P2ENDURE
PLUG & PLAY BUILDING RENOVATION

Validation report of reduced disturbance for inhabitants during renovation

Deliverable Report D3.5

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Colophon

Publishable executive summary

P2ENDURE promotes evidence-based innovative solutions for deep renovation based on prefabricated Plug and Play (PnP) systems. The primary objective of this deliverable report is to present a new method for the disturbance assessment in the renovation process and possible strategy of its reduction. The techniques mainly used to collect the required information are questionnaires for building's end-users and on-field measurements of environmental quantities derived from the on-site renovation works (e.g. particular matters). The document presents also the metrics developed to assess the disturbance through dedicated Key Performance Indicators (KPIs).

The presented methodology will be applied during the retrofit of the occupied P2ENDURE demo cases. A complete analysis of results will be achieved when all the renovation activities on those buildings will end.

List of acronyms and abbreviations

BIM: Building Information Model

IAQ: Indoor Air Quality

IEQ: Indoor Environmental Quality

KPI: Key Performance Indicator

PM: Particulate Matters

PnP: Plug and Play

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1. INTRODUCTION

1.1 Objectives

P2ENDURE project proposes a set of innovative technologies and solutions to support and optimize the overall renovation process, from mapping to monitoring:

- PnP prefabricated envelope components: e.g. Multifunctional panels, smart windows, rooftop retrofit module (described in deliverable D1.1),
- PnP technical systems: e.g. PnP Heating, Ventilation, and Air Conditioning (HVAC) systems, modular bathroom module, smart connectors (described in deliverable D1.3),
- On-site 3D technologies: e.g. 3D scanning, 3D printing/robotics, Comfort Eye (described in deliverable D1.5).

So as to evaluate the effectiveness of a solution, multiple parameters are analysed: from the cost reduction, to the improved inhabitants' comfort. Together with them, one of most important aspect in the task T3.3 is to analyse the disturbance for end-users and its minimization. In fact, it is expected that PnP solutions can reduce the impact of construction activities for deep renovation (e.g. no need to abandon the building, reduced time etc.). To assess this aspect, the level of occupants' disturbance will be evaluated through the verification of installation time and space together with users comfort during renovation works. The most of the disturbance assessment will be performed through surveys applied to the inhabitants. This document presents the complete methodology form data collection to KPIs calculation. Results from the field application to determine the real disturbance reduction will be analysed after that the renovation will take place in the demo cases.

1.2 State of the art

During the renovation processes, there are many situations which may release contaminants and pollutants that can impact on the IAQ for the inhabitants. Moreover, there are many other factors that can create a disturbance for people inside the building. Unfortunately, there are few examples of disturbance assessment in literature that is specifically applied to deep renovation works. [1] and [2] present a new approach of evaluating renovation alternatives taking into account, among others, the disturbance aspect for end users. [3] is introducing a "social KPI" in building renovation that considers the safety of the work area and the sensation of unease for the inhabitants. The approach presented in [4], which was developed by the FP7 PANTURA project, proposes a set of indicators for the safety of residents and for the noise, dust and waste generation, but during a bridge reconstruction.

The previous researches lay the foundations of which elements have to be taken into account for a disturbance analysis in the P2ENDURE scenario, but a new methodology has to be developed to be applied to PnP deep renovation process.

2. Scope

A good building renovation process should not affect significantly the normal life of the residents. This can consider both the possibility to continue living in the same building with some disturbance and to move somewhere temporarily. The more the technologies applied to the retrofit are Plug & Play, the less disturbance will occur in most of the cases.

Having inhabitants in the building during the retrofit process, can lead to:

- **Environmental hazards**. Some of the processes and techniques applied to most of the renovation processes can be harmful for a non-trained person that remains close to the work area. This can be toxic compounds dispersed in air (e.g. asbestos fibers, lead-contaminated debris, fumes from heavy machinery, molds) or harmful noise exposure.

- **Disturbance.** Even if the retrofit process does not affect the inhabitants' safety, it can affect the normal life and even the productivity if the building hosts a commercial activity.

Given that the environmental hazards are considered and regulated by each EU nation's legislation, it is important to assess the disturbance part, so as to evaluate the effectiveness of the P2ENDURE PnP solutions.

3. Methodology

The methodology for the disturbance evaluation has to take into account:

- Different end uses of the building, that can lead to maximize or minimize the disturbance level (e.g. retrofit activities during normal work hours can more affect offices and schools rather than residential units);
- Different methods for assessing the indicators (Surveys, long term measurement, spot measurement);
- Consider if the building is normally occupied or not.

