P2ENDURE
PLUG & PLAY BUILDING RENOVATION

Mobile inspection tool for building condition assessment

Deliverable Report D2.3

Deliverable Report: D2.3, issue date on 28 February 2017

P2ENDURE
Plug-and-Play product and process innovation for Energy-efficient building deep renovation

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Colophon

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Publishable executive summary

This deliverable (D2.3) describes the prototype software tool for building condition assessment used in the P2ENDURE demonstration cases. The condition assessment primarily takes place as part of the 'mapping process' before renovation.
This report is the documentation of the software demonstrator. The software demonstrator is available online. Access to the software demonstrator can be obtained through the P2ENDURE contact as stated on the project website.

The mobile inspection tool is a user friendly ICT tool for building condition assessment. The software can be operated on a mobile device (a tablet) and desktop / laptop computer.
Within the P2ENDURE project, the tool is to be deployed by the consortium partners responsible for the demonstration cases of deep renovation projects to gather the same kind of data based on a coherent methodology for inspection and respective analysis of the existing condition before renovation.

This pre-renovation information will be saved for the later comparison between the condition before and after renovation in order to provide tangible and measureable evidence of the improvement through the implementation of P2ENDURE Plug-and-Play solutions for deep renovation.

The software is an enhanced and extended version of the state-of-the-art building inspection and maintenance software developed by DEMO Consultants. P2ENDURE specific considerations and deep renovation scope, including project typologies ranging from deep renovation to transformation, are addressed in the upgraded tool.

List of acronyms and abbreviations

BIM: Building Information Model
HVAC: Heating, Ventilation, Air Conditioning
ICT: Information and communication technology
KPI: Key Performance Indicator
MEP: Mechanical, Electrical, and Plumbing
PnP: Plug and Play
S-o-t-a: State-of-the-art

Definitions

The term **'deep renovation'** in accordance with the EU Energy-Efficiency Directive is a cost-effective refurbishment that reduces both the delivered and final energy consumption of a building by a significant percentage compared with the pre-renovation levels; typically more than 60% energy saving as indicated by the European Commission Staff Working Document (SWD(2013) 143 final).
In P2ENDURE, the definition of deep renovation applies within the framework of major renovation, which means: more than 25 % of the surface of the building envelope undergoes renovation; or, the total cost of the renovation of the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated.
Furthermore, deep renovation project in P2ENDURE should have aims at:

- 60% energy saving; and
- 15% cost saving compared to traditional renovation techniques; and
- 50% time saving and thereby reduction of disturbance during renovation.

Contents

1. Introduction

1.1 Objective

This deliverable describes a mobile inspection tool for building condition assessment which is developed to collect evidence of the building condition before deep renovation. In order to measure and compare the results of deep renovation of the demonstration buildings it is crucial to generate a detailed technical report to analyse the technical feasibility for deep renovation, as well as to serve a starting point for developing the deep renovation designs, or a plan for converting the building function or typology where relevant.

This tool supports the innovative on-site activities, proposed in P2ENDURE within the first step of the 4M modular process – mapping, are condition assessment based on (self)inspection technology and assessment of the functional qualities and potential of the existing building (see: P2ENDURE deliverable D2.1).

The mobile inspection tool is based on the RE Suite software solution, including the relevant software applications and modules, developed by DEMO Consultants. This software supports an objective and measurable condition assessment methodology for existing buildings and building components. Within P2ENDURE, RE Suite is further developed, not only as reliable and accurate method of determining the technical state of a building and the required maintenance/renovation action to enhance its durability and service life, but also to give technical baselines for building deep renovation and transformation.

The goals of developing the mobile inspection tool within P2ENDURE are:

- Gathering condition information of existing buildings for the real demonstration projects of deep renovation in a coherent way / according to the coherent criteria
- Consolidating technical baselines before renovation
- Providing input for enriching BIM models of the existing buildings

1.2 Structure of this report

The following chapter of this report (Chapter 2) describes the methodology for condition assessment. This methodology was developed in a past EU collaborative research project, and it has been elaborated and implemented as the most commonly used technical norm in the Netherlands. In the P2ENDURE, the broader relevance and applicability of this methodology for deep renovation projects in Europe are explained.

The subsequent chapter (Chapter 3) reviews the state-of-the-art RE Suite software, and defines the specific P2ENDURE requirements to extend and enhance the software. The requirements are consolidated into three categories: functional, technical and interface-related. These requirements are examined for the technical and practical feasibility for the respective software development in P2ENDURE.

Accordingly, Chapter 4 presents the software development plan and the proof-of-concept of the P2ENDURE software of mobile inspection tool. The software prototype will be continuously developed and improved. The demonstrator version will be made available online, and the access can be obtained by contacting the P2ENDURE Coordinator.

The final chapter (Chapter 5) presents the overview of inter-relationships between the mobile inspection tool (this deliverable D2.3) and the other software tools and BIM-related instruments developed or optimised within the Work Package 2 of the P2ENDURE project. This chapter also discusses and recommends the follow-up research, development, testing and demonstration activities in P2ENDURE, especially regarding the software tools and BIM.

2. Condition assessment

2.1 Methodology

Taking into consideration that all inspectors differ in their knowledge, education, attitude, or motivation, interpretation of the buildings technical condition is prone to biased opinions. Therefore, a reliable and consistent inspection tool based on a coherent methodology is needed. The inspection tool is expected to give clear guidelines for condition assessment to follow step by step for possibly most objective results.

The P2ENDURE mobile inspection tool is developed based on the state-of-the-art RE Suite software tool that is already available on the Dutch market and follows the Dutch technical norm for condition assessment, i.e. NEN 2767. The norm was developed based on in-depth research funded by European Commission and conducted by an international consortium (i.e. EU project "Condition Assessment of Buildings and Building Components") and gives clear directions for an effective and efficient condition assessment that can be easily adjusted for application in other European countries.

Experts from DEMO Consultants were involved at the inception of the condition assessment in the Netherlands and Europe and subsequently contributed to the development of the Dutch technical norm NEN 2767. The methodology is user-friendly, easy to operate, meant for performing a quick scan assessment, and not strictly based on the technical knowledge of the inspector; nevertheless, understanding of a building structure is required.
There are few steps within the inspection protocol according to the NEN 2767to determine a condition of a building component:

- Step 1: Defining defects – which defects are present?
- Step 2: Defining aspects of the defects (seriousness, intensity and extent) – how serious are the defects?

Seriousness	Intensity	Extent
- **Minor (esthetical)**	- **Staring (hardly noticeable)**	- **Incidental (< 2%)**
- **Serious (degradation)**	- **Progressing (clearly noticeable)**	- **Partial (2-10%)**
- **Critical (malfunction)**	- **Developed (obvious)**	- **Regular (10-30%)**
		- **Frequent (30-70%)**
		- **General (≥ 70%)**

- Step 3: Assessing condition score based on aspects of the defects.

The combination of these aspects gives a condition score of buildings components:

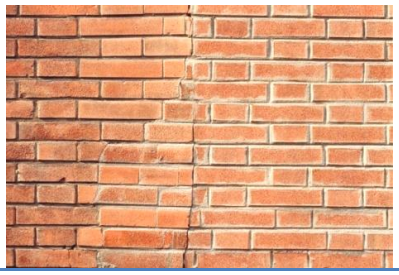
Condition score & Description		Condition state
1	Very good condition	Occasional minor defects
2	Good condition	Occasional signs of ageing
3	Reasonable condition	Localised visible ageing , components functionality not at risk
4	Borderline condition	Component functionality occasionally at risk
5	Bad condition	Ageing condition is irreversible
6	Very bad condition	Technical state for replacement/demolition

In summary, the overview of condition matrix NEN 2767 is shown below:

condition matrix NEN 2767 — **DEMO RE Suite**

SERIOUSNESS	EXTENT														
minor / serious / critical	incidental			partial			regular			frequent			general		
	< 2%			2 – 10%			10 – 30%			30 – 70%			≥ 70%		
INTENSITY															
starting	1	1	1	1	1	1	1	1	2	1	2	3	2	3	4
progressing	1	1	1	1	1	2	1	2	3	2	3	4	3	4	5
developed	1	1	2	1	2	3	2	3	4	3	4	5	4	5	6

The methodology can be explained refer to the following example of defect classification of brickwork:

Minor defects	Serious defects	Critical defects
Defects on surfaces affecting mainly aesthetical performance: ***biological growth, chipping, staining, chromatic alteration, surface finish deterioration, efflorescence, graffiti, pollution***	**Defects undermining functional performance of the walling system:** ***ageing/degradation of joints, flaking/spalling, holes & blisters, horizontal & vertical cracks, moisture retention, swelling/bulging, presence of vegetation***	**Defects undermining physical-mechanical performance & stability of walling system:** ***bowing of external leaf of cavity walls, detachment, diagonal cracks following horizontal & vertical joints, intrinsic cracks, loss***
		

The inspection standardisation is an essence of condition assessment to measure the physical quality of building components/buildings objectively and uniformly, to provide insight into the maintenance condition of building components/buildings, to be used as a basis for determining maintenance costs & repair prioritisation and to enable better management & control of maintenance work.

2.2 Scope of P2ENDURE mobile inspection tool

The P2ENDURE project aims to provide evidence-based innovative solutions for deep renovation. The mobile inspection tool, developed within this deliverable, supports the method to inspect the existing building consistently, and thus to generate a measurable and an objective baseline before renovation. This baseline will later be used to validate the improvements made through implementation of P2ENDURE solutions, both products as well as process innovations in deep renovation.

In P2ENDURE, condition assessment will be conducted in the selected demonstration buildings covering following typologies and scope of intervention:

- Deep renovation of residential buildings and districts
- Deep renovation of public buildings
- Transformation from public or historic buildings into dwellings

The functional and technical requirements of the inspection tool vary according to the scope of deep renovation intervention and the purpose of condition assessment. In P2ENDURE, the focus of tool development lies on enhancing, customizing and configuring the RE Suite software tool (which was originally designed for condition assessment for building maintenance) for application in building deep renovation and transformation.

To ensure good performing buildings, the building components, including MEP/HVEC systems, should be well maintained and renovated/replaced when necessary. The mobile inspection tool helps to gather all materials and information about buildings' technical condition and functional capabilities and to make the best decision according to most effective renovation strategy.

The NEN 2767 can be applied for both building components and MEP/HVAC systems, however, with the inspection tool only visual condition assessment of the MEP systems is possible, e.g. checking if there is no visible leakage, damage or corrosion of the pipes. Detailed inspection of the performance of the MEP/HVAC systems must be performed by a specialist.

3. Requirements for tool development

This chapter defines and consolidates described functional, technical and interface requirements for the P2ENDURE mobile inspection tool. These requirements are translated into the software development plan, which is subsequently implemented in the extension and enhancement of the existing software tool RE Suite by DEMO Consultants B.V.

In the following sections in this chapter, the underlying software tool is reviewed (subchapter 3.1), and the P2ENDURE software requirements are presented in three parts (subchapters 3.2, 3.3 and 3.4).

3.1 Description of the underlying software tool

3.1.1 Software design

The RE Suite, developed by DEMO Consultants, is a tool that supports collecting, structuring, analysing and disseminating information of buildings and civil infrastructure. It is a comprehensive software solution, which allows various parts to be automated. The software has a modular design and can be implemented in a modular system.

RE Suite supports the entire cycle of real estate development and information management. The tool provides continuous insight into real estate information; and therefore, puts the asset manager better in control of the real estate portfolio.

