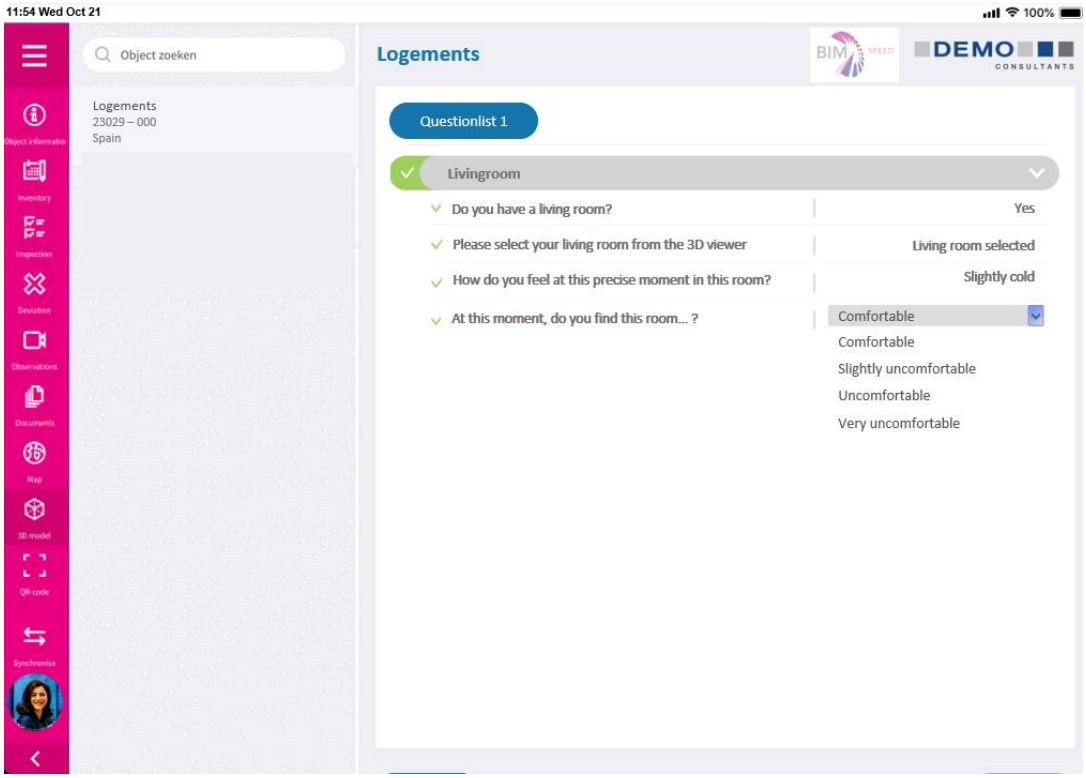



Figure 13: New interface of RE OnSite

While previous versions of RE OnSite contained a basic BIM-viewer it was occasionally unstable dependent on the IFC-file on display. The BIM-viewer has been reworked and the issues have been patched. Additionally, space-based interaction was added to allow users to select spaces instead of elements for BIM-Speed purposes. Because the intended use for the Inhabitant's app sees users as primarily contributing to small portions of a larger BIM-model, filtering based on floor was required for an optimal user experience. Although filtering based on unit would be ideal, however, there currently is no guaranteed support for unit identification in the IFC to make this impossible.

As explained in 0, some questions are spatial and pertain to a specific room. To this end, question lists, and BIM-models are now able to be linked by use of spatial questions. These questions guide the user to the 3D viewer where they can select a space in a BIM-model as an answer to the question. In the background the GUID of the space is extracted from the BIM-model and used as an answer to the question.

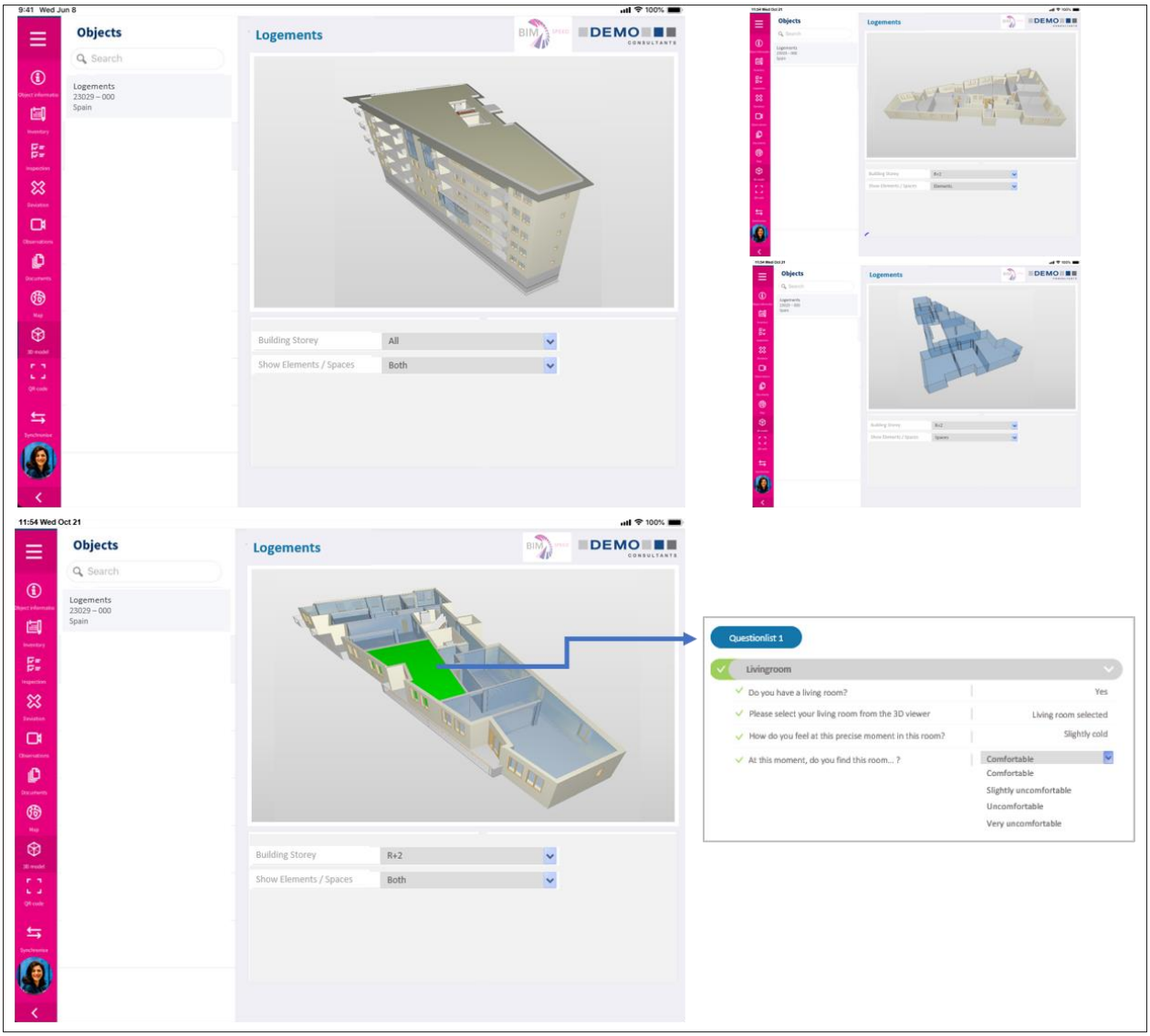



Figure 14: mock-up showing the implementation of the BIM viewer and spatial questions

## 3.4 Functionalities of the app

### 3.4.1 Translation to other other languages

The software framework of the app uses a multilingual system by which the translation of all UI elements can be arranged automatically. A simple user preference setting indicates which language is the preferred language for any user. This goes for users who are managing the question list dissemination in the client software, but for the crowdsourcing user accounts as well. Three languages can be offered in this system by default: Dutch, English, and German. Six more languages can be added optionally. This multilingual functionality covers UI elements such as buttons, menu items, and standard texts like e.g. the user-consent page. However, it should be noted that any question list content, which is created by filling in a template, does not fall under this multilingual system. This means that if a question list should be disseminated in multiple languages, then the question list should be manually duplicated, translated to a different language, and distributed separately. It should be noted as well that if question lists are distributed into multiple languages, then the analysis tools of the crowdsourcing results should also be able to analyse multilingual answers. Offering questions to inhabitants in their native language does improve the user-friendliness for the inhabitants greatly, but it comes with the downside of having to do multilingual answer analysis. For proof of concept, sticking to one overall (English) language will most likely be the easiest to realise. A demonstration of the app can be found here.

