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Old buildings, new cities: Analysis of Brussels' Leopold quarter building typologies as a driver to identify optimal retrofitting strategies

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ABSTRACT: In Europe, several studies show that prolonging the life of a building has lower environmental impact than demolishing and building a new one. Retrofitting of residential buildings provides thus a considerable potential in energy conservation and sustainability benefits. But retrofitting an old house is a delicate process. This paper stresses the role of energy efficiency retrofitting of old dwellings in Brussels as the key element to achieve the European Union (EU) energy efficiency targets. The approach of this study is to conceive the buildings as a stock rather than individual entities, by developing a preliminary classification by construction system and building components. This approach seeks to contextualize the heritage value, by the identification of the elements that define it, and to achieve holistic improvements of the energy performance of the whole stock in order to highlight the importance and relevance of retrofitting the old residential building sector.

The result is a series of scenarios that supposes a first step of the aimed methodology to identify in an early stage the best solutions for this specific part of the building stock to achieve the energy efficiency targets defined by the Energy Performance of Buildings Directive (EU, 2010).

Keywords: Old Building stock; energy efficiency retrofitting; Heritage value; renovation; dwelling retrofitting.

1 INTRODUCTION

Studies have concluded that a deep renovation is the ideal solution from an ecological and economic perspective, and that surface renewals only contribute to increasing the risk of losing the set climate targets and not exploit the potential total savings (Müller, 2011). The urban fabric

of European cities is largely shaped by old and inefficient residential buildings whose energy demand can exceed 200kWh / m² per year (Economidou et al., 2011).

Retrofitting the existing stock of housing is recognized in the construction industry. The number of existing buildings exceeds the number of new homes. In United Kingdom, the number of new buildings was calculated to contribute at most 1% per year to building stock (Gaterell and McEvoy, 2005), the other 99% are already built buildings and produce about 26% of carbon emissions induced by energy use (Eurostat, 2009). Studies show that the environmental impact to extend the life of a building is definitely less than demolition and new construction (Filer, 2008). Hence, retrofitting of residential buildings in particular provides considerable potential in energy conservation and sustainability benefits later.

However, although the need for integrated solutions to maintenance and renovation is well known by the construction sector actors, no need for specific knowledge on how and when to apply successfully the maintenance, management, adaptation, transformation and redesign is defined (Thomsen, 2011). Moreover, many vital decisions are taken in the early stages of the design process that can determine the success or failure of the design, as a decision made earlier can have a bigger impact with less effort. Designers need tools that help them to create better and more sustainable rehabilitation projects (Konstantinou, 2014).

This study seeks a methodology to support decision-making and enable the development of a retrofitting strategy for different cases and specifications. It is intended that the designers know the energy impact of the project according to the solutions adopted.

2 DECISION MAKING PROCESS

Depending on the rehabilitation objectives required in each case, various solutions could be found. The aim is not to give an optimal solution but to help (Economidou, 2011) make right choices without compromising the interests of the designer, client or user. To this end, the so called matrix TCS (TCS stands for Typology, Component, Solution) is defined. This matrix aims to gather all the measures that could be applied in the retrofitting of the defined stock, sorted by building typology and main building components. The target is to offer different retrofitting solutions and their overall impact in the decrease of energy demand. The measures provided are all extracted from previous retrofitting interventions from literature review. The TCS matrix aims, though, to improve the design process by providing retrofitting strategies for different building typologies and specific configurations, without limiting the designer choice.

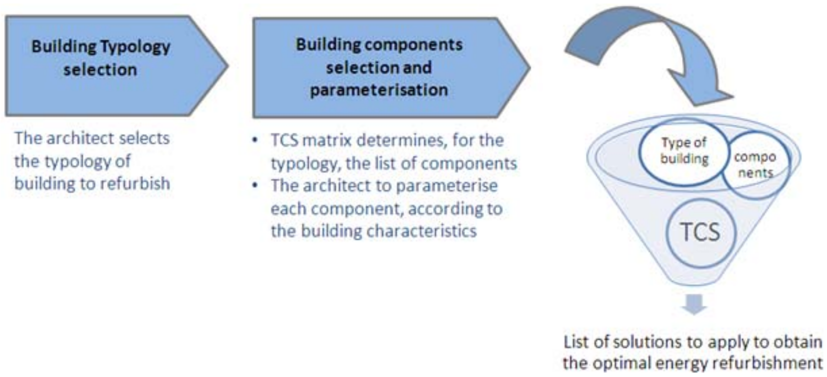


Figure 1. Concept of Optimal Retrofitting

In future steps, the retrofitting strategies and their energy efficiency value are expected to be complemented with an economic evaluation to help the designers to provide the cost-optimal retrofitting to clients while obtaining the expected new energy performance.