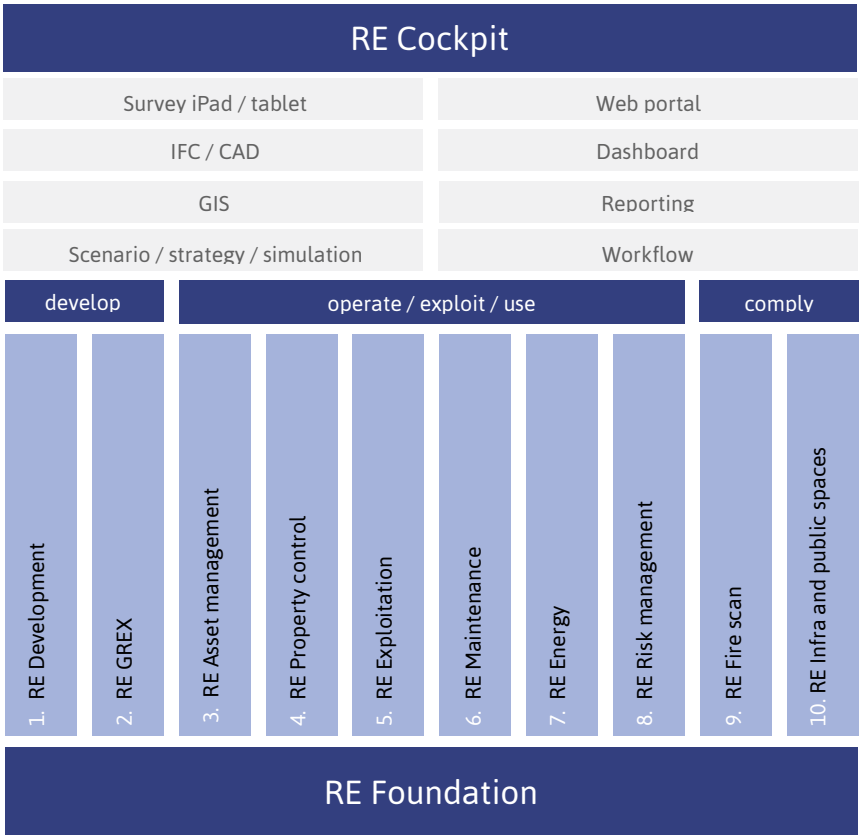
The main functionalities / features of RE Suite are:

- facility for control and continuous insight for everyone in the organization;
- standard and individual composed reports generated in Word, Excel or PDF;
- customized solution - tailor-made to specific needs;
- compatibility with modern techniques and standards: BIM, CityGML, GIS, etc.;
- adaptable layout depending on the needs and software familiarity of individual users;
- multi-user application, even in different locations; customize access rights by the application manager;
- preservation of customized solutions, specific settings and extensions in the new versions and updates.

The functional structure of the RE Suite contains three tiers:

- Foundation
- Applications
- Cockpit

These tiers are of modular-built as shown in the following scheme.



Foundation

The RE Foundation Server consists of the data model, links to other external sources and ERP (Enterprise Resource Planning) and administrative systems. From the RE Foundation the data is managed, e.g. the objects, components or encoding.

Applications

The Application tier of the RE Suite consists of functionally related applications that for professional property management, for example:

- RE Maintenance results in a long-term maintenance planning, indicating risks and costs of building maintenance and monitoring quality levels of real estate.
- RE Energy indicated the energy level and buildings' energy performance. The tool allows carrying out energy inspections and generating energy index certificates.
- RE Risk Management manages risk and cost level and monitor the quality of real estate.

All the applications within the RE Suite are based on the same database - RE Foundation. They also use the same generic modules for unlocking the information, e.g. web management, GIS or reporting.

Cockpit

The third tier contains generic modules that can be implemented and used separately from the applications, for example:

- The RE Surveying software allows data to be collected, accessed and controlled "out in the field" on iPad or tablet PC.
- RE Dashboard – Key Performance Indicators for property control, asset management and performance based contracting. The tool helps to display collected data, e.g. on building's performance, in a clear way allowing analysing, comparing and showing the data effectively. The RE Dashboard is independent from applications in the RE Suite and can be applied for any kind of data.

RE Suite is sold per license or offered as SaaS (where the number of users is unlimited). The software is suitable for client-server environments, cloud application, but also can be used on a stand-alone PC.

3.1.2 Access and authentication

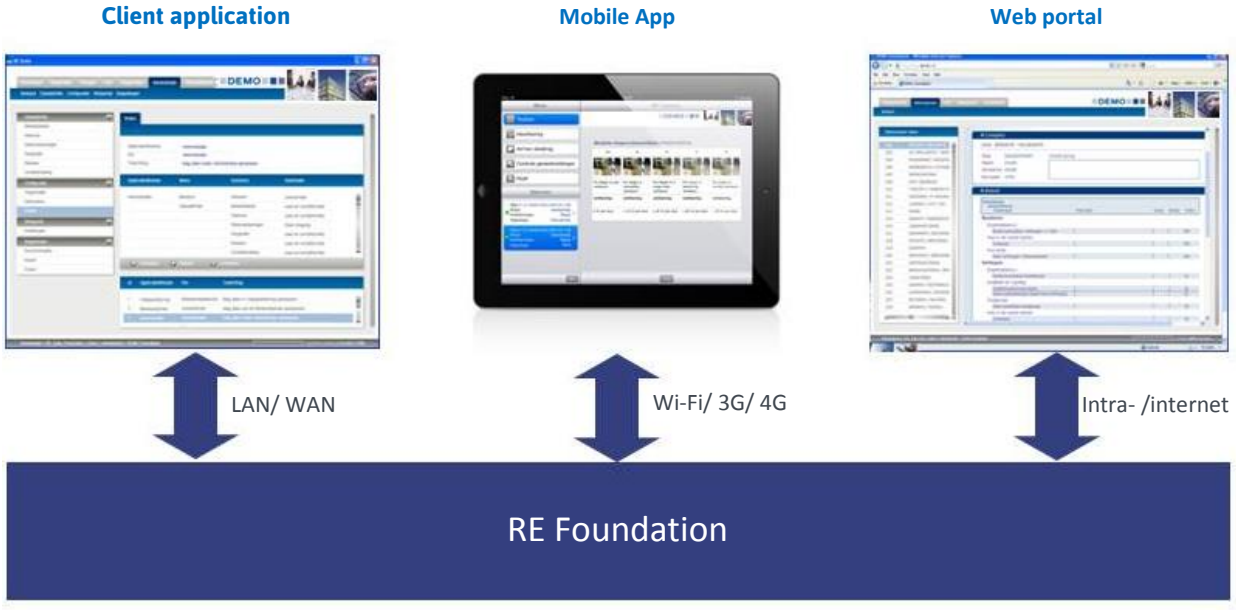
Access to the inspection tool is possible in three ways:

- Client application (LAN/WAN)
- Mobile App (Wi-Fi/3G/4G)
- A web portal (intra-/internet)

The user is able to log in to the system supplying his/her credentials.

RE Suite components were developed based on a multi-user design, which means that different users can work with the tool simultaneously from different locations while a strong focus on security aspects is maintained. Access rights can be adapted to different user levels through the application manager, and the authorizations can be set for profiles and users at a detailed level.

The main IT Architecture of RE Suite is shown in the following scheme:



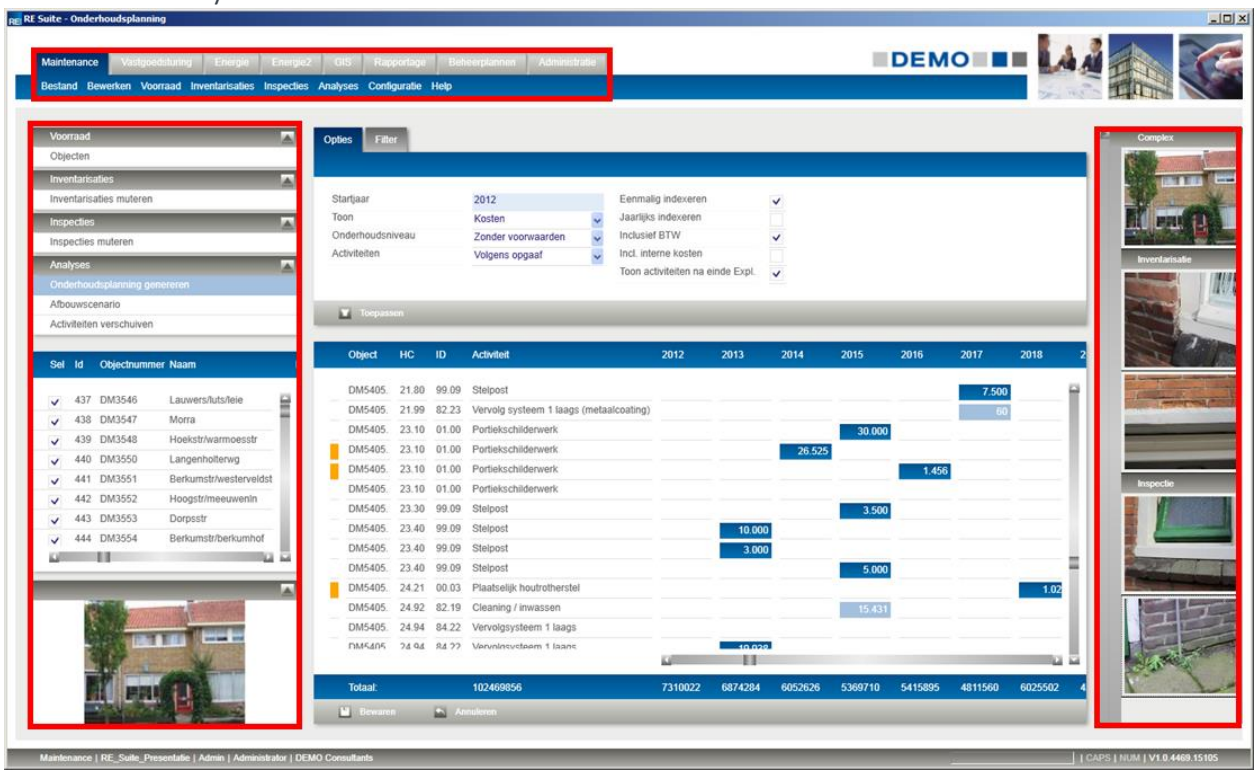
3.1.3 Software navigation screen

RE Suite has an intuitive user interface, which is subjected to continuous improvement based on user experience and research on ergonomic software interface. A user can navigate through the software tool according to the following logic:

- When the inspection specialist is out in the field, the current location of this user is shown on the map. The buildings in the surrounding area are visualised and made possible to be selected.
- Process navigation menu can be found on the left stripe of the main screen, and it can be easily managed in a step-by-step approach.
- Tabs with the various applications and modules are placed on top of the screen.
- An overview of the data can be generated in the Reporting module.
- In the Administration section, it is possible to adjust the basic tool and the user settings.
- An additional grey menu bar on the right side of the screen will appear where images that are associated with a selected building are displayed.

An example of the navigation screen is shown in the following. The detailed explanation of the navigation and the screen layout is described in the user manual (Appendix 1)

RE Suite screen layout:



3.1.4 Access to files

The required documents and check lists as well as product, building and design specifications and related guidelines (database or BIM) can be imported and accessed on the mobile inspection tool. This will enable the inspector to view relevant instructions and information related to the assigned activities. This is done by web-based application which can be used device independent and available documents on a web page and to download documents, images and movies that are related to a certain part of the BIM model via the Internet.

It is also possible to take photos of the building components during the inspection. These picture files will be kept and made available for review in the subsequent analysis phase.

3.1.5 Software application RE Maintenance

The software application RE Maintenance facilitates the development of long-term maintenance schedules, according to the methodology in the Dutch technical norm NEN 2767 for condition-based maintenance. Long-term maintenance planning is an instrument to manage risks and costs of maintenance and to monitor quality levels of real estate.
It is used to manage object data, to identify what needs to be inspected, enter and control the inspection data, edit long-term maintenance schedules in various scenarios, and to report flexible on these topics.
In conjunction with RE Maintenance, a mobile app for iPad is available. With this app, data can be showed and imported when the inspector is out there in the field (on the building site).

RE Maintenance consists of the following features:

- Property management: importing and modifying object data. All the information and materials related to inspected buildings are included in the tool to give full control over the data. This data can automatically be updated by linking with the primary system;
- Inventory: importing and modifying inventory data. Inventory allows managing the parts that have to be inspected, with corresponding materials and units, using standardized code;
  The number of criteria that can be selected is large. Selection is possible via, e.g. operational codes, work types, place codes, geographical area or location, free selection codes;
- Inspection: importing and modifying inspection data;
- Analysis: developing maintenance plans, creating scenarios, setting service levels and shifting activitie;.
- Reporting: comprehensive portfolio analyses and reports in the Word, Excel or PDF, based on relevant decision criteria;
  RE Maintenance can generate the following reports: maintenance plans, site inspection forms for the purpose of re-inspections, and lists of defects and activities;
- File management: organizing and editing files and their properties, selecting criteria and policy labels.
- Configuration: adjusting and increasing standard business and user settings;
- Object information and data: the master data, including building components, activities, and list of defects as well as company and user settings can be managed in the Administration tab;
  RE Maintenance uses a database containing data of building components, possible defects and activities with associated characteristics such as cost ratios, cycles, units and various encodings.

An illustration of the software is shown in the following.

When the inspections are carried out at location, the inspector has two options: "paper inspection " or " digital inspection". For paper inspection, the tool generates inspection forms. The inspector can note his findings and later at the office, enter the information in the software. For digital inspection, the inspector uses his mobile device with the appropriate inspection data available, and enters his findings directly in the software. By synchronizing the mobile device with the client software the data will immediately be available at the office. The software on the mobile device has the same functionality as the “Inspections” interface of the RE Maintenance. In the case of digital input in the field, the software leaves the possibility to authorize the information at the office, before sending it to the central data base of the RE Maintenance.