### 3.4.2 Installation and configuration

The app can be downloaded from generic application stores such as the Apple AppStore. On first start up, the app will ask for consent of the user (described in section 4) and then configuration to connect to the BIM-Speed servers and questionnaires. This is as simple as answering the popup question with “BIM-SPEED”.


Figure 15: User identification

### 3.4.3 User identification

Users log in with their unique username based on postal code and unit number. This both uniquely identifies users and their apartments. After credential validation the relevant questionnaire and BIM-model is downloaded in the background.

### 3.4.4 User consent

informing participants about how their data is collected and being used by the project is a basic requirement. After logging in, a user will be asked to agree on an informed consent form. This consent form is included in the APPENDIX 4 – Informed Consent Information for crowdsourcing.

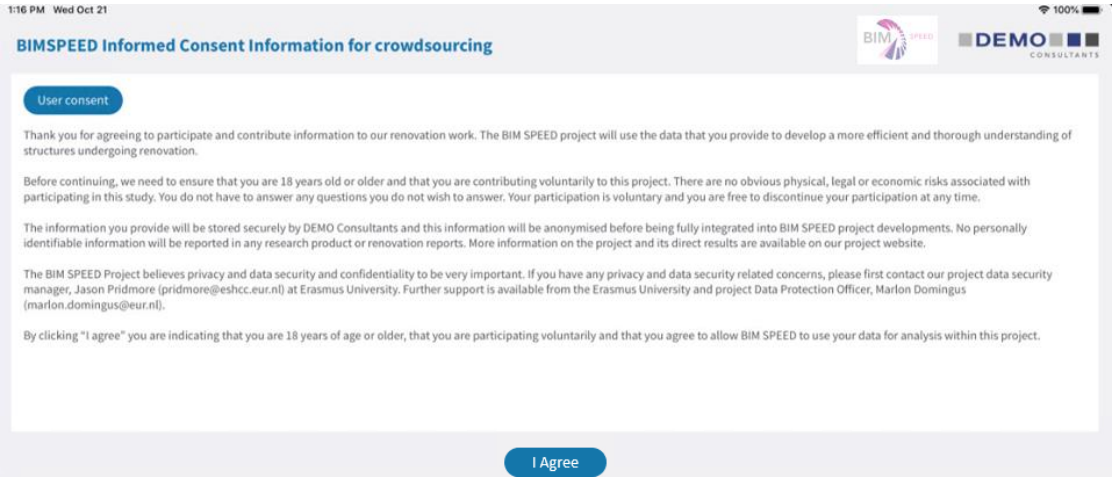



Figure 16: Informed consent

### 3.4.5 Navigating questions

The app opens immediately with the questionnaire. The questionnaire is ordered in logical groups, which are displayed in summary using a (collapsed) tree-like structure. By tapping a group, it expands, showing its contents. By tapping a question, it is shown in more detail along with ways to answer.

Because of answer-driven questioning, irrelevant questions are hidden from the user. For example, if asked "do you have a second bedroom?" and the answer is "no", additional questions relating to the second bedroom are not shown. At any time, users can go back to the questionnaire summary. However, after answering a question they can also click previous or next to go to the preceding or following question immediately.

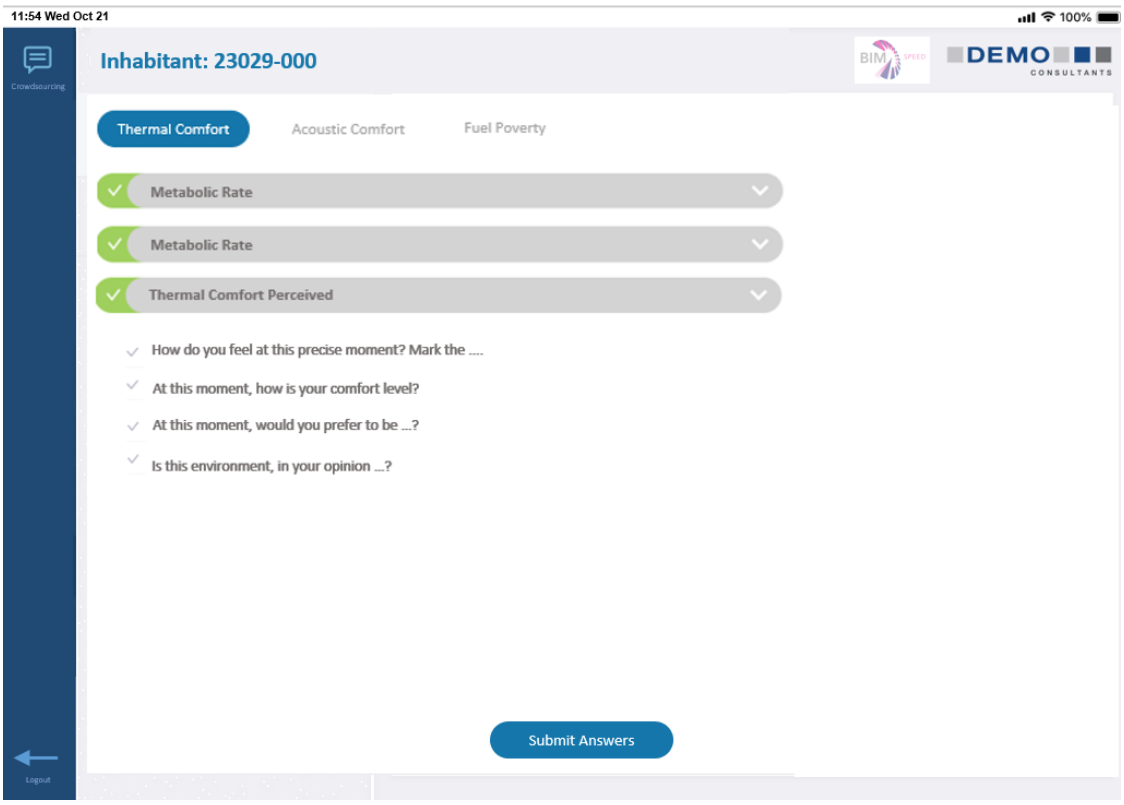



Figure 17: navigating between questions

### 3.4.6 Answering regular (non-spatial) questions

Upon tapping on a question in the summary opens the question in the full-screen view. This includes the group structure in which the question is located but emphasises the question itself. The user is guided to provide an appropriate answer. For open questions, a text entry field allows users to provide any textual input. For multiple-choice questions the available options are shown in a list. Optional default answers come pre-selected.