So as to collect all the required information, we have chosen two methods: surveys and measurements.

The Table 1 shows the information required and the assessment method.

Table 1: Information required for the disturbance assessment.

Variable	Comments	Assessment method
Safety of residents	The safety sensation of each inhabitant can be subjective and can affect the normal behaviour.	Surveys
Noise and vibrations	Maximum noise emission in work area is regulated by the state's legislation, however, even below this threshold it can affect the normal life of inhabitants.	Surveys
Dust emissions (particulate matter)	PM 2,5 Annual mean: 25 µg/m3 PM 10 24h mean: 50 µg/m3 Annual mean: 40 µg/m3	Spot (or long term) measurement
Total time for construction activities outside the building	Amount of time for construction activities outside the building.	Surveys
Total time for construction activities inside the building	Amount of time for construction activities inside the building.	Surveys
Surface occupied by the construction activities	Amount of surface occupied for construction activities and related ones.	Surveys
Generation of waste: Waste treatment and disposal	Mass of waste in the building (To be defined)	Surveys

3.1 Survey part

The main assessment method shown in Table 1 is to perform surveys. The questions will be posed to the inhabitants and, optionally, to the retrofit workers through a service like SurveyMonkey and results will be saved in the SharePoint.

Table 2: Questions for the disturbance survey

Category		Question	Answers
Basic information	1	**Write / choose the name of the building**	Open answer or Combobox with the name of all P2Endure demo cases
	2	**Define your interaction with building**	• Resident (W_1=1); • Habitual worker (W_1=1); • One-time worker (W_1=0.3); • Guest (W_1=0.3);
	3	**Define how much time do you spend in the building**	• Less than 3h a day (W_2=0.2); • From 3h to 6h (W_2=0.5); • More than 6h (W_2=1);
Questions for the occupants	4	**Evaluate if there are some retrofit activities that can be dangerous for you.**	(0 no danger, 1 light danger, 2 medium danger, 3 high danger)
	5	**Evaluate how often you are feeling in danger during the retrofit activities.**	(0 never, 1 rarely, 2 sometimes, 3 often)
	6	**Evaluate how often you feel disturbed by the vibrations are caused by the retrofit activities.**	(0 never, 1 rarely, 2 sometimes, 3 often)
	7	**Evaluate how often you feel disturbed by the noise caused by the retrofit activities.**	(0 never, 1 rarely, 2 sometimes, 3 often)
	8	**Evaluate how often you feel disturbed by the dust caused by the retrofit activities.**	(0 never, 1 rarely, 2 sometimes, 3 often)
	9	**Evaluate how often you feel disturbed by unpleasant odour caused by the retrofit activities.**	(0 never, 1 rarely, 2 sometimes, 3 often)
Question for the construction company	10	**Amount of time for construction activities outside the building.**	[Hours]
	11	**Amount of time for construction activities inside the building.**	[Hours]
	12	**Percentage of working hours performed in the period when building is occupied.**	[%]

13	**Amount of surface occupied for construction activities and related ones.**	[m^2]
14	**Mass of waste in the building (To be defined)**	[kg]

This part of the methodology proposes 14 questions with multiple choices or open answer:

- Questions 4÷9 are the main core of the questionnaire: they are 6 simple question with a score from 0 to 3. In all of this part, the more is the score, the more is the disturbance sensation. The total score of this part (S) can be from 0 (minimum disturbance) to 18 (maximum disturbance).
- Questions 2÷3 define the weight for the index definition. They take into account at what type of end user is applied the survey. The more the building is linked to the interviewed person, the higher is the weight of the answer. The total weight is calculated in $W = W_1 \cdot W_2$.
- Questions 10÷14 are optional open answers for comparing disturbance assessment between different buildings. These questions can be asked only to the building owner or the company performing the renovation.