3.1.6 Software application RE Asset Management

RE Asset Management enables an assessment of quality of buildings and building components in order to assert control over the real estate asset over time. The management plans provide insight into proposed policies and management measures, including information on district, building and location.

The main features of RE Asset Management are:

- Comprehensive portfolio analyses and reports based on relevant criteria.
- Integration of primary management and housing allocation systems.
- Management of visual materials (photographs, maps).
- Generation of management plans.
- Possibility of multi-user operability, even at different locations.

3.1.7 Software module RE Dashboard

The RE Dashboard is a useful application to display the Key Performance Indicators (KPIs) for property control, asset management and performance-based contracting. The tool helps to visualize collected data, e.g. on building's performance, in a clear way, what makes displaying these data and comparing it to other case alternatives easy and comprehensive. The system provides continuous insight into the current state of affairs.

The main features of the RE Dashboard are:

- All the visualizations are on one screen;
- The visualizations can vary depending on the specified (key) performance indicators. The user can determine the definition of the information;
- List of changes can be displayed;
- The application is web based so it can be viewed anywhere;
- The displayed information is automatically updated without an intervention of the user;
- Multiple dashboards can be created, e.g. to set up a hierarchical structure for different departments.

The possible visualizations of indicators and KPIs on the dashboard are:

- Numeric value, "petrol gauge" or traffic light to visualize one KPI;
- x/y graph to visualize two KPI's graphically correlated;
- Spider diagram to provide a multi-indicator analysis with several KPI's;
- Drilldown to generate a list of data modifications underlying the calculation of an indicator. This list can be filtered, sorted and capped for the first x data changes;
- Trend graph to indicate the change of an indicator of KPI value in the last/defined period.

An example of the RE Dashboard with possible visualizations is shown in the following figure.

3.1.8 Software module RE 3D

The RE 3D allows to display BIM models for a better overview of the building structure and components. There are two ways to open a BIM model using this tool: 1) by opening a locally stored model; or 2) by viewing the model directly from the data server Microsoft SharePoint. In order to view BIM models they can be uploaded to the server (model / data repository), after which they are available for viewing / use on mobile devices.

In the displayed BIM model, all building components are listed and it is possible to change the basic properties of the building components, e.g. a name or an assigned label, although it is not possible to change the geometry of the model.

An example of the display of RE 3D is shown in the following.

3.2 P2ENDURE functional requirements

As described in the previous chapter RE Suite – Maintenance provides detailed information on an existing state of a building and building components and gives recommendations for most efficient maintenance strategy. Within P2ENDURE the tool is further developed to perform condition assessment for building renovation and to analyse function of a building to help in deciding on strategies for building renovation and adaptation to new functions. Below the main functional requirements of the tool adapted to condition assessment for building renovation and transformation are described in more details.

3.2.1 Condition assessment for building renovation/transformation

In order to create a strategy for building renovation and transformation many aspects have to be taken into consideration, e.g. possible technological solutions for retrofitting, or financial consequences of each solution. The difference between condition assessment for the maintenance purpose and for the renovation purpose is that in order to provide relevant data for renovation strategies, limitations and constrains in building renovation have to be taken into consideration, e.g. constrains in renovation of historical buildings.

As a systematic methodology a list of building components and parameters for building analysis, with regard to building renovation and transformation, from the ENDIS project (http://endis.nl) on sustainable building with regard to energy neutral and durable steel construction was integrated in the database of the inspection tool. The goal of ENDIS is to design and build sustainable and energy efficient building. The tables “Parameters for building analysis” and “Measures for sustainable renovation” (Appendix 2 & 3) indicate all aspects that must be considered in order to make technical and functional analysis of a building for a renovation and transformation strategies.

Other important aspects that must be taken into account when defining possible strategies for building renovation are:

- Geographical location: customize functionality of the tool will allow specifying characteristics of the location;
- Differences in the inspection methods depending on the country: first version of the mobile inspection tool will be in English language what will determine the terminology of the building components and inspection procedures. The terminology as well as functional requirements, that are specific for each country, will be implemented in the later versions of the tool and kept constantly updated according to the comments of the users during the course of P2ENDURE as well as after the project completion, depending on the demand for the tool.

3.2.2 Requirements for software navigation screen

Within P2ENDURE, the additional application for building condition assessment with regard to building renovation is developed as a part of the state-of-the-art RE Suite tool. The 'Renovation' module is located in the horizontal tab on the top of the screen. The user is able to navigate to the part subjected to inspection/renovation via map, BIM viewer and/or a specific number (an ID of a building component or other relevant item).

Detailed explanation of the navigation and the screen layout is described in the user manual (Appendix 1).

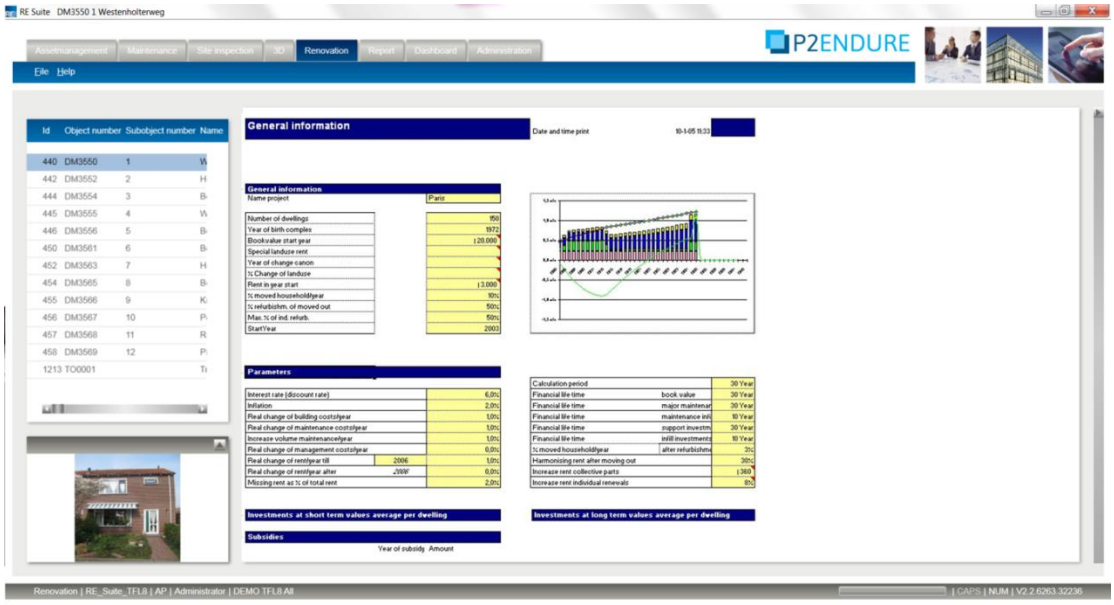


Figure 1: Screen layout in the Renovation module

3.2.3 Requirements addressing the targeted user groups

Data management is an important part of an inspection. Before starting an inspection at location first we must establish which buildings and which parts should be inspected. The inspection tool must provide a good property management and inventory system to manage the objects that have to be inspected with corresponding materials and information. In addition, object strategies and exploitation forms (policy labels) should be processed. The number of criteria that can be selected in the tool is very extensive and includes, inter alia: operation codes, work types, funds, place codes, building type, owners, cluster, rayon or region, geographical area or location, free selection codes. Generated schedules are easy to adjust (shift start years, change cycle and divide activities). In the P2ENDURE tool it is possible to create a report on the building condition, renovation strategies and functional analysis, besides the standard reports.

3.2.4 Requirements on 3D model viewer

With the RE 3D application it is possible to view, rotate and zoom in/out a BIM model in IFC format and to change basic parameters of the components, e.g. a name or an assigned label, although, it is not possible to change the geometry of the model. The aim for development of the P2ENDURE inspection tool is also to allow viewing 3D models based on point clouds generated from a laser scanning. The 3D viewer will be if feasible integrated directly within the Mobile Inspection Tool.

Currently the application is being further developed within the ongoing European project – INSITER, where the BIM model is visualised on the mobile device by means of an integrated BIM viewer.

To view 3D models on a mobile device internet connection is not required. If the device has enough storage capacity to download a BIM model the models can also be viewed offline, e.g. while performing an inspection.

3.2.5 Requirements on Dashboard

The application RE Dashboard is further developed to visualize the aspects related to building renovation and transformation for an easy comparison of the results to different renovation strategies.

The data can be configured and specified based on the available data that is directly retrieved from a data source or indirectly derived data, e.g. from an IFC model.

3.3 P2ENDURE technical requirements

The Inspection Tool will be deployed on and made available in a SAAS (Software as a Service) environment running on Microsoft Windows Terminal Server 2008 R2. This environment should be capable of handling at least 10-50 concurrent users without loss of performance, and should be available 99% of the time excluding scheduled maintenance windows.

The SAAS environment will be running Microsoft SQL Server 2008 R2 to facilitate the storage of all data related to KPI analysis and decision support.

A separate CMIS platform will be used for the exchange of input and output files for different steps in the P2ENDURE workflow. CMIS is an open standard for content management and is applied on the Microsoft SharePoint server. The Decision Support Tool should be able to interface with this CMIS platform.

3.3.1 Requirements on software environment

The software programs are developed in de the programming model: Microsoft .NET solution; where the following languages are used:

- Clients: C#, WPF; Web: Java script, Ajax, HTML 5, JSON, MVC, WCF and Restful web services;
- Apps: Objective-C, Xcode, Xamarin;
- Server operating software environment: Microsoft IIS web server, Microsoft SQL database server, Microsoft SharePoint server, OpenBim server, PostgreSQL server.

3.3.2 Requirements on databases

For the purpose of the P2ENDURE mobile inspection tool, the following databases will be used:

- Open Source BIM server
- MS SharePoint with CMIS open standard interface: for all static files, not IFC

Each database is an existing mature product; this means a well-defined API is available for all three databases used. OS BIM server is an open source product and its API is open, clear and extendable. SharePoint is a closed source Microsoft product, however it supports CMIS, what is the open standard for interaction.

3.3.3 Requirements on connection to other databases

To create a realistic strategy for building renovation and transformation of its function, data from different sources need to be analysed and compared. The inspection tool can download information from outside sources, e.g. requirements/restrictions for renovation and preservation of monuments if available.

3.3.4 Requirements on data formats

In order to view BIM models, IFC 2x3 or IFC4 files upload and download functionality for the BIM server is required to feed the BIM server with new or updated IFC models.
The BIM model is visualised on the mobile device by means of an integrated BIM viewer.

We foresee at this moment that in the decision support tool that will be developed in month 24 of P2ENDURE (D2.4) gbXML – a BIM format focused on energy calculations will be integrated. However there is a diverse amount of studies at this moment about the applicable formats for energy calculations based on BIM. In this rapidly evolving field it is difficult to predict what the best applicable solution will be within next 24 months. At this stage the gbXML format is most likely the best option to integrate. The definitive choice will be made based on the then available best practices.

The AutoCAD applications, that are widely used, had native formats, namely DW-x family. DWG, as an abbreviation for drawing, is the format for vector-based drawings, where DXF is the data format and DWF the format optimized to visualize it on the web. Within P2ENDURE we will explore whether integration of the CAD formats (i.a DWF, DWG, DXF) as a CAD viewer can be useful for a better overview of a building structure during a building inspection. There will be either an option to convert the DWG formats or a separate viewer will be developed for backwards compatibility purposes.

3.3.5 Requirements on file sharing system

A file sharing system is a useful functionality in order to share documents between the inspector and other partners so the results of the inspection in the generated report are immediately available for elaboration. The file sharing system also provides a possibility to be able to download needed documents on a mobile device.

The system consists of two entities:

- File Sharing System as backend software that runs on a server
- A mobile App that will be applied by the surveyor/inspector on site to download the required documents from the SharePoint server.

Sharing documents between different partners requires a certain structure in which the documents are organised. The structure should be created applying document libraries in the following way:

- Process library: In this library the generic process related documents are stored like process flow, quality assurance documents
- Product library: In this library the product related libraries are stored like panels, glazing, building materials, equipment.
- Project library: In this library the project related documents are stored like contracts, project organization, goals, planning, progress, quality control documents.

All document storage locations are provided with unique identifiers so they can be uniquely addressed by means of a URL (link). This way documents that are related to an IFC element from the BIM model can easily be found applying the unique identifier of the IFC element itself (GUID).

Providing documents to the file sharing system:

The back office workers apply their web browser in order to store documents, pictures, movies on the file sharing system.