A photo-strip at the bottom of the screen allows users to take photo's as illustrative additions to textual answers. Simply clicking on the plus icon starts the native device camera. Users can take photos,

confirm their addition and see them appear in the photo-strip. By clicking on an image in the photo strip, the image is enlarged for detailed viewing. Here additional buttons become available, such as the ability to delete the photo (by clicking the trash icon) or drawing on the photo to emphasize areas or elements by clicking the pencil icon. Drawing is supported by undo and redo buttons to correct any mistakes made. Clicking save or cancel will persist or revoke changes to the image.

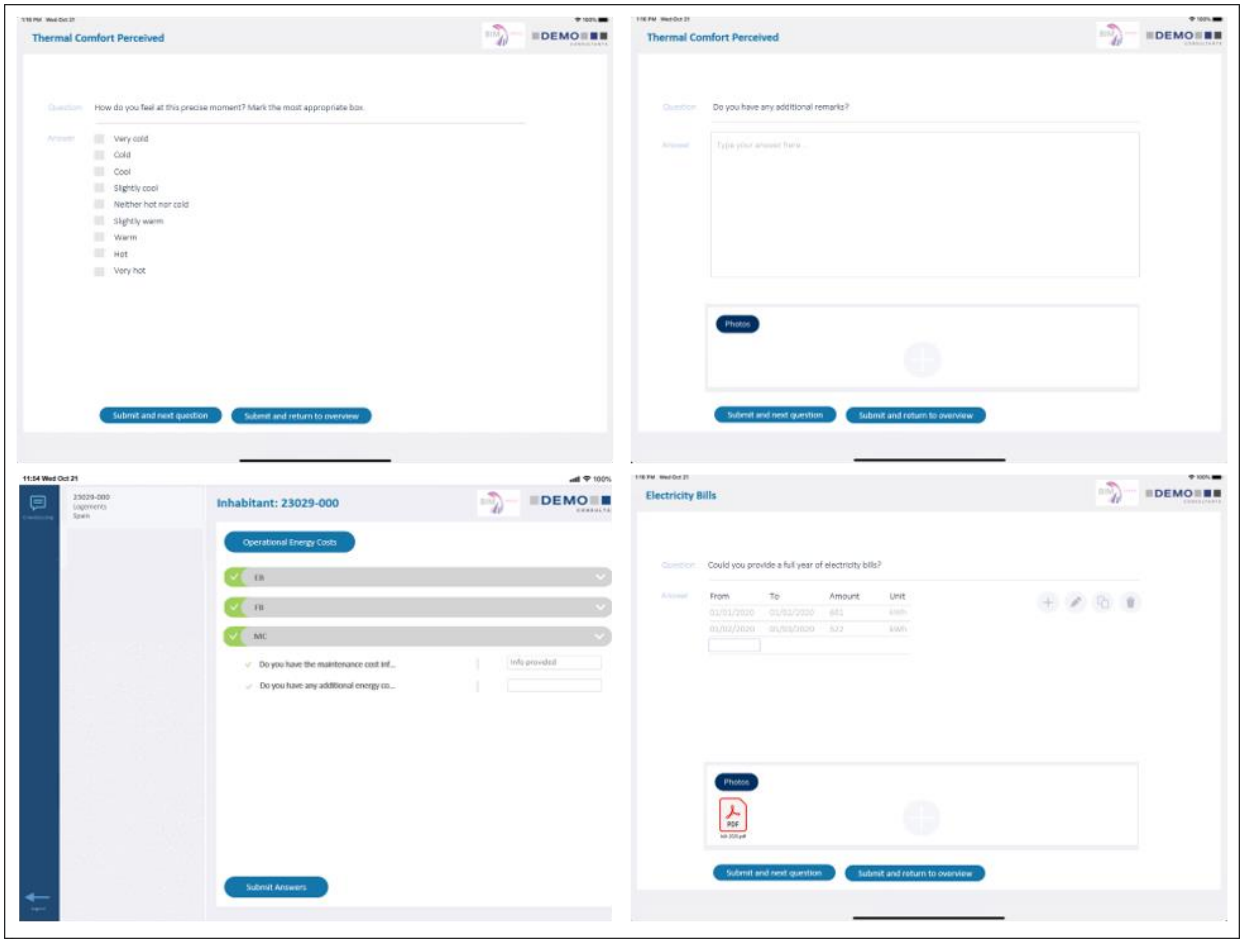



Figure 18: Answering set of questions

### 3.4.7 Answering spatial questions

Some questions relate to the BIM-Model, for example “which is your living room?” By clicking the 3D-viewer button a new page opens, showing the related 3D-model of the building. Rotating the 3D-model occurs by dragging a single finger across the model. Dragging two fingers close together allows for panning the camera. A pinch-gesture zooms in or out.

By using the floor selection option on the bottom of the screen users can filter the shown elements to only the relevant floor. Tapping a space results in the space being highlighted. The user is asked to confirm their choice and if this is agreed to, the 3D-viewer closes, returning the user to the questionnaire. In the background the space GUID is filled out as an answer, representing the user's space selection.