Given *n* the number of questionnaires applied to a single building or part of it, the index derived from this methodology can be defined as:As defined,

3.2   Measurements

The only measured parameter in Table 1 is the Particulate Matters (PM). Particulate matters can be originated by multiple activities: from the heavy machinery fumes, to the dust due to the debris movements and other various machineries. PM concentration during a certain period is a good index of how heavy the retrofit work is. The less are the PM concentration and, usually, the less invasive are the works. UNIVPM built a system based on an optical sensor coupled with a Linux-based datalogger that can be placed in an occupied room so as to log this parameter for the whole duration of the retrofit process.
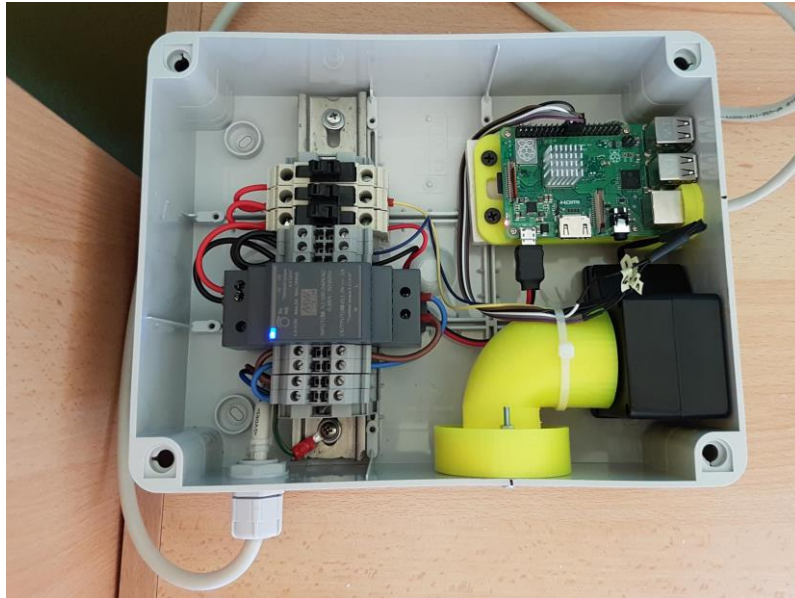
The EU directives, set two thresholds in base of the particle's diameter (Table 3) and from them, can be derived a PM index that is the *number of hours in a day when one of the PM concentration exceeds the limits*.

Table 3: Limits on particulate matters concentration in air

Mean particle diameter	EU directives Limit	Limits for KPI_{pm}
PM2.5	Annual mean: 25 µg/m^3	Hourly mean: 30 µg/m^3
PM10	24h mean: 50 µg/m3	Hourly mean: 45 µg/m^3
	Annual mean: 40 µg/m3	

Calculation method

The calculation method is very similar to the one used in the P2ENDURE thermal comfort assessment. Basically, we want the percentage of hours in which PM concentration trespass our imposed limits. The calculation is very simple:

1. For each considered room in the building, calculate the hourly average of PM10 and PM2.5 concentration.
2. Count how many hours each day have a PM concentration outside the limit exposed in Table 3 (h_{out10} and $h_{out2.5}$).
3. Calculate the following daily indexes and average them for multi-day monitoring.

3.3 Potential reduction of disturbance in P2ENDURE solutions

The P2ENDURE solutions are expected to have impact on the disturbance reduction during the renovation process. In fact, PnP solutions are characterized by a higher amount of activities off-site (in the factory) and less on site, reducing the impact in terms of time, space and need of local construction activities. In particular:

- Fermacell PnP façade panels. They can reduce the amount of work inside the building, because the modules are built inside a factory. Using them instead of building a normal brick wall can lead to a faster installation work and less dust dispersed in air. In fact, one of the most dust-generating process is to prepare the concrete and cut bricks and other construction materials. The other advantage is that the area permanently occupied by the work activities, can be less, due to the lower need of stockpile construction materials and machines. The last advantage is to include in the panel part of the HVAC system, so as to not have the need of cut a big part of the needed ducts inside the walls.

- Modular prefab bathroom and kitchen units. Similar to the Fermacell prefab panels, can be used bathroom and kitchen units built in off-site. In the Enschede demo site, has been installed several modules of them, leading to a faster and cleaner installation.

- Detailed BIM model with 3D scanning. Due to the fact that the BIM model contains all the building details, collision and interference can be solved before the real construction process, so as to reduce the work time and the linked disturbance.

4. Conclusions

This Deliverable presents the methodology for disturbance assessment during a building renovation activity that will be applied in the P2ENDURE demo cases so as to evaluate the effectiveness of the renovation solution. Some of the P2ENDURE solutions could help the disturbance reduction in a renovation process with inhabitants, especially the solutions that reduce the on-site work as much as possible. In fact, prefabricated components, like panels with embedded insulation and MEP, accelerate and simplify the installation phase. The methodology presented in this deliverable allows the assessment of the amount of disturbance that the renovation work causes, making use of both subjective and objective investigations. The entire methodology, from data collection to KPIs calculation, will be applied to the demonstration cases during the renovation process.

References

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