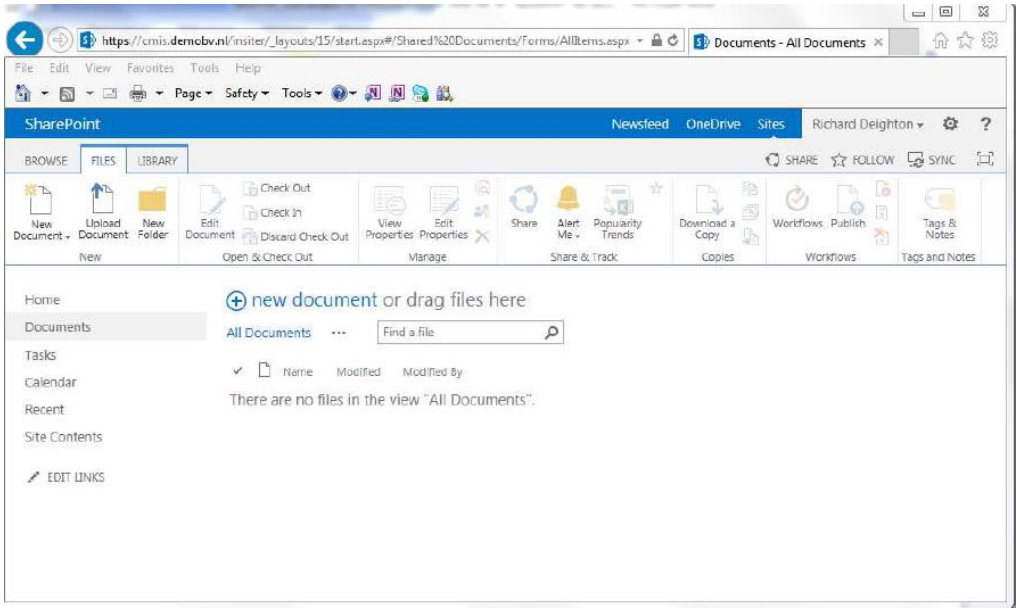


Figure 2: Illustration of file sharing system in P2ENDURE software

Retrieving documents from the file sharing system:

The inspector on site is able to download the documents from the SharePoint server via an App on his/her mobile device. Documents are presented on the mobile device as shown in the picture below.

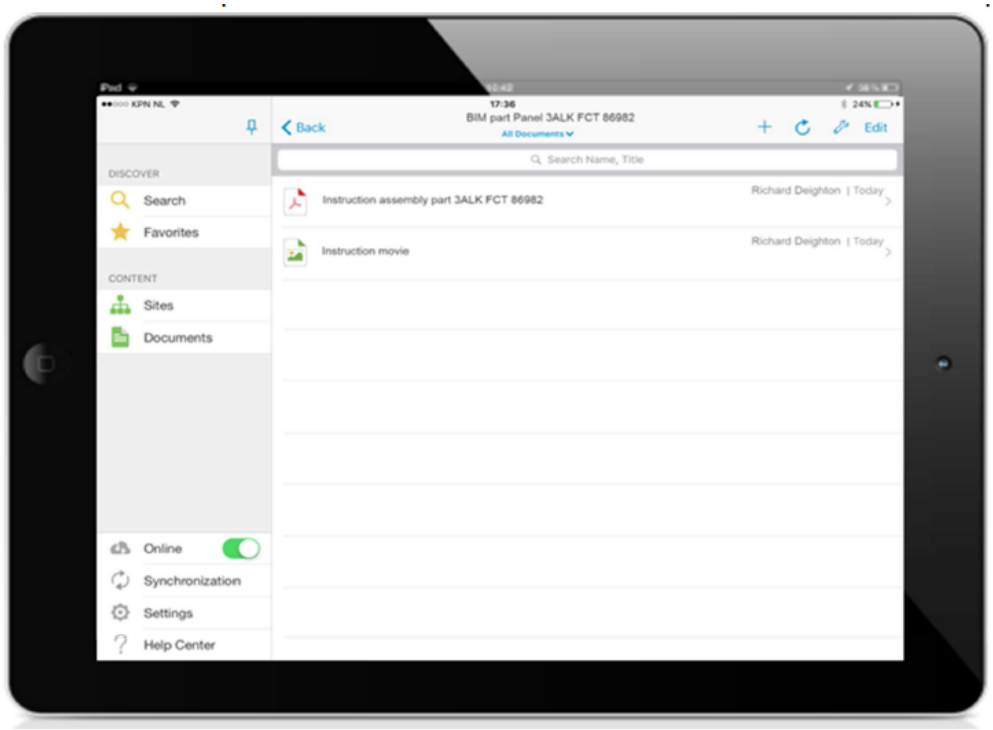


Figure 3: Illustration of documents retrieval on mobile device

3.3.6 Requirements on dashboard performance

In order to create reliable data visualisation in the Dashboard module it is important to determine which information and/or data are to be displayed: which data is required, where the data is stored, how can it be accessed and what the refresh rate is (e.g. once a day/week/month/year, real time). The next step is to foresee a (automated) mechanism for acquiring the data with the desired frequency. Once that is established the dashboard software must be able to filter and aggregate the supplied data in order to provide a meaningful value that can be displayed and presented as information.

3.4 P2ENDURE interface requirements

An interface is a shared boundary across which two or more parts interact. This chapter describes interface requirements for compatibility between the inspection tool and other systems components that the tool will interact with. For example, the inspection tool should be able to extract properties of a building from a BIM model and related guidelines from other databases and include it in its own database. The tool should also be able to import documents and checklists (mostly related to standard processes).

3.4.1 Connection to the P2ENDURE BIM platform and parametric modeller

The BIM parametric modeller will be developed by Technische Universität Berlin month 12 of P2ENDURE within D2.2.

Using the generalized use case BIM, P2ENDURE allows customizing renovation options through a parametric design modeller. The tight integration of BIM and the parametric modeller will enable a participatory design process involving the whole value-chain, involving clients, end-users, and all suppliers.

P2ENDURE configures tests and deploys an open-standard IFC BIM platform that enables monitoring, controlling and managing the retrofitting solution. The platform will be composed of tools to respectively perform the monitoring and control tasks, the energy management tasks, and the BIM for design, manufacturing, assembly and 3D printing. The BIM platform will not only enhance information management, but also enable data interaction between buildings and other systems in the district energy grid. An interface will be created between the platform and the mobile inspection tool. It will be possible to download relevant parts of BIM models through model view definitions or view directly from the platform and integrate their attributes in the analysis for building renovation and transformation.

3.4.2 Connection to the P2ENDURE decision-support tool

By month 24 of P2ENDURE a decision support tool (DST) for asset management, life-cycle cost (LCC) and energy monitoring will be developed by DEMO Consultants. The DST tool will be an instrument to analyse possible design solutions in a structured way by quantifying, comparing and analysing KPIs associated with the design alternatives.

Data from different sources/databases will be analysed and compared in order to create optimal renovation strategy for a selected building. The DST tool will consist of a viewer of the IFC BIM model, a retrieval system for energy calculation results performed by other energy calculation tools, a lifecycle calculation module, and a Content Management Interoperability Services (CMIS) on a Microsoft SharePoint data server. Different tools can be interfaced with this solution (such as Microsoft SharePoint, CSTB eveBIM tool).

4. Software development

4.1 Software development plan

This chapter describes standardized process of software development and implementation.
In the rapidly digitalizing environment the role of software becomes more and more important. Software is used not only in PC's and laptops, phones and other smart devices, like tablets and GPS navigation devises, but it is applied almost in any modern device from vacuum cleaners to toasters. The development of software therefore is a large and fast growing business with well-defined processes and development methods.

DEMO has been engaged in software development for almost twenty years, both for our customers as well as for internal use. The customers represent both governmental and private organisations in the Real Estate and Civil Infrastructure sectors. Our software has been developed and implemented either as in-house installation or as cloud-solution implemented for local municipalities, construction firms, housing corporations, property managers, owners and operators of civil infrastructures or public spaces, such as the Port of Rotterdam.

In general a software development process is divided in several phases: **requirement specification**, **design**, **development of data models and coding (also known as implementation)**, **testing**, **deployment and finally maintenance**. This process is known as the Waterfall method. In the last twenty years we have experienced changes in the approach and techniques, however, in general it is still the most common method to manage the software development process. Recently the Scrum Agile framework became popular, as it helps to improve productivity and quality. Nevertheless, every project and its approach are influenced by the project's nature (research, commercial, maintenance etc.), involved teams, budget, lead-time and scope. The process that we will follow within the P2Endure project is derived from the latest techniques and technologies, our experience and is based on the Waterfall method.

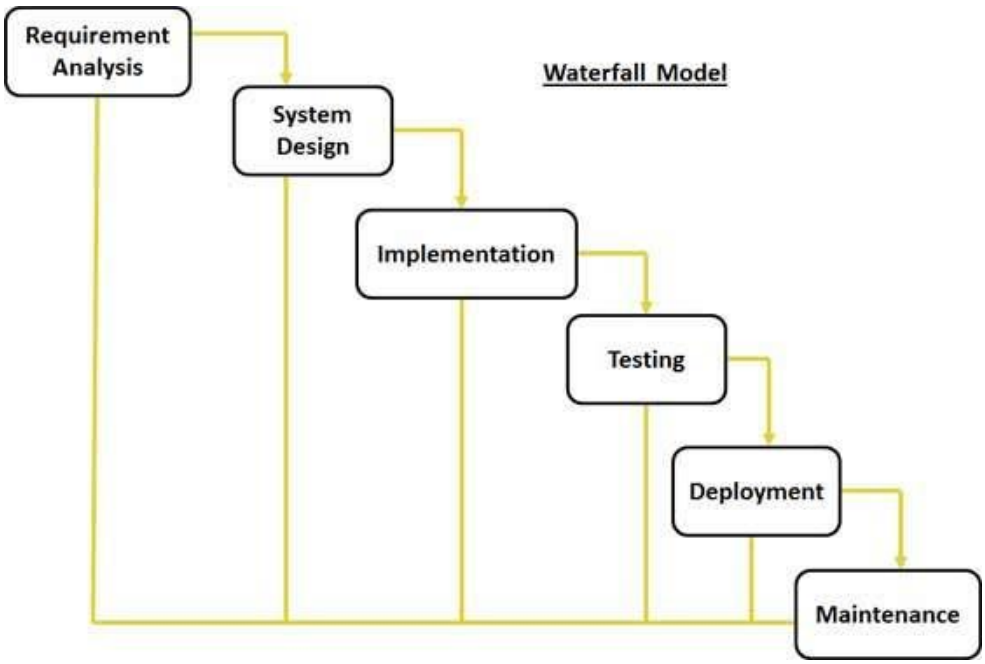


Figure 4: Waterfall method

The advantages of this method are:

- It is easy to implement.
- It is efficient for both small and large systems.
- Documentation is done simultaneously and not at the end of the project, when there is usually lack of budget and time.
- The method requires the fulfilment of a phase, before proceeding to the next one for easier project management.
- Testing is partially done at early stages.
- In general it leads to a shorter lead time.

The drawbacks of this method are:

- It is not always possible to state 100% of the requirements explicitly at the beginning.
- The stakeholders (customer, partners and users) can only see the working software at the end of the project.
- It requires good management skills and a lot of attention to follow the sequential flow.

To overcome the drawbacks of this method DEMO shows intermediate results to the stakeholders to receive their feedback for most optimal result. Especially in a research project this has proven to be an efficient and effective process.

DEMO delivers innovative, reliable and user-friendly software developed in a close collaboration with its customers and partners. The software has been developed for national and international use, and thus, it complies with strict protocols to develop, redevelop, test, implement and support. The software is kept up to date to suit changing requirements.
DEMO relies on the latest techniques in the field of software development, such as Microsoft.NET, SQL, Ajax, WPF, and IOS Object – C, Xamarin. Before applying these techniques in the solutions, they are extensively tested by certified developers regarding practicality and stability. Significant attention and effort are dedicated to ensuring a solid development method and the stability of modular architecture of the software.

The phases of the software development process are:

Phase 1 – Requirement specification and design

- Project planning – Development of a project plan.
- Functional Brief (Specification) – Analysis of specifications; analysis of integration requirements of existing software and required adaptations; development of functional brief and review of a functional brief.
- Functional Design (FD document) – Development of functional design; specification of screens of client application, mobile apps, web portal and reporting formats; description of role and authority of users; review of functional design by stakeholders.
- Technical Design (TD Document) – Development of technical design (TD document); final selection and test of external systems (linked to the to-be-developed tool) and adaptation data model; establishment of source documents for input data in the tool; internal review of technical design by the consortium; and development of test specification (test listing).
- Control and acceptation – Final workflows, screens and configurations; internal review of workflow by the consortium.

Phase 2 – Implantation: Development

- Development of software modules supporting files, data, data scripts and installation protocols.
- Development of relational databases; software development in Microsoft.NET of modules; software development in Xamarin of iPad app and Configuration and Realisation (Screens, Objects, Users, Reports, Web pages, etc.).
- Testing – Internal technical testing of software application.