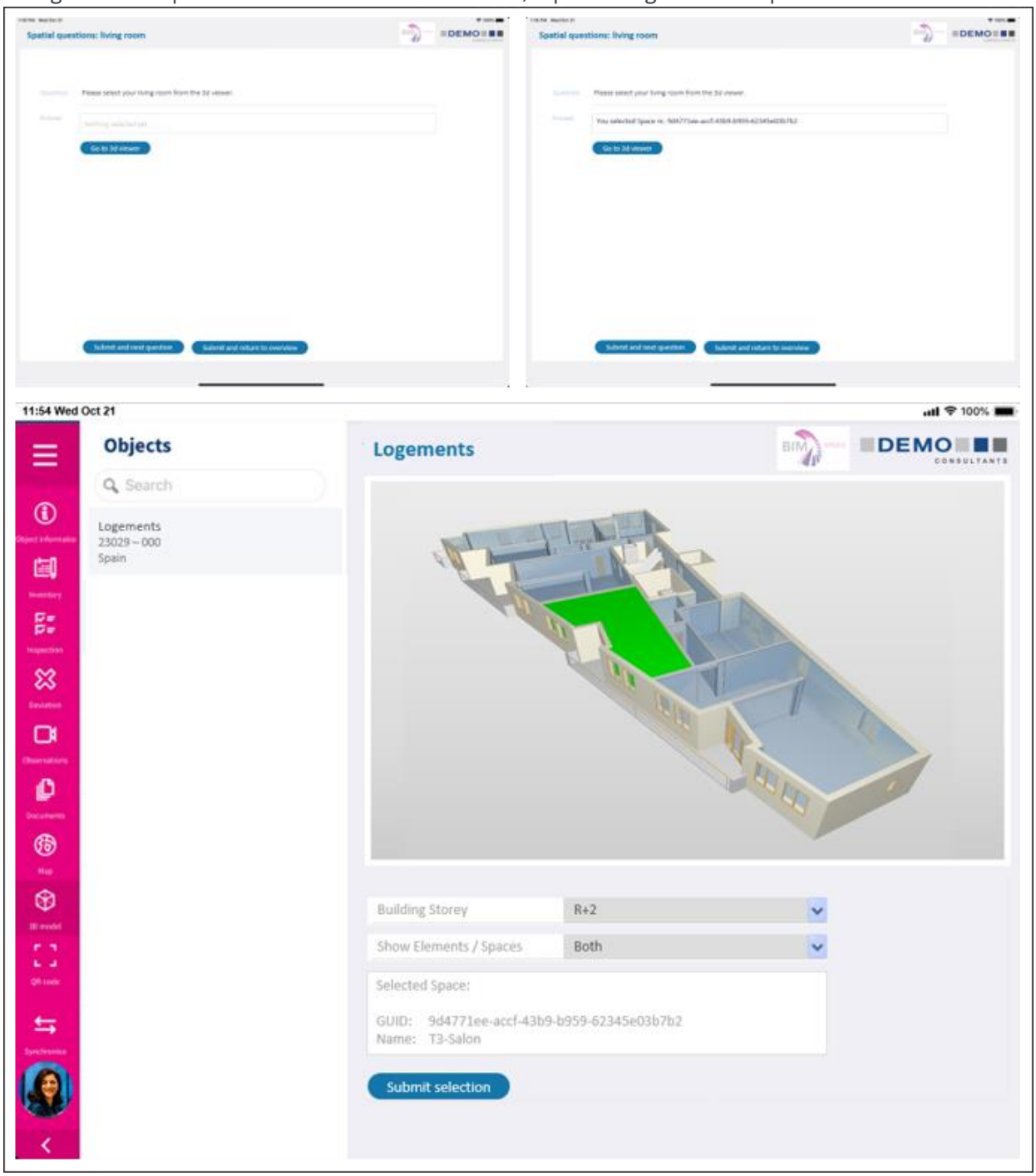



Figure 19: A mock-up showing the interaction with the BIM model

### 3.4.8 Exhaustive questioning for room types

The question list contains questions relevant for room types, of which there may be multiple instances. For example, a user may be asked to identify a bedroom, before a set of questions may be asked relating to it. A user will be led through this group of questions and finish with the question: “is there another bedroom?”. If answered yes, the user will be asked to identify another bedroom and the question group is repeated. This iteration repeats until the user indicates there are no more bedrooms.

| Visibility rule | vraaggroep | vraaggroep volgorde | Natural key | Question Type | Question | Answer Options |
|---|---|---|---|---|---|---|
| | | | has_bedroom_1 | 0 | Do you have a bedroom? | yes;no |
| has_bedroom_1=yes | | | | | Please select your largest bedroom from the 3d viewer. | |
| has_bedroom_1=yes | | | | 1 | What is the cooling tempeature in this room? | |
| has_bedroom_1=yes | | | has_bedroom_2 | 0 | Do you have another bedroom? | yes;no |
| has_bedroom_2=yes | | | | | Please select your next largest bedroom from the 3d viewer. | |
| has_bedroom_2=yes | | | | 1 | What is the cooling tempeature in this room? | |
| has_bedroom_2=yes | | | has_bedroom_3 | 0 | Do you have another bedroom? | yes;no |
| has_bedroom_3=yes | | | | | Please select your next largest bedroom from the 3d viewer. | |
| has_bedroom_3=yes | | | | 1 | What is the cooling tempeature in this room? | |
| has_bedroom_3=yes | | | has_bedroom_4 | 0 | Do you have another bedroom? | yes;no |
| has_bedroom_4=yes | | | | | Please select your next largest bedroom from the 3d viewer. | |
| has_bedroom_4=yes | | | | 1 | What is the cooling tempeature in this room? | |
| has_bedroom_4=yes | | | has_bedroom_5 | 0 | Do you have another bedroom? | yes;no |
| has_bedroom_5=yes | | | | | Please select your next largest bedroom from the 3d viewer. | |
| has_bedroom_5=yes | | | | 1 | What is the cooling tempeature in this room? | |

Figure 20: Exhaustive question pattern

### 3.4.9 Completing the questionnaire

Finally, when all questions have been answered the user returns to the questionnaire summary. Here the user can review their answers and correct them if desired. Once satisfied the user can choose to hand in the questionnaire with the button on the bottom, connecting to the internet and sending the answers to the server for them to be processed.

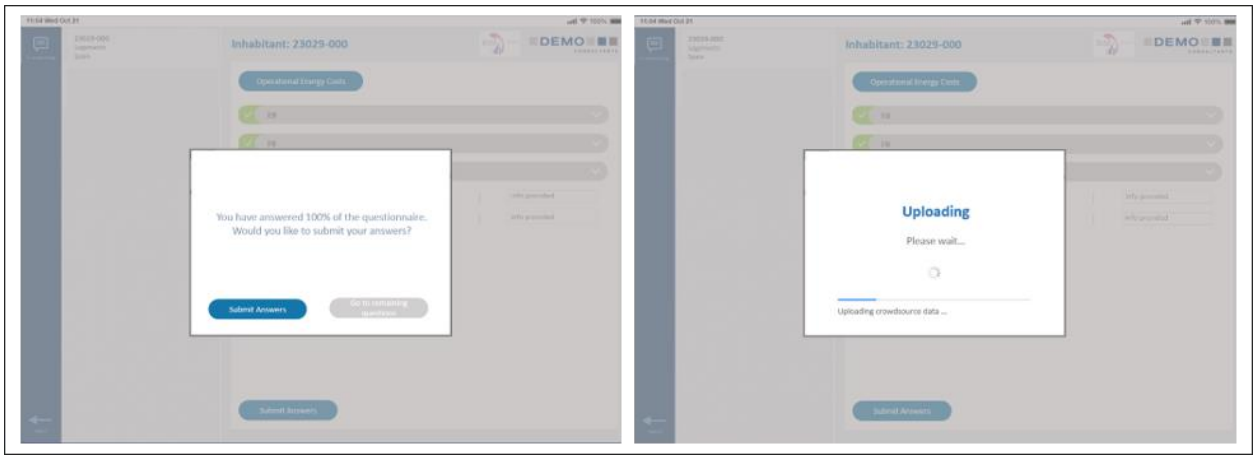



Figure 21: Submitting the answers

## 3.5 Storing the result in the BIM_SPEED Platform

Question lists and their answers are stored securely in DEMO's SQL database. Transmission of the data is end-to end encrypted through the HTTPS protocol. On disk the data is encrypted using Transparent Data Encryption (TDE). For the purposes of BIM-SPEED the answers are exportable with the press of a button. This results in the generation of several JSON-documents.

First, a master document contains the sum total of all questions and answers. Second, the questions are ordered in logical groups, with each group's contents being stored in a separate file. An example of such a logical group is 'thermodynamic questions for WP3'.

Filenames identify the relevant postal code, unit number and logical grouping of its contents. Finally, all JSON-documents are uploaded to the BIM-SPEED platform. The upload process makes use of the following API call, which is specifically offered by the KROQI EDMS Server API:

*/api/1.0/edms/projects/{project_id}/docs/{doc_id}/content*

This API call can be used for both document content retrieval as well as document content update. In the case of document content update this call is used as a PUT request. The data stream is end-to-end encrypted through use of the HTTPS protocol.