Phase 3 – Verification: testing and documentation

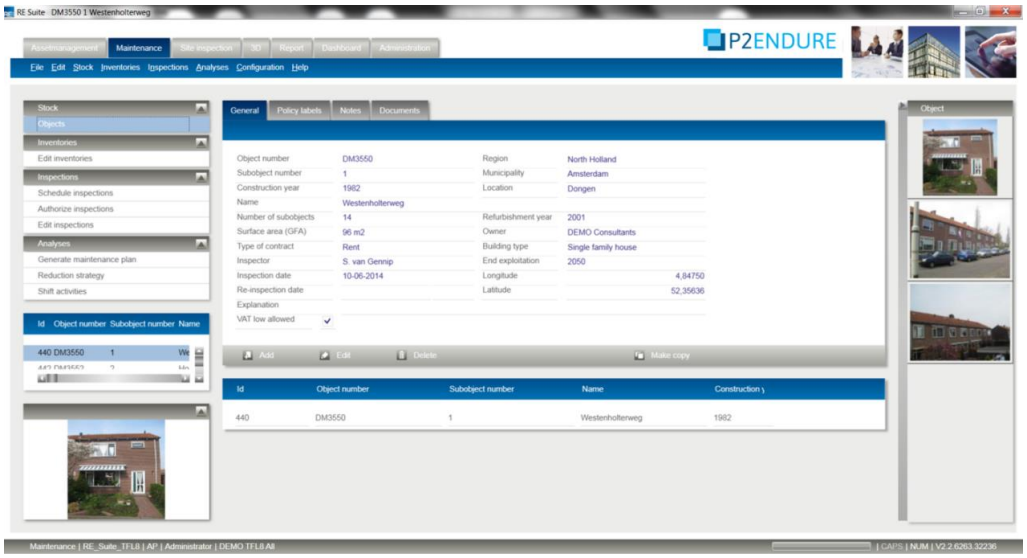
- System integration test – Internal test and problem solving; user test and stakeholder review and rework and bug-fixing / problem solving.
- Documentation – User document (User guide); installation instructions; and test reports.
- Acceptation test – Acceptation review by stakeholders; software commissioning. The software is as much as possible automatically tested. The testing and reworking is strongly supported by Team foundation and SharePoint technology.

Project management for this software development tasks within the P2Endure project is as follows:
At the beginning of the project, a kick-off meeting with the team members was held and a SharePoint site was setup dedicated to the P2Endure project. This project site contains all the relevant documents, project planning, the deliverables and an issue-tracker to streamline the development and testing activities. The overall project leader manages budget, organisation / communication, time, documentation and the quality of process and product. The appointed task leaders manage the described tasks. The consortium is working according to ISO 9000 management protocols.

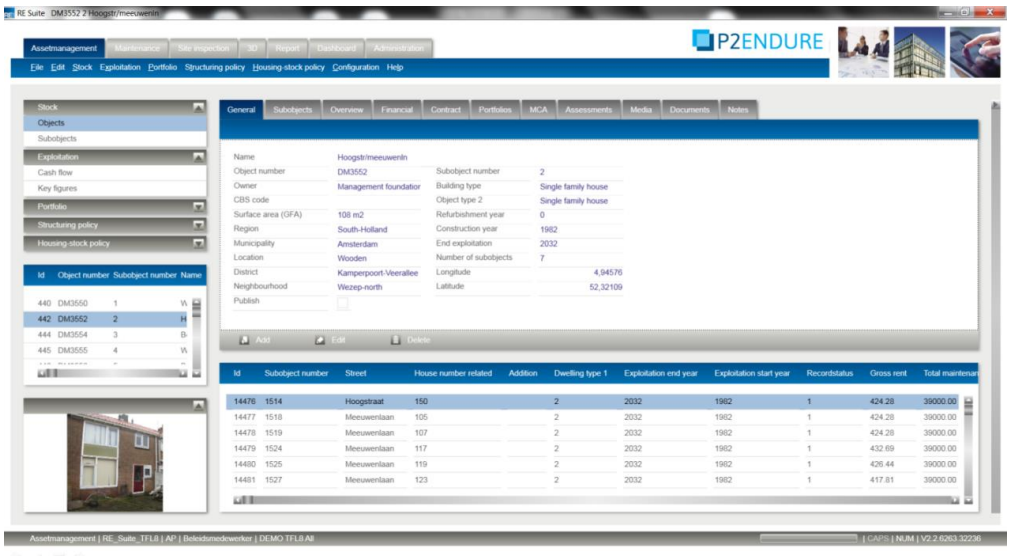
The work breakdown structure is the roadmap for this project. On a weekly base the project team is checked on work progress, budget, possible deviations and risks. Both time registration and meetings about content and progress play an important role in this process.
The work is conducted with daily or weekly coordination through tele/video conference, i.e. GoToMeeting. Physical meetings are organised when needed. Additional developers and supporting staff can also participate in meetings and teleconferences. The consortium has professional facilities to host such meetings.

4.2 Proof of concept

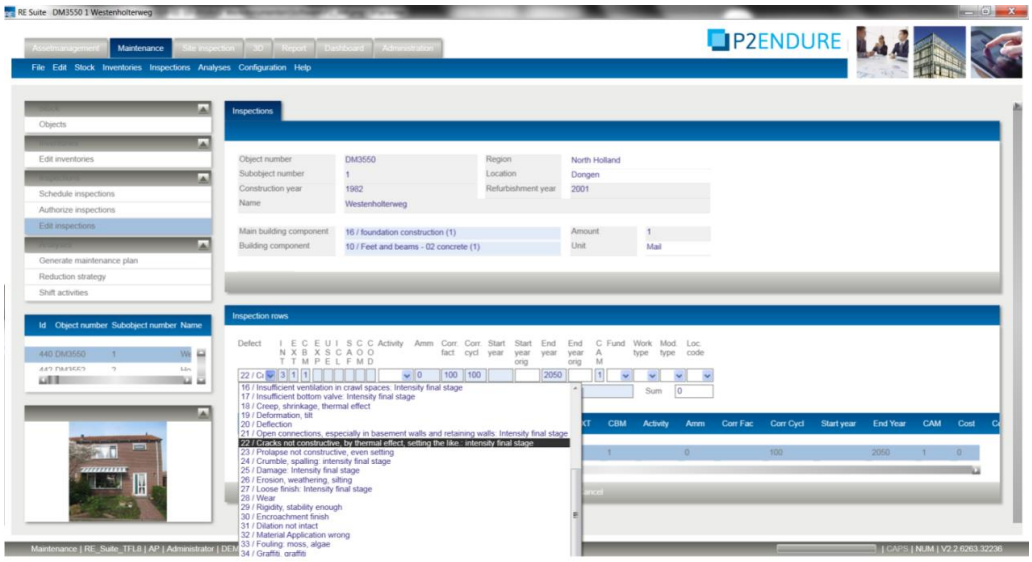
The client software contains several tabs with software items when gathering, structuring and analysing the data and information. The Maintenance application generates maintenance plans based on the current status of the building and the results of its condition assessment. The software contains all the relevant basic data that are needed to make an inventory and inspection of a building. The following figure illustrates the definition of basic building (case) data.



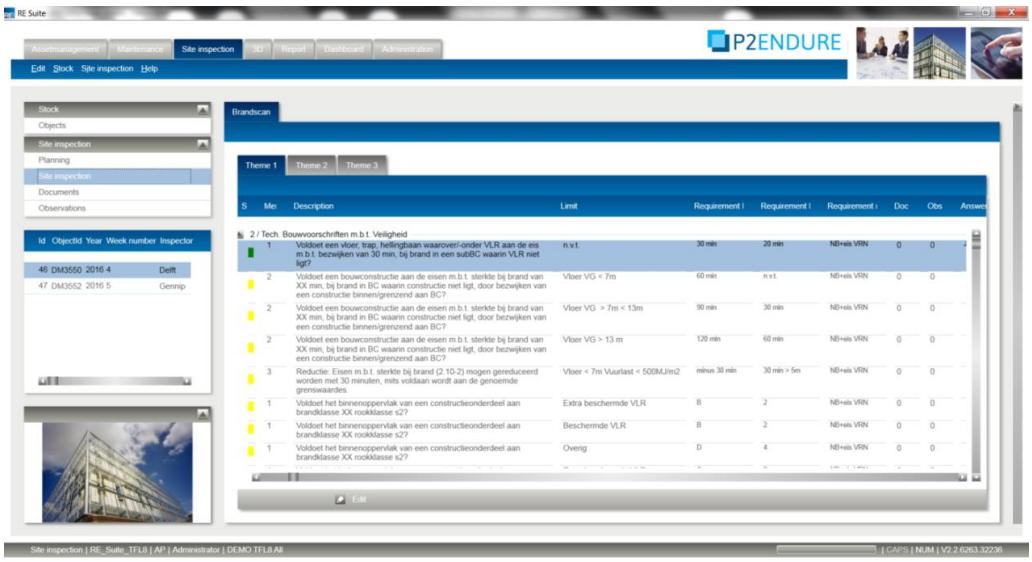
The technical condition of a building is just a part of the required information to support a solid decision on what kind of renovation strategy should be followed. Asset management is a process of managing the performance of a building. The building performance is related not only to the technical condition but also to the core business and financial situation of a company and these aspects must be also considered for a renovation strategy.



To assess the status as built, or more precise as-is, the technical condition should be assessed through inspection. This is done via a standardized norm NEN 2767, which is made suitable for this process. As an example the figure below illustrates a standard defect with its relevant information. This information defines the condition as well as the costs of the activities for renovation/maintenance.

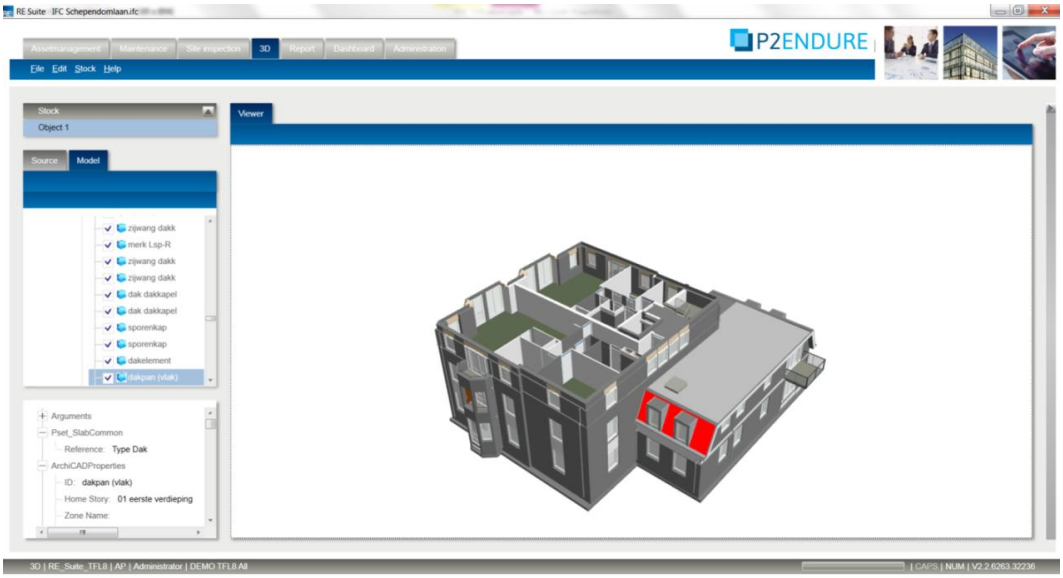


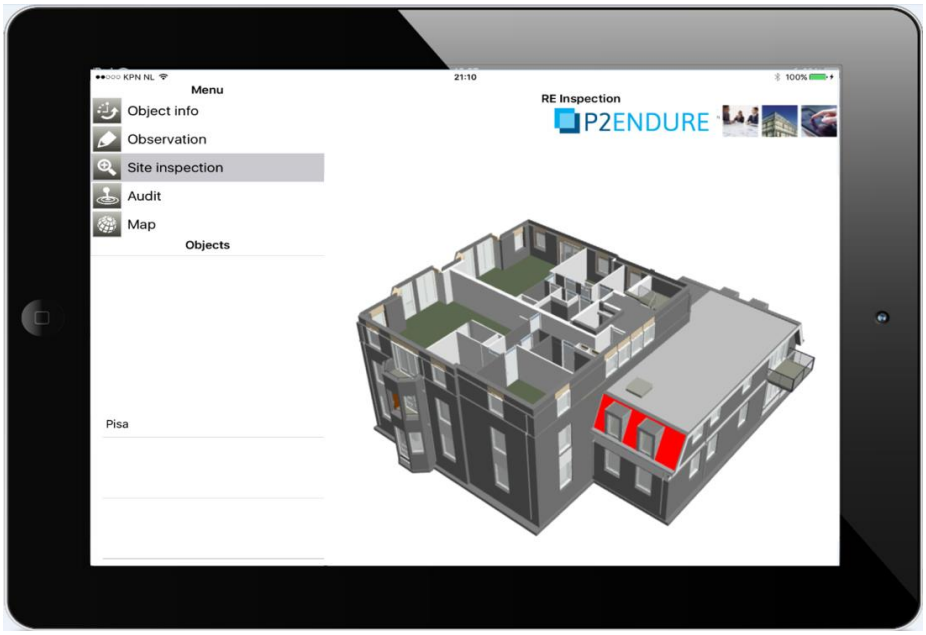
As indicated before, not only technical condition but also other aspects should be taken into account to generate possibly the best maintenance/renovation strategy. One can think of financial items, functional potential, legislation, fire safety, cultural heritage aspects, and agreements. These aspects differ from project to project. Therefore, the software should contain a flexible checklist, based on the applicable aspects. A sample checklist is shown in the following.



The available BIM model is not only used for identification of building parts, components and spaces, but also for quantity take offs, which are useful for analysis. Additionally, the visualization of the building through a BIM model is a very useful mean of communication. The illustration of the visualisation of a BIM model is shown in the figure below.

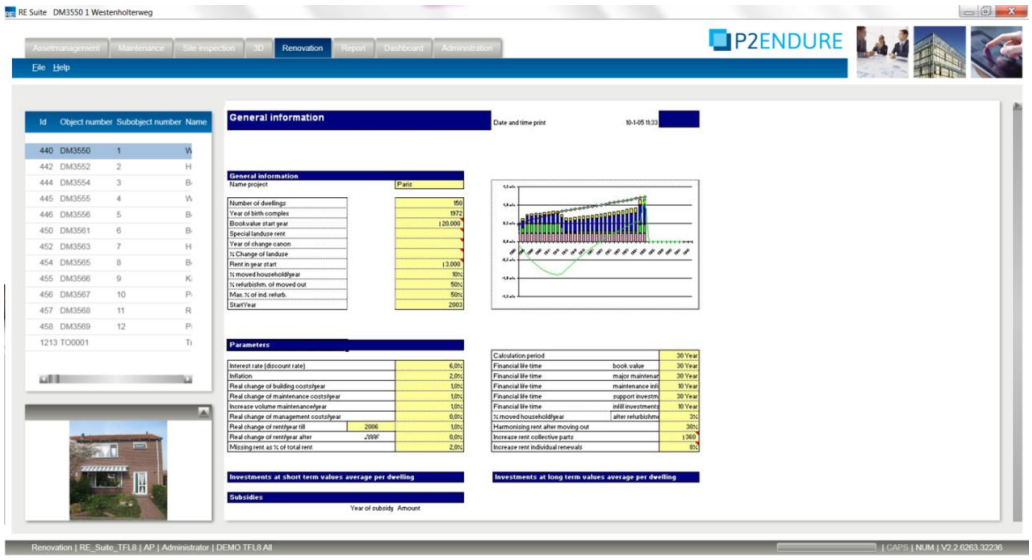
All the required and available data and information are synchronized with the tablet devices that are used for the inspection. This iPad example visualizes the building that is managed in the client software and allows the inspector to use this information on location.





When the inspection is completed and the gathered data is structured and analysed, the results are show in various ways to provide the user with the required feedback to choose the best strategies. Since a lot of detailed data and information can easily overwhelm the user, the art of presentation is to make complexity simple. Therefore, the software visualised this information in infographics on a dashboard. The relevant KPI's are shown below.

In addtiion to the high level information on the dashboard detailed relevant financial results are calculated and presented in the screen below. The software contains all the neccesary algorithms to indicate all relevant financial real estate ratios.



5. Follow-up in relation with other ICT tools in P2ENDURE

The mobile inspection software tool, which is presented in this deliverable, is part of a series of practical ICT tools in P2ENDURE. These ICT tools are developed, optimised and deployed to facilitate the deep renovation process as a whole. This process is known as the "4M modular process" and described in the deliverable D2.1.

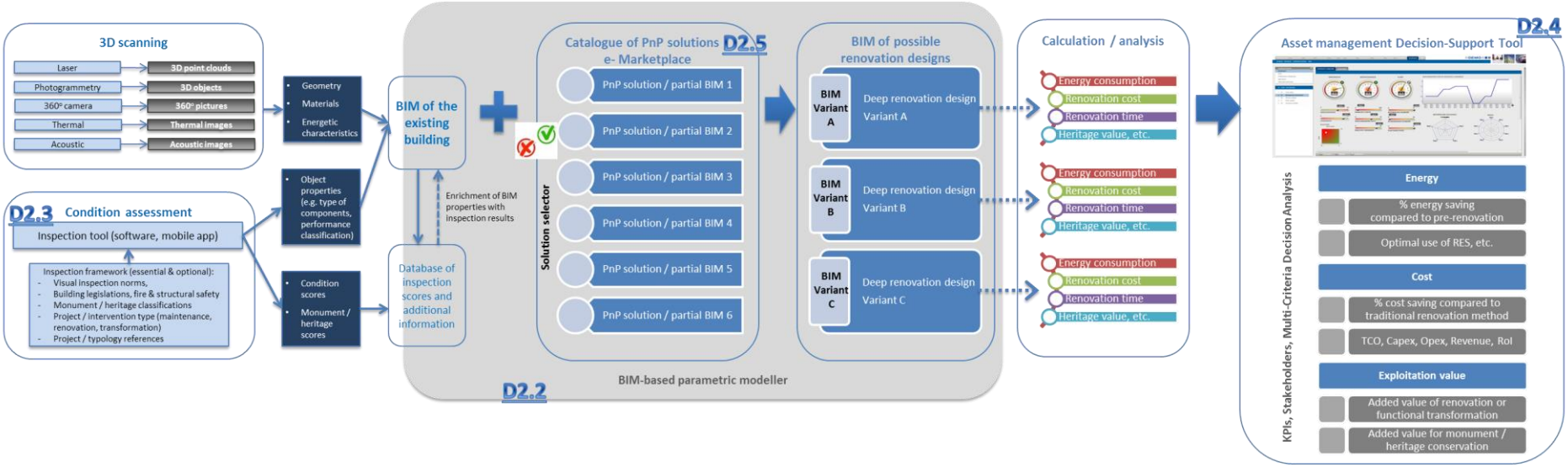
The various ICT tools in P2ENDURE contribute to:

1. Establish a solid baseline before renovation (the mobile inspection tool).
2. Facilitate the renovation design process by configuring the suitable PnP / prefab solutions for deep renovation (the parametric modeller; presented in deliverable D2.2).
3. Connect to the existing e-Marketplaces for building renovation products and services (presented in deliverable D2.5).
4. Provide BIM-based input for energy calculation / energy simulation of the possible deep renovation designs.
5. Support the decision-making at deep renovation, i.e. to decide on the most optimal renovation design, as well as after renovation, i.e. to accommodate energy performance monitoring data and to perform real estate asset management in long-term based on a coherent set of KPIs (asset management and LCC tool; presented in deliverable D2.4).

   This is the supporting instrument to analyse possible design solutions and monitor real deep renovation performance in a structured way by quantifying, comparing and analysing KPIs associated with the selected solutions.

   The decision-support tool of P2ENDURE shall also have an added functionality to give an insight into the limitations and constraints in building deep renovation or transformation. This function will allow creating feasible renovation strategies that might differ for each project even though the used set of KPIs will remain similar.

The preliminary overview of the ICT tools in P2ENDURE is shown in the following scheme. During the following period within the P2ENDURE project, the mobile inspection tool will further be optimised depending on the connections with the other ICT tools as well as the needs and feedback from the users when the mobile inspection tool is tested and implemented in the pilot deep renovation projects.


3D scanning
Laser
3D point clouds
Photogrammetry
3D objects
360° camera
360° pictures
Thermal
Thermal images
Acoustic
Acoustic images
Geometry
Materials
Energetic characteristics
D2.3 Condition assessment
Inspection tool (software, mobile app)
Inspection framework (essential & optional):
- Visual inspection norms,
- Building legislations, fire & structural safety
- Monument / heritage classifications
- Project / intervention type (maintenance, renovation, transformation)
- Project / typology references
Object properties (e.g. type of components, performance classification)
Condition scores
Monument / heritage scores
BIM of the existing building
Enrichment of BIM properties with inspection results
Database of inspection scores and additional information
Solution selector
Catalogue of PnP solutions D2.5
e- Marketplace
PnP solution / partial BIM 1
PnP solution / partial BIM 2
PnP solution / partial BIM 3
PnP solution / partial BIM 4
PnP solution / partial BIM 5
PnP solution / partial BIM 6
BIM-based parametric modeller
D2.2
BIM of possible renovation designs
BIM Variant A
Deep renovation design Variant A
BIM Variant B
Deep renovation design Variant B
BIM Variant C
Deep renovation design Variant C
Calculation / analysis
Energy consumption
Renovation cost
Renovation time
Heritage value, etc.
D2.4
Asset management Decision-Support Tool
KPIs, Stakeholders, Multi-Criteria Decision Analysis
Energy
% energy saving compared to pre-renovation
Optimal use of RES, etc.
Cost
% cost saving compared to traditional renovation method
TCO, Capex, Opex, Revenue, RoI
Exploitation value
Added value of renovation or functional transformation
Added value for monument / heritage conservation

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BIM parametric modeller, Deliverable Report D2.2 P2ENDURE
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Microsoft – SharePoint, Content management, document management, workflow management and web content management software
https://products.office.com/enGB/sharepoint?legRedir=true&CorrelationId=461ba077-b342-4c98-8c6d-e2f995c6a145

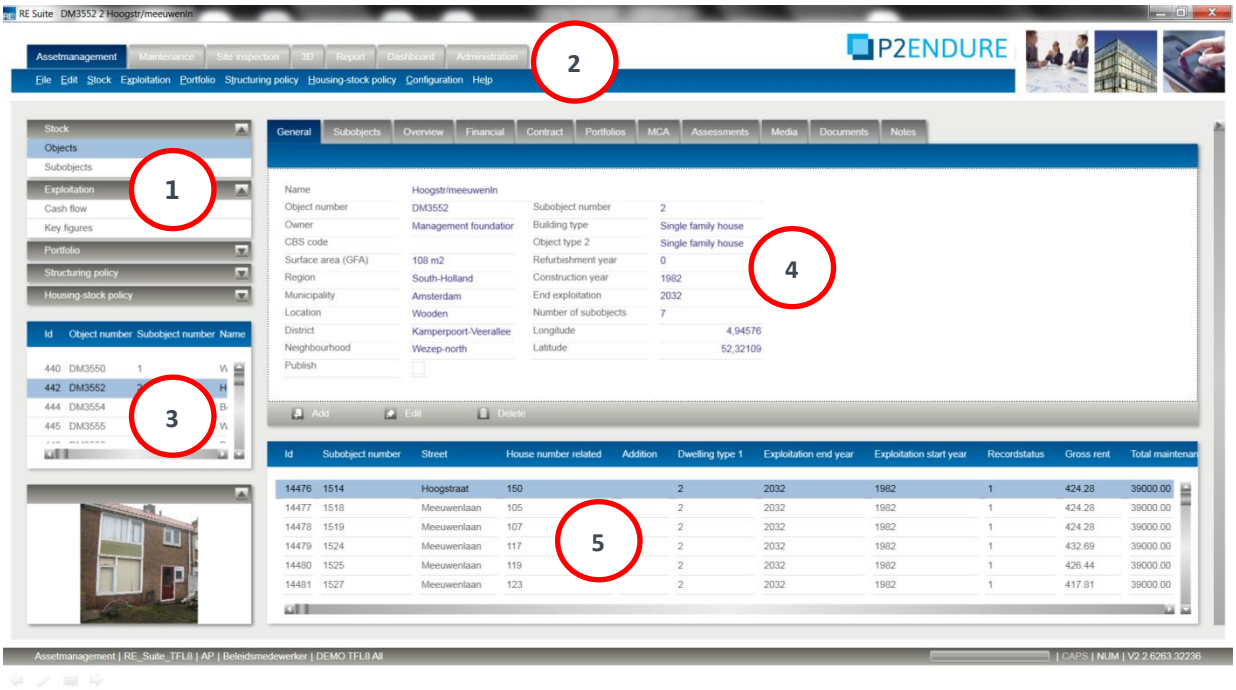
Interface (computing)
https://en.wikipedia.org/wiki/Interface_(computing)

APPENDIX 1 – User manual of the inspection tool

This is the first version of the user manual that will be adjusted according to the comments from the project partners and inspectors during and after performing building condition assessment of the P2ENDURE demonstration cases.