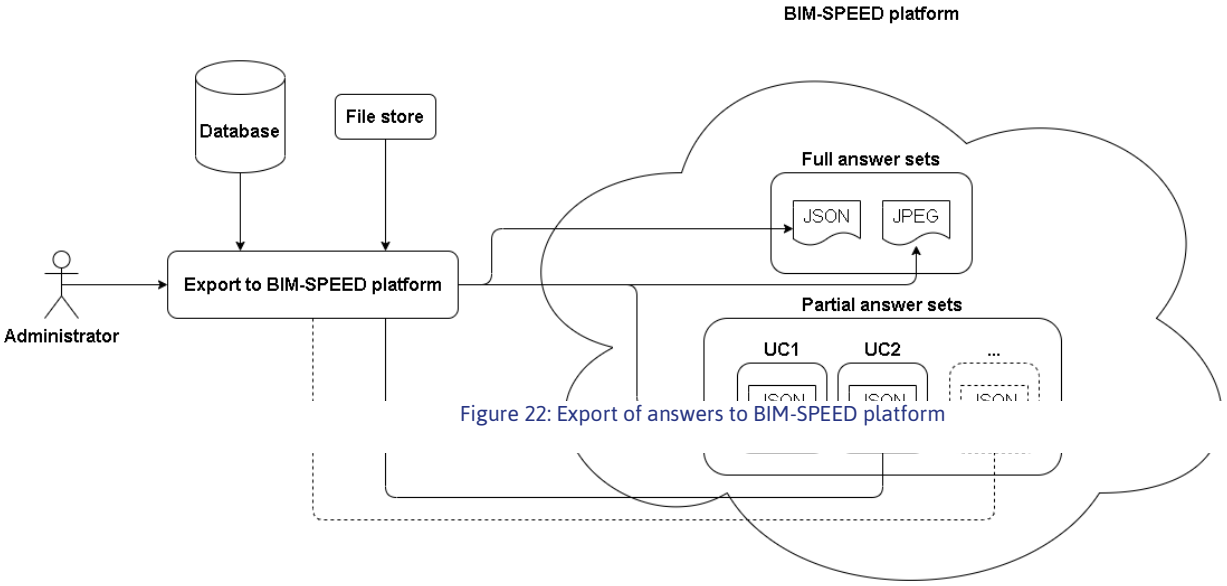



Figure 22: Export of answers to BIM-SPEED platform

## 3.6 Android and iPhone Implementation and testing

The proof of concept app is tested for Apple iPads of various sizes. However, the underlying technology, architecture and framework supports both Android tablets and smaller devices such as Apple iPhones and Android smartphones. Thus, upon confirmation of the proof of concept success the app can be made available to a wider audience and will be tested in a few pilot cases of BIM_SPEED project. The conceptual frame work and the current proof of concept has been already presented to the Dutch demonstration case.

# 4. Compliance with privacy and ethical considerations

The data collected through the Inhabitants app is seen as vital to achieving the objectives of the BIM SPEED project. This app will produce valuable data based on the lived experiences of occupants; this data collection is not easily achieved through sensors or monitoring equipment. However, in the process, the use of this app relies on potentially sensitive personal data for effective use within the project. This raises privacy and ethical concerns. Within the BIM SPEED project, we have identified and determined means to deal with three key issues related the crowdsourcing of inhabitant information through the app. These are specifically: issues of consent; specified purposes for data collection; and the security of the collected data.

## 4.1 Inhabitant Informed Consent

As noted, the gathering of data from occupants provides information critical for the success of the BIM SPEED project. However, as part of this process, informing participants about how their data is collected and being used by the project is a basic requirement. As outlined in Deliverable 11.2, BIM SPEED maintains different forms for informed consent. For the app, we will make use of the consent form in Deliverable 11.2 that requests agreement from the user before any data is input into the app or sent to BIM SPEED databases. The user must agree before proceeding with the app use. This informed consent request indicates to the user that their data will be kept confidential and stored securely and that no personally identifiable information will be included in project reports or outcomes. Additionally, the informed consent process indicates whom to request further information or to report concerns.

## 4.2 Privacy and purpose specification

The request for informed consent is connected to the process of specifying the purposes for which users' data is being collected. This is a critical aspect within the General Data Protection Regulation (GDPR) which requires assurances on safe handling of privacy-sensitive data. The tools and workflows used within the BIM SPEED project and in particular the use of the Inhabitants app is fully GDPR-compliant.

As noted in the description of the questions in section 2.2, we have identified responses that may have the potential to produce privacy sensitive information. While a full evaluation of the issues in this process and the data produced will be analysed as part of Deliverable 6.4 (Evaluation and recommendations of BIM data security, privacy, social and ethical aspects), this initial coding is indicative of where the project may begin to see concerns related to these issues.

The Inhabitants App indicates how the data will be used directly to the inhabitant. The raw (personalised) data is used for analysis purposes through an aggregation process, removing personalisation in the process. This limits the distribution of personalised data within the consortium. As noted, inhabitants have given their explicit consent in sharing their information with the BIM-SPEED consortium. Privacy statements that describe information security are likewise available as are the persons to whom concerns should be reported.

Should inhabitants retroactively wish to rescind their permission they can contact DEMO Consultants who can and will remove any and all personalised privacy-sensitive data from both proprietary servers and the BIM-SPEED platform.

## 4.3 Data Security

Alongside obtaining consent and giving a clear indication of the purposes for the data collection, BIM SPEED ensures that the data collected from Inhabitants is securely stored and transferred between relevant databases within Europe (and thus subject to GDPR). Data from the Inhabitants app contains individualised information that is stored securely. No inhabitant can view another inhabitant's answers or even the questions they were asked. Server-side data is protected by both firewalls, encryption, and authentication mechanisms, allowing access only to (a specified subset of) BIM-SPEED consortium members.

## 4.4 Overall ethical compliance

While these areas of concern regarding data collection and use have been identified as key concerns for this deliverable, the integration of the data these processes produce within the developing BIM SPEED platform and toolkit remains central to ethical concerns raised by digitalisation processes within the renovation sector. Inhabitant participation in the BIM SPEED process should be seen as both an asset and a liability and the data produced treated with special attention. As noted, these issues and more will be elaborated on in later project deliverables.

# 5. References


[1] I. Artola, "DIRECTORATE GENERAL FOR INTERNAL POLICIES POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY Boosting Building Renovation: What potential and value for Europe?," 2016.

[2] E. Estellés-Arolas and F. González-Ladrón-De-Guevara, "Towards an integrated crowdsourcing definition," *Artic. J. Inf. Sci. XX*, pp. 1–14.

[3] "UNI EN 15251:2008 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics," 2008.

[4] "UNI ISO/TS 15666: Assessment of noise annoyance by means of social and socio-acoustic surveys." 2010.

[5] S. Review, "ANSI/ASHRAE 55:2004 Draft for Thermal Environmental Conditions for Human Occupancy," *Methods*, 2003.

[6] ASHRAE, *ASHRAE Handbook Fundamentals 2005*. 2005.

# 6. APPENDIX 1 – Perceived acoustic and thermal comfort

***Environmental Quality Evaluation of pre and post renovation buildings***

One of the buildings' main goal is to provide comfortable environmental conditions for its occupants. A lower condition of indoor comfort corelates with a higher probability of low productivity and degraded well-being of its occupants. Thus, maintaining optimal thermal conditions in all occupied spaces is a key feature in assuring a higher environmental quality. Within the framework of Work Package 4 (conducting performance simulations of renovation scenarios), several use cases pertaining to Indoor Environmental Quality Evaluation of pre and post building renovation are defined. These use cases which aim to measure thermal and acoustic comfort require **inhabitants' input** to enable comparison between the occupants perceived comfort and the simulated comfort value.

In the framework of assessing comfort KPIs, objective and subjective indicators can be compared to provide a validation of the reliability of the KPI. The subjective indicators are based on **user perception**, which is generally investigated through interviews; the questions in the interview are developed with the aim to understand the perception of comfort by inhabitants of the building.

In Annex H of ISO15251[3], a method for the evaluation of the parametric subjective sensation (thermal sensation, air quality, etc.) through questionnaires is proposed (see APPENDIX 1 - Methodologies for subjective evaluations).