Main screen layout

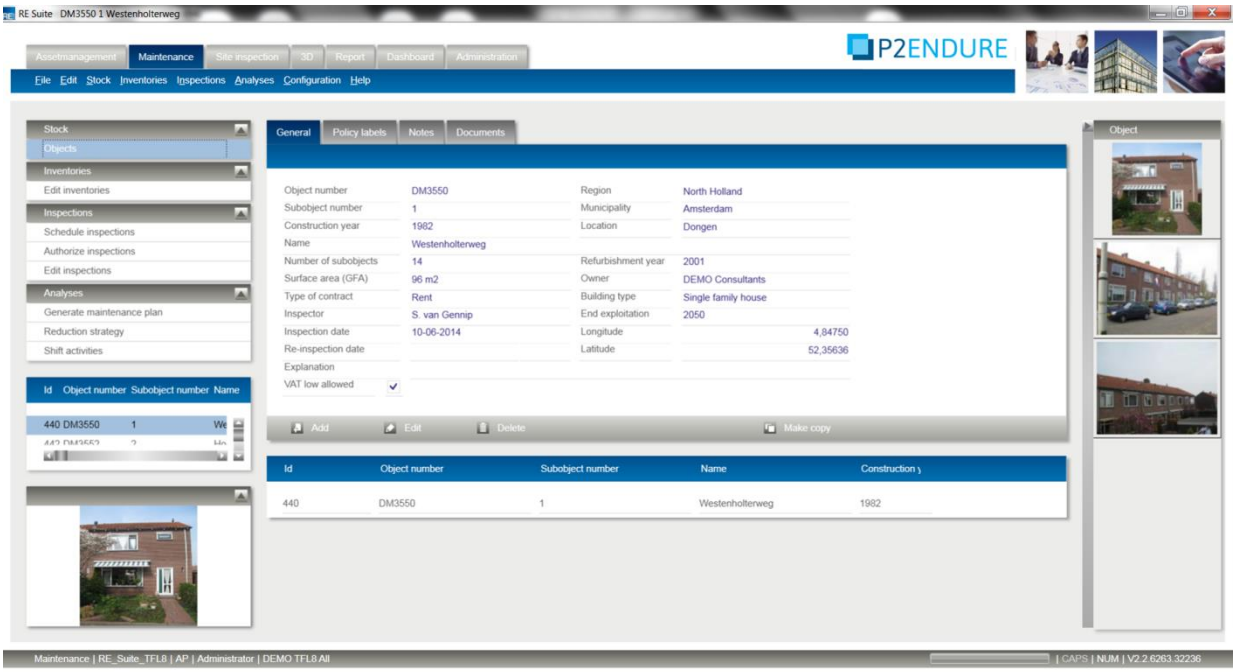
The following image shows the main screen navigation areas of the mobile inspection tool.



The main highlighted areas of the tool are:

1. **The menu bar**: the menu bar is used to switch between application modules by selecting different tabs. In the 'Maintenance' tab it is possible to manage objects, inventories, inspections and analysis. Overviews of the inspection data and maintenance schedules can be generated in the module 'Report'. In the 'Administration' tab it is possible to adjust settings and manage user accounts.
2. **The process navigator**: this control can be used to navigate through the various functions of the currently selected application module.
3. **The object navigator**: this control is used to select objects that are used within the selected process. This control can also be used to search for/filter on specific objects.
4. **The working area**: the edit panel for case definitions for the currently selected process/object.
5. **Secondary working area** (optional): a list of items contained within the currently selected object.

On the left side of the screen the process navigator contains the following categories: Stock, Inventory, Inspection and Analysis. Here you can see the list of imported/created objects, including a main picture of the selected object. The detailed information is displayed in the middle part of the screen. On the right side of the screen the photo panel appears when selecting an object. You can enlarge the image by selecting it.



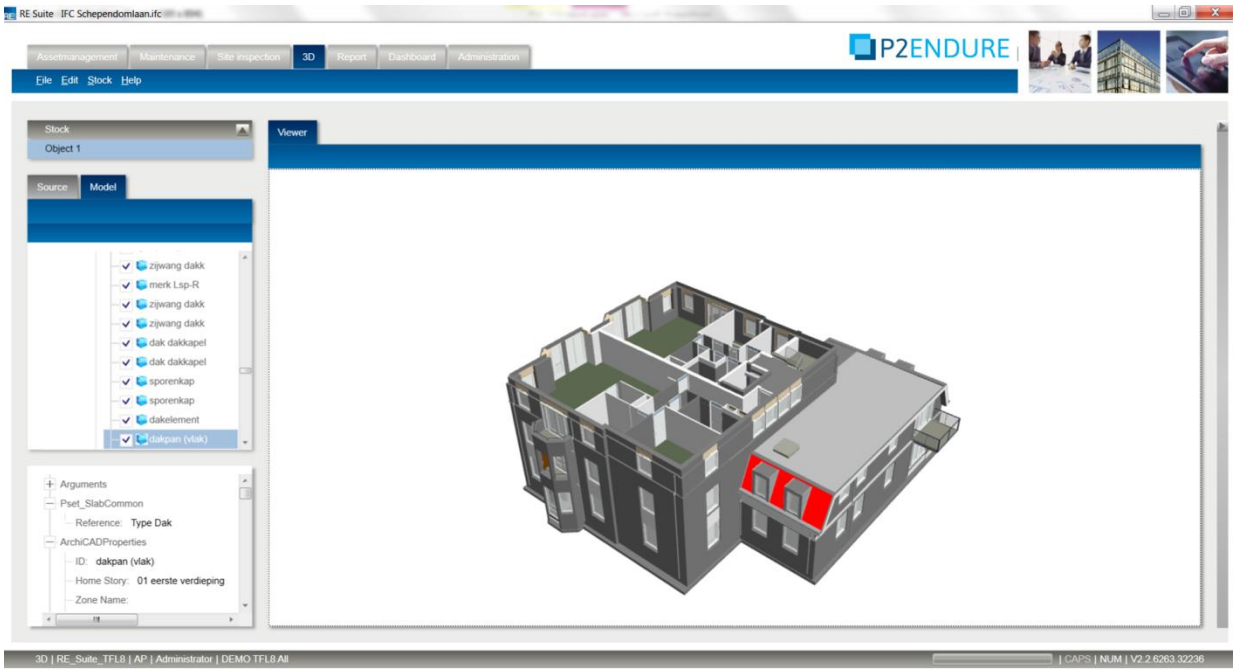
Defining project case

Date entry takes place in the Maintenance module. You can create an object and define its inventory and inspection data. The object data is managed in the process 'Object' within the 'Stock' category. The following information should be defined: inspector, region, city, location, owner, building type, policy label, property strategy, and maintenance strategy. After entering the information click 'save' to save the information.

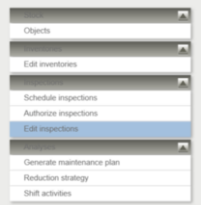
After completing filling the basic object data in, the inventory data can be added by clicking 'Edit inventories' in the 'Inventories' category. An inventory is a list of building components that are present in the selected building and it should contain at least one survey line. Click 'Save' when all the required information is entered. In the working area all the buildings and buildings components are displayed in the tabs 'Main building component' and 'Building component'. Select an object to view/edit its components.

It is also possible to copy the data (including inventory and inspection data) from an existing object by selecting the information and clicking 'Create copy'. The object can be deleted by clicking 'Remove'.

In the module "RE 3D' it is possible to open and display BIM models for a better overview of the building structure and components. There are two ways to open a BIM model using this tool: 1) by opening a locally stored model; or 2) by viewing the model directly from the data server Microsoft SharePoint. In order to view BIM models they can be uploaded to the server (model / data repository), after which they are available for viewing / use on mobile devices.
In the displayed BIM model, all building components are listed and it is possible to change the basic properties of the building components, e.g. a name or an assigned label, although it is not possible to change the geometry of the model.

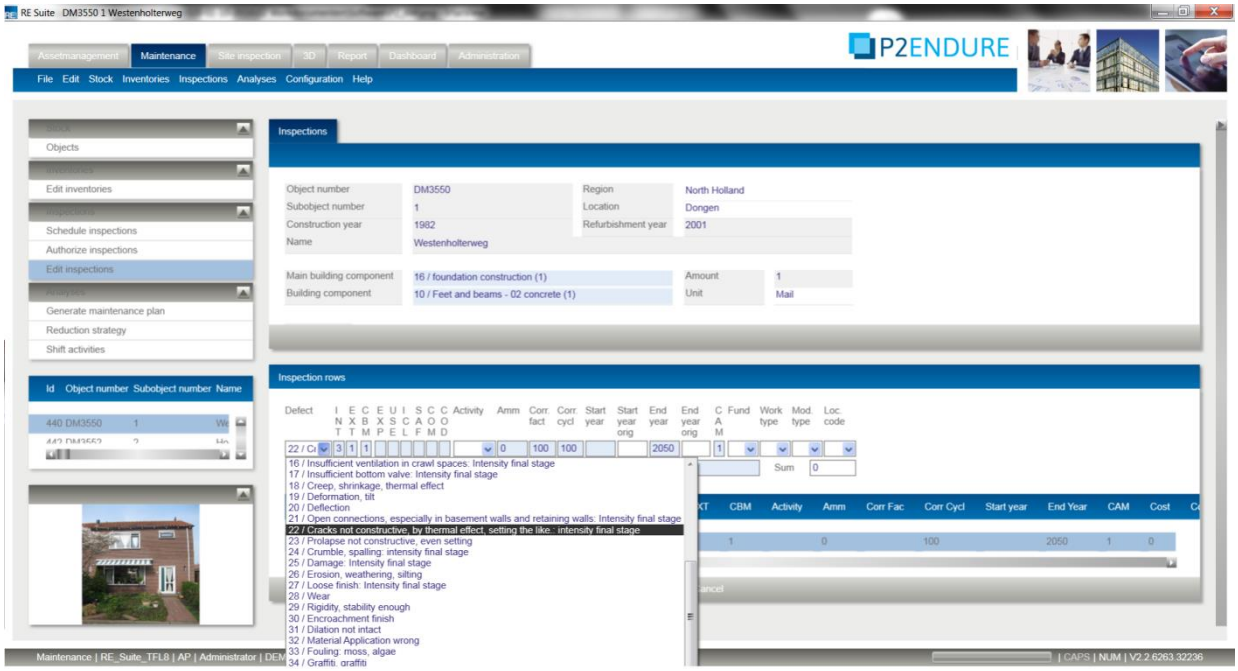


Performing inspection



Next step is to enter the inspection data by clicking 'Edit inspection' in the 'Inspection' category in the process navigator. You can select a component in the same way as when entering the inventory data. The list only shows the building components that were added in the inventory data.

The inspection data is entered using the input table (as shown in the image below). After selecting a component, click 'Add' at the bottom of the screen to enter relevant information.



Condition assessment:

- **Defect:** If applicable, specification of the defect of the building component; choose one from the list
- **INT:** Intensity of the defect in scale from 1 to 3 (see the description of the NEN 2767 in the chapter 2.1 'Methodology' of the D2.3 deliverable report)
- **EXT**: Extent of the registered defect in scale from 1 to 5 (NEN 2767)
- **CBM**: Condition of the component. The condition is calculated by the software based on the defect, intensity and extent filled in by an inspector. The scale of the component condition is from 1 to 6 based on the Dutch norm NEN 2767. The result will determine the maintenance and renovation planning.

Risk parameters:

The inspector indicates other aspects influencing possible maintenance and renovation of the building. The level from 1 to 3 needs to be specified for each aspect corresponding accordingly to: no effect, slight effect and strong effect.

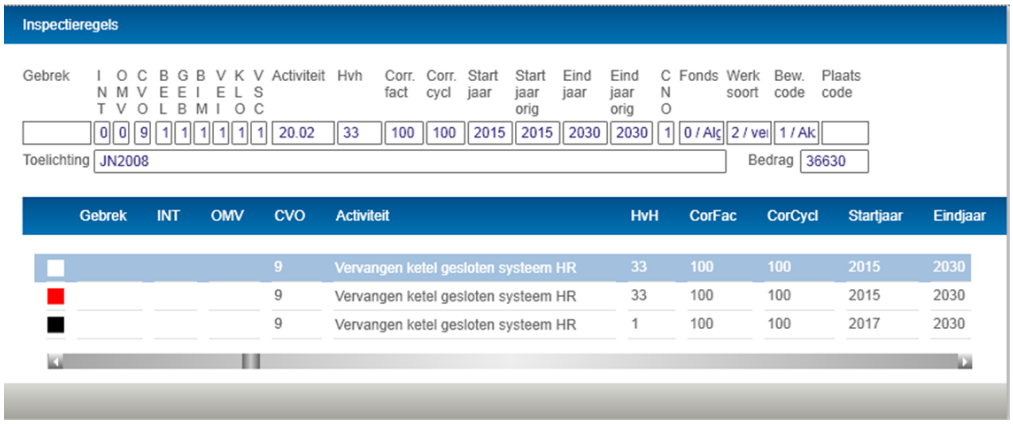
- **EXP:** Experience of user
- **USE:** Use/function of the building
- **ICL:** Indoor climate/environment
- **SAF:** Safety
- **COM**: Complaints management/service
- **COD:** Consequential damage

Other activities and parameters:

- **Activity:**The maintenance activity can be selected here.
- **Amm:** The amount/scale of the activity can be increased here.
- **Corr. fact:** The correction of the costs generated by the software.
- **Corr. cycle:** The correction of the maintenance cycle generated by the software.
- **Start year:** The beginning year of the building maintenance plan.
- **Start year orig**: In case of changes in the maintenance/renovation plan this field indicates the original starting year.
- **End year**: The last year of the building maintenance plan.
- **End year orig:** In case of changes in the maintenance/renovation plan this field indicates the original last year.
- **CAM:** Suggested condition after maintenance/renovation in scale from 1 to 6.
- **Fund**: The budget for the maintenance/renovation.
- **Work type:** Type of work for the activity, e.g. painting, carpeting, plumbing. The types of work are aligned with the organisation and can be entered in the module 'Administration'.
- **Mod. type**: Type of operation of the activity, e.g. reparation, cleaning maintenance, replacement.
- **Loc. code**: Assigning activity to selected parts or places, e.g. the activity that should be applied only to front façade but not to other parts of the building. The location codes are aligned with the organisation and can be entered in the module 'Administration'.
- **Comments:** Additional explanation of the inspection
- **Sum:** Automatically calculated cost of the activity

During the inspection on-site, photos of the building and building components can be taken and added to the object database. The images will be automatically linked to the server and available to others. The first image is chosen to be displayed in the overview of the building information.

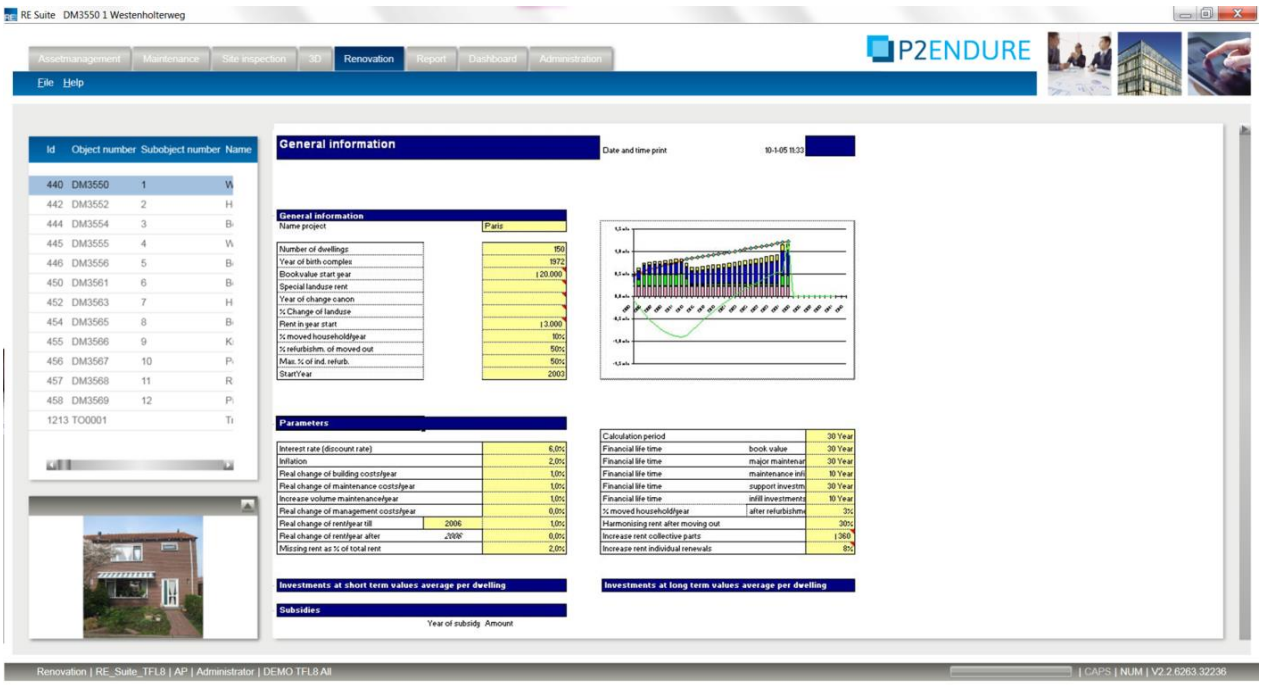
While using the mobile inspection tool the implemented new data needs to be authorised by confirming the changes at the bottom right panel of the screen. On the list of the building components, red colour indicates that the inspection is added or modified to the object, white colour – the original, unchanged component and black colour indicates that the inspector wants to remove the component from the list. By clicking 'Approve' or 'Reject' you authorise or reject the changes.



During the inspection on a mobile tool, e.g. iPad, the inspection form opens after clicking on the building. Visual inspection needs to be performed for every indicated building component by indicating the defect, from a list of possible defects, and its intensity and extent according to NEN 2767.

Upon completion of the inspection all the modified components are marked in orange colour. By tapping 'Sync' the results of the inspections, including taken photos, are synchronized with RE Suite.
If the synchronisation was successful and all the data are saved on the server, the colour is changed into green. If no internet connection is available, the synchronization can be attempted later. In such case the inspection data is stored on the iPad.

After completing the inspection and switching back to RE Suite, in the Maintenance and Renovation 'Analysis' process, the inspection data is translated into a periodic plan. The list indicating the scheduled activities is automatically generated by the software and can be customized according to own preferences. The features to save or print a report with the results can be found in the 'Reporting' module.



In the Dashboard module the collected data can be visualized in a clear way. The displayed information is automatically updated without any intervention of the user. An example of the RE Dashboard with possible visualization is shown in the following.

The possible visualizations of indicators and KPIs on the dashboard are:

- Numeric value, “petrol gauge” or traffic light to visualize one KPI.
- x/y graph to visualize two KPI’s graphically correlated.
- Spider diagram to provide a multi-indicator analysis with several KPI’s.
- Drilldown to generate a list of data modifications underlying the calculation of an indicator. This list can be filtered, sorted and capped for the first x data changes.
- Trend graph to indicate the change of an indicator of KPI value in the last/defined period.

APPENDIX 2 – Parameters for building analysis

(Reference: ENDIS project http://endis.nl)

A	**General**
	General information • Address • Size, location, orientation of the plot • Year of construction • Dimensions L x W x H • Number of floors • Roof shape, e.g. flat or angled • Types of porches, galleries and balconies • Elevators, lifts and possibility of implementing a lift in a building • Function per floor
B	**Ambitions/ potential**
	Ownership • Owner and his/her aspirations/interests regarding the building renovation • Ownership status (leasehold) • Financial possibilities • Environmental ambitions, e.g. energy efficient, bio-based, circular Economy • Value of the building • Expected economic, technical and functional lifespan • Desired economic, technical and functional lifespan Urban planning • Opportunities and possibilities to improve urban situation/quality • Flexibility of the zoning/land use plan • Possible extensions of the building • Allowed building heights (impact on visibility and shadows) • Condition of the location, parking and public facilities Monumental status • Historical, cultural heritage value • Cultural importance, architectural values, history and name of the architect • Monumental status

	• Constraints in renovation Function • Possible improvements of the building and its function • Possibilities and restrictions for new functions • Possible improvements of the area • Potential target users • Tendencies in the area development, e.g. demographic trends Quality and comfort • Complaints and objections from the residents, users, or the owner • Current and desired function of the ground floor areas • Current and desired energy consumption
C	**Area, building, function analysis**
	Sound • Quality of sound insulation against noise within the building, e.g. of the ventilation system • Quality of sound insulation against outside noise Building materials and components • Possible reuse of the building components/materials • Life cycle analysis (LCA) • Floor and floor area • Façade (including orientation) and façade surface area • Condition, defects of the building materials and components • Occurrence of asbestos • Glass and glass surface area • Window frames • Ceiling – materials and finishing • Non-load bearing interior walls • Door openings • Insolation • Lighting system and energy consumption (possible replacement) Construction, building system • Available documents, drawings, CAD files, BIM model • Calculations of, e.g. floor load • Type and condition (stability) of the construction • Foundation (maintenance period, condition, quality) • Floors

- Walls (load-bearing and non-load-bearing)
- Roof
- Facades
- Balconies and galleries
- Floor heights, headroom, maisonettes (differences in heights per floor)

Installations

- Heating and cooling system
- Ventilation system
- Cold and hot water system
- Shafts and down pipes
- Chimneys

Implementation

- Accessibility for building vehicles and equipment, e.g. crane, truck
- Selection of a crane: weight and dimensions of the load, need for special lifting equipment, e.g. slings, height above the ground where the load should be placed, space restrictions for accessibility of the crane

Environment

- CO2 emission
- Life-cycle assessment (LCA)
- Ecological footprint

APPENDIX 3 – Measures for sustainable renovation

(Reference: ENDIS project http://endis.nl)

	A. District/ area	B. Building	C. Dwelling
1. Architecture & urban scale	A.1.1. Public space • Possible improvements (public facilities) A.1.2. Infrastructure • Possible improvements of infrastructure • Possible improvements of parking facilities • Underground waste containers	B.1.1. Building plinth • Storage rearrangement • Functional changes regarding plinth • Ground floor functional requirements B.1.2. Splitting/merging • Splitting apartments • Merging vertically • Merging horizontally B.1.3. Vertical access • Implementing lifts B.1.4. Adding space • Adding space horizontally (additional storey) • Adding space vertically (outbuilding) B.1.5. Entrance • Entrance refurbishment B.1.6. Fire safety • Fire resistance (60min) B.1.7. Maintenance • Painting	C.1.1. External elements • Closing a balcony • Adding a balcony • Enlarging a balcony • Loggias C.1.2. Bathroom, toilet, kitchen • Refreshing or renovating C.1.3. Other interior spaces • Floating screed • Interior renovation C.1.4. Fire safety • Smoke detectors C.1.5. Maintenance • Renovating/restoring stucco • Renovating/restoring windowsills • Renovating window and door frames

2. Comfort	A.2.1. Greenery • Improving greenery • Adding greenery A.2.2. Lighting • Improving public lighting	B.2.1. Greenery • Green roof • Roof garden • Green façade B.2.2. Safety • CCTV • Video intercom • Lighting at entrances, porches	C.2.1. Daylight, direct sunlight • Outdoor blinds C.2.2. Indoor quality • Adjustable temperature • Energy monitor • Home automation • Electricity points C.2.3. Acoustic • Sound insulation against noise within the building • Sound insulation against outside noise
3. Construction		B.3.1. Foundation • Strengthening the foundation B.3.2. Stability • Improving structural stability B.3.3. Maintenance • Refurbishing degraded concrete	C.3.1. Stability • Improving floor stability
4. Insulation		B.4.1. Wall insulation • Installing wall insulation • Reparation/replacement of external wall insulation B.4.2. Insulated glazing • Replacing glass with double/triple glazing • Restoration of existing frames B.4.3. Roof and floor insulation • Installing roof and floor insulation	C.4.1. Internal insulation • Installing internal wall insulation • Reparation/replacement of internal wall insulation

5. Installation	A.5.1. Underground infrastructure • Reparation/ replacement of sewer system • Grey water system A.5.2. Heat & cold generator • Geothermal energy • Thermal storage system • District heating • Industrial heat usage A.5.3. Generating electricity • PV panels at district level • Wind energy at district level A.5.4. Water management • Drainage system • Water surface buffer • Rainwater infiltration	B.5.1. Infrastructure • Vertical pipe shafts B.5.2. Heat & cold generator • Pumped-heat thermal storage • Biomass at building level B.5.3. Generating electricity • PV panels at building level • Wind energy at building level B.5.4. Ventilation • Collective ventilation system B.5.5. Maintenance • Reparation/replacement of drain pipes • Asbestos removal, disposal and replacement • Cleaning ventilation ducts	C.5.1. Infrastructure • Renewing electricity system • Renewing gas pipes C.5.2. Heat & cold generator • Individual air-source heat pump C.5.3. Generating electricity • PV panels on façade C.5.4. Ventilation • Individual mechanical extraction ventilation • Individual balanced ventilation system C.5.5. Release of heat • Radiators • Underfloor heating • Wall heating • Ceiling heating • Individual hot water supply