The formulation of questionnaire was based on bibliographic research in literature and on international technical specification, ISO/TS 15666[4] for acoustic comfort and ISO15251[3] for thermal comfort.

It is required that the responses to the questionnaire are linked to the pertained rooms and for this reason spatial questions have been implemented.

***Acoustic comfort use cases***

Noise pollutions have serious impacts on the well-being of building's occupants; well-known effects are annoyance and sleep-disturbance, as well as long-term health effects such as cardiovascular issues when continuously exposed to loud noises.

The Acoustic Comfort use-case provides a methodology to obtain an overall assessment of the acoustic comfort of a building in relation to surrounding noise using measured or simulated data. The main objective of the acoustic use-case is to investigate and eventually optimize indoor acoustic comfort levels. The analysis is performed for each room that shares a border with the external environment. Following this, the overall value for the building is calculated. The key output is the acoustic classification of building, which provides a clear and simple identification of the acoustic status of the building.

Improving acoustic performance of a building envelope during refurbishment processes can lead to an adequate indoor acoustic comfort, thus is an important parameter that should be introduced in retrofitting existing buildings. The Acoustic Comfort KPI assesses indoor acoustic comfort by considering an estimation of acoustic climate of the district in which the building is located and the envelope performances of the building. Acoustic climate is understood as a description of noise levels coming from sound emission sources in a given environment in time and space.

To calculate the acoustic comfort, inhabitants' input is required. To collect such input a questionnaire composed of five multiple-choice questions was developed (as shown in Table 1) with the purpose to evaluate the degree of perceived acoustic comfort in the living environment in relation to the external noise. The respondents will be asked to indicate only one answer and questions are divided in two categories:

a) Questions used for assessing the subjective KPI (questions number 1, 2, 3);
b) Questions used as indicators for the design team of a specific issue (questions number 4, 5).

Question number 4 is used to identify if other acoustic problems cause annoyance to the inhabitants (e.g. noise from service installations or building equipment). These fall outside the scope of BIM-SPEED project. Concerning question number 5, in case of evident differences between the responses of the questionnaire filled by the inhabitants, the answer to this question allows evaluation for whether the user response should be not considered (because of the high sound sensibility of the user).

Table 1: Acoustic Comfort Questions

| Category | No. | Question | Multiple Choices |
|---|---|---|---|
| Questions used for assessing the subjective KPI | 1 | Thinking about the period in which you have lived/worked in this area, how do you find the acoustic comfort of this room? | ☐High level<br>☐Good level<br>☐Acceptable level<br>☐Bad level<br>☐Very bad level |
| | 2 | Thinking about the period in which you have lived/worked/ in this area, do you hear noise generated from external noise sources (road traffic, railway traffic, industrial activities, etc.) when you are inside the room with closed windows? | ☐Very high<br>☐High<br>☐Acceptable<br>☐Low<br>☐Very low |
| | 3 | How much do you think that building envelope interventions (e.g. increasing wall and windows sound insulation) are | ☐Absolutely required<br>☐Required<br>☐Suggested |

| | | | |
|---|---|---|---|
| | | necessary in order to improve your acoustic comfort inside building? | ☐Not required<br>☐Totally useless |
| Questions used as indicators for the design team of a specific issue | **4** | Is the noise generated from external noise sources the main source of sound that interfered with your activities inside building? | ☐Extremely yes<br>☐Mainly yes<br>☐Acceptable level<br>☐Bad level |
| | **5** | How sensitive are you to noise in general? | ☐Very sensitive<br>☐Sensitive<br>☐Normal sensitive<br>☐Low sensitive<br>☐Unsensitive |

***Thermal comfort use cases***

The Thermal comfort use-case provides methodologies for evaluating thermal comfort using measured or simulated data, before or after the renovation process. The key objective of this use-case is to enhance the indoor comfort levels in all the possible situations.

Thermal comfort conditions may be expressed in controllable environmental factors, namely the following four main physical parameters: 1) air temperature, 2) mean radiant temperature, 3) air velocity, and 4) relative humidity. Additionally, besides the environmental factors, comfort is also influenced by the following two non-environmental factors: 1) metabolic rate, and 2) thermal resistance of the clothing. Quantitative knowledge is needed to identify which combinations of the above-mentioned six variables will lead to thermal comfort. In order to obtain such quantitative knowledge a questionnaire, composed of 6 multiple-choice questions was developed to collect input from inhabitants to evaluate the degree of thermal comfort in the living environment (as shown in Table 2) and non-environmental factors.

Table 2: Thermal comfort questions

| Category | No. | Partner | Multiple Choices |
|---|---|---|---|
| Questions used for assessing the subjective KPI | **1** | How do you feel at this precise moment in this room? | ☐Very cold<br>☐Cold<br>☐Cool<br>☐Slightly cool<br>☐Neither hot nor cold<br>☐Slightly warm |

| | | | |
|---|---|---|---|
| | | | ☐Warm<br>☐Hot<br>☐Very hot |
| | **2** | At this moment, do you find this room ...? | ☐Comfortable<br>☐Slightly uncomfortable<br>☐Uncomfortable<br>☐Very uncomfortable |
| | **3** | At this moment, would you prefer to be ... in this room? | ☐Much cooler<br>☐Cooler<br>☐Slightly cooler<br>☐Without change<br>☐Slightly warmer<br>☐Warmer<br>☐Much warmer |
| | **4** | The environment in this room, in your opinion is ...? | ☐Perfectly bearable<br>☐Slightly difficult to bear<br>☐Fairly difficult to bear<br>☐Unbearable |
| Questions used as indicators for the design team of a specific issue | **5** | Level of activity performed in this room is.. | ☐Sleeping<br>☐Seated, Reading, writing, PC use<br>☐Standing<br>☐Walking |
| | **6** | What type of clothes do you have at the time of the completion of this (mark the most appropriate solution)? | ☐Underwear, short pants/skirt, t-shirt/top<br>☐Underwear, t-shirt, light trousers/skirt, socks<br>☐Underwear, long sleeves shirt, Normal trousers/skirt, tights/socks<br>☐Underwear, shirt, trousers, light blouse long sleeves, socks<br>☐Underwear, shirt, trousers, sweater, socks<br>☐Other ..... |

Questions are divided in two categories:

a) Questions used for assessing the subjective KPI (questions number 1, 2, 3, 4);

b) Questions used as indicators for the design team of non-environmental factors to evaluate the thermal perception (questions number 5, 6).

Question number 5 is used to calculate the metabolic equivalent of task performed by a respondent. Metabolism is a variable in the comfort equation, which is measured with the unit MET (metabolic equivalent of task). One MET is equivalent to the thermal power dissipated by a subject sitting at rest, in other words, heat production of 58 W/m² (in which "m²" stands for the surface area of the body) (for further information see APPENDIX 2 - Activity levels). The ANSI/ASHRAE 55[5] defines typical activities and question number 5 is designed to provide the MET value to be used in comfort calculation. According to the standard the following metabolic equivalent is calculated for the following activates:

Table 3: metabolic equivalent of task

| Activity | Corresponding metabolic rate |
|---|---|
| Sleeping | 0.8 MET |
| Seated | 1.1 MET |
| Reading | 1.1 MET |
| writing | 1.1 MET |
| PC use | 1.1 MET |
| Standing | 1.4 MET |
| Walking | 0.2 MET |

Question number 6 defines the clothing condition, also a variable, which is used to calculate the comfort condition. The thermal resistance of the clothing considers the insulating capability of clothes, measured with the clo unit. One clo corresponds to 0.155m²°C/W which is the amount of insulation of a subject typically dressed in slip, shirt, pants, jacket, socks and shoes and thus the answers are predefined with typical sets of clothes; though the use of tables from the standards each individual garment correspond to a clo value (for further information see APPENDIX 3 – Clothing insulation). The overall insulation value can be calculated by simply taking the clo value for each individual garment worn by a person and adding them together.

To understand the perceived comfort, as many occupants' input as possible should be collected and for many spaces as possible. Direct subjective response of building occupants has been used for overall assessment of indoor acoustic and thermal comfort of the building, and, in the framework of BIMSPEED, to understand the building renovation actions required for enhancing Indoor Environmental Quality.

### *Evaluation of responses*

The subjective KPI calculation method consists of processing the answers of the specified questions.

At this point, there are two levels of calculating the KPI: an overall evaluation (at building scale) or a specific room evaluation. The latter is used for integration of data in a monitoring data collection process, and simply looks at the data as they are, without any further calculation.

While, the overall evaluation procedure is described in the following steps:

1. Correlate each answer to the classification schemes (every KPI, has a different classification, defined in Deliverable 4.1, for instance for acoustic comfort there are Building classes, A-B-C-D-E, with different noise limits) , assigning a score: score equal to 5, if the answer allows to state that the condition of "acoustic/thermal comfort" within room is completely respected; 1, for the contrary;
2. Calculate, for each room, the average value of the scores obtained from the questionnaire, as explained in step 1, for each respondent.
3. Calculate, for each room, the average value of the scores obtained in step 2 of all the respondents;
4. Calculate the subjective KPI according to the Eq:

$$subjective\ KPI = \left(\frac{\sum_{i=1}^{n} A_i * RA_i}{A_{tot}}\right)$$

Where $A_i$ is the reference floor area of each room sharing a border with the outdoor environment i [m2], $RA_i$ is the average value calculated for each room i [-] and $A_{tot}$ is the total reference floor area of all the rooms bordering to the external environment [$m^2$]. Then the KPI is expressed in a percentage scale from 0% to 100 %, through a linear interpolation from 1 to 5, where the score 1 corresponds to 0 % and the score 5 to 100 %. In this way, the subjective KPI follows the same classification scheme of Deliverable 4.1's KPIs.

In this way, the objective and subjective KPIs can be compared to each other, to evaluate how the human perception leads away from the comfort measure, based on simulation or experimental measurements of the acoustic or thermal quantities.

# 7. APPENDIX 1 – Methodologies for subjective evaluations (ISO15251[3])

Subjective questionnaires can be used to evaluate the indoor environment. Subjective scales are presented to the occupants at fixed time intervals (daily, weekly, monthly, etc.). The scales can be presented through intranet on each person's PC or handed out as hard copies. The questionnaires should be filled out during middle morning or middle afternoon. Not just after arrival or after a lunch break. The results can be presented as average values and/or distributions.

Table 4: Examples of questionnaires for subjective evaluations in Annex H of ISO15251

| Question | Multiple Choices |
|---|---|
| How do you rate your thermal sensation? | Cold<br>Cool<br>Slightly cool<br>Neutral<br>Slightly warm<br>Warm<br>Hot |
| How do you perceive the temperature? | Clearly acceptable<br>Just acceptable<br>Just unacceptable<br>Clearly unacceptable |
| Do you want the room temperature? | Higher<br>No change<br>Lower |
| How do you perceive the air quality? | Clearly acceptable<br>Just acceptable<br>Just unacceptable<br>Clearly unacceptable |

The percentage of people voting acceptable (thermal environment and air quality) is calculated for each of the representative spaces in the buildings. A weighted average according to the number of people in the different spaces are calculated and used for classification. More details can also be included by showing the distribution of votes on the 7-point thermal sensation scale and showing the percentage of people wanting higher, no change and lower room temperature.

The results can be shown in a table like the example in Table 5:

Table 5: Examples of results of the subjective reaction classification

| Classification based on occupants' responses | Percentage | | | | | | |
|---|---|---|---|---|---|---|---|
| People finding the thermal environment acceptable | 85 | | | | | | |
| People finding the indoor air quality acceptable | 80 | | | | | | |
| Distribution on thermal sensation votes | -3 | -2 | -1 | 0 | +1 | +2 | +3 |
| | 0 | 5 | 10 | 53 | 20 | 10 | 2 |
| Distribution of temperature preference | Colder | | Unchanged | | | Warmer | |
| | 20 | | 75 | | | 5 | |

# 8. APPENDIX 2 – Activity levels (ANSI/ASHRAE 55[5])

The data visible in Table 6 are reproduced from Chapter 8 of the 2001 ASHRAE Handbook, Fundamentals[6]. This handbook chapter provides additional information for estimating and measuring activity levels. General guidelines for the use of these data follow.

Every activity that may be of interest is not included in this table. Users should use their judgment to match the activities being considered to comparable activities in the table. Some of the data in this table are reported as a range and some as a single value. The format for a given entry is based on the original data source and is not an indication of when a range of values should or should not be utilized. For all activities except sedentary activities, the metabolic rate for a given activity is likely to have a substantial range of variation that depends on the individual performing the task and the circumstances under which the task is performed.

As metabolic rates increase above 1.0 met, the evaporation of sweat becomes a more and more important factor for thermal comfort. The PMV method does not fully account for this factor and this standard should not be applied to situations where the time-averaged metabolic rate is above 2.0 met.

Table 6: Metabolic Rates for Typical Tasks

| Activity | Metabolic Rate met units | $W/m^2$ | $(BTU/h \cdot ft^2)$ |
|---|---|---|---|
| **Resting** | | | |
| Sleeping | 0.7 | 40 | (13) |
| Reclining | 0.8 | 45 | (15) |
| Seated, quiet | 1.0 | 60 | (18) |
| Standing, relaxed | 1.2 | 70 | (22) |
| **Walking (on level surface)** | | | |
| 0.9 m/s, 3.2 km/h, 2.0 mph | 2.0 | 115 | (37) |
| 1.2 m/s, 4.3 km/h, 2.7 mph | 2.6 | 150 | (48) |
| 1.8 m/s, 6.8 km/h, 4.2 mph | 3.8 | 220 | (70) |
| **Office Activities** | | | |
| Seated, reading or writing | 1.0 | 60 | (18) |
| Typing | 1.1 | 65 | (20) |
| Filing, seated | 1.2 | 70 | (22) |
| Filing, standing | 1.4 | 80 | (26) |
| Walking about | 1.7 | 100 | (31) |
| Lifting/packing | 2.1 | 120 | (39) |
| **Driving/Flying** | | | |
| Automobile | 1.0-2.0 | 60-115 | (18-37) |
| Aircraft, routine | 1.2 | 70 | (22) |
| Aircraft, instrument landing | 1.8 | 105 | (33) |
| Aircraft, combat | 2.4 | 140 | (44) |
| Heavy vehicle | 3.2 | 185 | (59) |
| **Miscellaneous Occupational Activities** | | | |
| Cooking | 1.6-2.0 | 95-115 | (29-37) |
| House cleaning | 2.0-3.4 | 115-200 | (37-63) |
| Seated, heavy limb movement | 2.2 | 130 | (41) |
| Machine work | | | |
| sawing (table saw) | 1.8 | 105 | (33) |
| light (electrical industry) | 2.0-2.4 | 115-140 | (37-44) |
| heavy | 4.0 | 235 | (74) |
| Handling 50 kg (100 lb) bags | 4.0 | 235 | (74) |
| Pick and shovel work | 4.0-4.8 | 235-280 | (74-88) |
| **Miscellaneous Leisure Activities** | | | |
| Dancing, social | 2.4-4.4 | 140-255 | (44-81) |
| Calisthenics/exercise | 3.0-4.0 | 175-235 | (55-74) |
| Tennis, singles | 3.6-4.0 | 210-270 | (66-74) |
| Basketball | 5.0-7.6 | 290-440 | (92-140) |

# 9. APPENDIX 3 – Clothing insulation (ANSI/ASHRAE 55[5])

The insulation provided by clothing can be determined by a variety of means and if accurate data are available from other sources, such as measurement with thermal manikins, those data may be used. When such information is not available, the tables in this appendix may be used to estimate clothing insulation using the method described below.

Table 7 lists the insulation provided by a variety of common clothing ensembles. If the ensemble in question matches reasonably well with one of the ensembles in this table, then the indicated clo value should be used.

Table 8 presents the thermal insulation of a variety of individual garments. These garments may be added to or subtracted from the ensembles in Table 7 to estimate the insulation of ensembles that differ in garment composition from those in Table 7. For example, if long underwear bottoms are added to Ensemble 5 in Table 7, the insulation of the resulting ensemble is estimated as $I_{cl}$ = 1.01 clo + 0.15 clo = 1.16 clo.

Table 7: Clothing Insulation Values for Typical Ensembles

| Clothing Description | Garments Included [b] | $I_{cl}$ (clo) |
|---|---|---|
| **Trousers** | 1) Trousers, short-sleeve shirt | 0.57 |
| | 2) Trousers, long-sleeve shirt | 0.61 |
| | 3) #2 plus suit jacket | 0.96 |
| | 4) #2 plus suit jacket, vest, T-shirt | 1.14 |
| | 5) #2 plus long sleeve sweater, T-shirt | 1.01 |
| | 6) #5 plus suit jacket, long underwear bottoms | 1.30 |
| **Skirts/Dresses** | 7) Knee-length skirt, short-sleeve shirt (sandals) | 0.54 |
| | 8) Knee-length skirt, long-sleeve shirt, full slip | 0.67 |
| | 9) Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater | 1.10 |
| | 10) Knee-length skirt, long-sleeve shirt, half slip, suit jacket | 1.04 |
| | 11) Ankle-length skirt, long-sleeve shirt, suit jacket | 1.10 |
| **Shorts** | 12) Walking shorts, short-sleeve shirt | 0.36 |
| **Overalls/Coveralls** | 13) Long-sleeve coveralls, T-shirt | 0.72 |
| | 14) Overalls, long-sleeve shirt, T-shirt | 0.89 |
| | 15) Insulated coveralls, long-sleeve thermal underwear tops and bottoms | 1.37 |
| **Athletic** | 16) Sweat pants, long-sleeve sweatshirt | 0.74 |
| **Sleepwear** | 17) Long-sleeve pajama tops, long pajama trousers, short 3/4 length robe (slippers, no socks) | 0.96 |

a) Data are from Chapter 8, *2001 ASHRAE Handbook, Fundamentals.*
b) All clothing ensembles, except where otherwise indicated in parentheses, include shoes, socks, and briefs or panties. All skirt/dress clothing ensembles include panty hose and no additional socks.

Table 8: Garment Insulation

| Garment Description [b] | $I_{clu}$ (clo) | Garment Description [b] | $I_{clu}$ (clo) |
|---|---|---|---|
| **Underwear** | | **Dress and Skirts [c]** | |
| Bra | 0.01 | Skirt (thin) | 0.14 |
| Panties | 0.03 | Skirt (thick) | 0.23 |
| Men's briefs | 0.04 | Sleeveless, scoop neck (thin) | 0.23 |
| T-shirt | 0.08 | Sleeveless, scoop neck (thick), i.e., jumper | 0.27 |
| Half-slip | 0.14 | Short-sleeve shirtdress (thin) | 0.29 |
| Long underwear bottoms | 0.15 | Long-sleeve shirtdress (thin) | 0.33 |
| Full slip | 0.16 | Long-sleeve shirtdress (thick) | 0.47 |
| Long underwear top | 0.20 | **Sweaters** | |
| **Footwear** | | Sleeveless vest (thin) | 0.13 |
| Ankle-length athletic socks | 0.02 | Sleeveless vest (thick) | 0.22 |
| Pantyhose/stockings | 0.02 | Long-sleeve (thin) | 0.25 |
| Sandals/thongs | 0.02 | Long-sleeve (thick) | 0.36 |
| Shoes | 0.02 | **Suit Jackets and Vests [d]** | |
| Slippers (quilted, pile lined) | 0.03 | Sleeveless vest (thin) | 0.10 |
| Calf-length socks | 0.03 | Sleeveless vest (thick) | 0.17 |
| Knee socks (thick) | 0.06 | Single-breasted (thin) | 0.36 |
| Boots | 0.10 | Single-breasted (thick) | 0.42 |
| **Shirts and Blouses** | | Double-breasted (thin) | 0.44 |
| Sleeveless/scoop-neck blouse | 0.13 | Double-breasted (thick) | 0.48 |
| Short-sleeve knit sport shirt | 0.17 | **Sleepwear and Robes** | |
| Short-sleeve dress shirt | 0.19 | Sleeveless short gown (thin) | 0.18 |
| Long-sleeve dress shirt | 0.25 | Sleeveless long gown (thin) | 0.20 |
| Long-sleeve flannel shirt | 0.34 | Short-sleeve hospital gown | 0.31 |
| Long-sleeve sweatshirt | 0.34 | Short-sleeve short robe (thin) | 0.34 |
| **Trousers and Coveralls** | | Short-sleeve pajamas (thin) | 0.42 |
| Short shorts | 0.06 | Long-sleeve long gown (thick) | 0.46 |
| Walking shorts | 0.08 | Long-sleeve short wrap robe (thick) | 0.48 |
| Straight trousers (thin) | 0.15 | Long-sleeve pajamas (thick) | 0.57 |
| Straight trousers (thick) | 0.24 | Long-sleeve long wrap robe (thick) | 0.69 |
| Sweatpants | 0.28 | | |
| Overalls | 0.30 | | |
| Coveralls | 0.49 | | |

# 10. APPENDIX 4 – Informed Consent Information for crowdsourcing

*To be shown and agreed to before residents input information into any digital application or BIM SPEED database:*

Thank you for agreeing to participate and contribute information to our renovation work. The BIM SPEED project will use the data that you provide to develop a more efficient and thorough understanding of structures undergoing renovation.

Before continuing, we need to ensure that you are 18 years old or older and that you are contributing voluntarily to this project. There are no obvious physical, legal or economic risks associated with participating in this study. You do not have to answer any questions you do not wish to answer. Your participation is voluntary and you are free to discontinue your participation at any time.

The information you provide will be stored securely by DEMO Consultants B.V. and this information will be anonymised before being fully integrated into BIM SPEED project developments. No personally identifiable information will be reported in any research product or renovation reports. More information on the project and its direct results are available on our project website.

The BIM SPEED Project believes privacy and data security and confidentiality to be very important. If you have any privacy and data security related concerns, please first contact our project data security manager, Jason Pridmore (pridmore@eshcc.eur.nl) at Erasmus University. Further support is available from the Erasmus University and project Data Protection Officer, Marlon Domingus (marlon.domingus@eur.nl).

By clicking “I agree” you are indicating that you are 18 years of age or older, that you are participating voluntarily and that you agree to allow BIM SPEED to use your data for analysis within this project.

I agree  I disagree

If I agree – proceed to user inputs