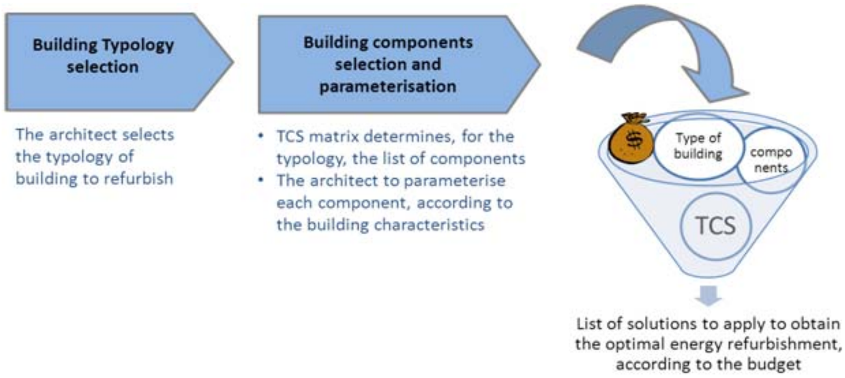


Figure 2. Concept of Cost-Optimal Retrofitting

3 HISTORIC RESIDENTIAL BUILDING: STATING THE PROBLEM

Building retrofitting could be considered as one of the most culturally enriching architectural strategies, as the expression of different historic periods makes the built environment much richer. Reusing existing buildings can be, thus, an efficient way of spreading culture, to which respect to previous interventions is necessary (APUR, 2013).

Common practice in the retrofitting of old buildings is based on the improvement of the envelope. It is the first step when updating these buildings, which are generally the un-insulated heavyweight constructions. Modern construction techniques have to be carefully applied to old buildings, which have a delicate thermal balance. Yet, old dwellings have severe drawbacks that prevent them from good environmental performance: poor daylight, high-energy consumption or limited opportunities for natural ventilation are common characteristics of the housing type (3ENCULT, 2013).

Old buildings might seem an improbable target for development of energy efficiency dwellings. However, the scope for improvement is certainly large and the benefits of their preservation go beyond mere technical considerations. On the one hand, they are valuable constructions that might be especially protected due to their strong link to city identity. On the other hand, they are buildings whose inadaptability to current demand can be a threat to their preservation.

Nowadays, to reduce the energy demand in buildings is translated, in the existing building stock, in the implementation of renovation solutions stipulated in the different regulatory frameworks. The Directive of the European Parliament and Council on the Energy Performance of Buildings (EU, 2013) imposes to the member states to adopt tools to calculate the energy performance, to apply minimum regulation on energy performance in the renovation works, to certificate the buildings and to assure the control of the heating and cooling systems.

The implementation of these interventions in the ancient building stock is facing numerous problems that need to be evaluated to obtain the expected reduction in the energy demand. In fact, the impact of these measures has not yet been assessed at a large scale, as no data from previous interventions is available.

3.1 Building typologies catalogue

This paper focuses on the study of the context and the identification of the main characteristics that are common to the old dwelling stock of Leopold quarter in Brussels, linked to their energy performance.

The first task to be accomplished is to define this specific building stock. The methodology proposed is based in the description of the components that characterize each typology and gather them in the form of a catalogue. The first problem encountered while defining the study was that there was not an official list of the building types of the area, so it has to be created. What was a problem in the beginning, resulted to be an interesting approach to classify and map

historic building stocks.

Beginning with a literature review that thoroughly defined the building typology, and the data extracted from the Brussels Cadastral matrix, the dwelling typologies are defined according to their general description (Situation/implantation, Spatial organization, Inner circulation and staircase, building systems and materials, roof and building materials and façade and building materials) and its main geographical characteristics (disposition in relation to the road, size of the plot, volume, floor level, number of floors, annexes...)

With the help of Python® software, a list of the building typologies was defined as well as its percentage over the overall of the typology in Brussels (Figure 3).

Type	Nb Buildings	Building typology - Extension East	Percentage over the whole BCR
1	8	*Maison Bourgeoise* Neo-Clasical	0.29%
2a	774	*Maison Bourgeoise* with *bel étage* (1 dwelling)	3.89%
2b	1032	*Maison Bourgeoise* with *bel étage* (>1 dwelling)	4.97%
3a	254	*Hôtel de Maître* or *Hôtel particulier*	5.81%
3b	55	Maison de rapport	4.73%
4a	48	Modest House before 1919	0.56%
5	47	Appartment building	3.31%
TOTAL	2218		

Figure 3. Number of buildings by typology. Extension East of Brussels.

With the help of ArcGis® mapping tool, is the first time that the typologies integrating the neighborhood have been mapped, being considered the first interesting outcome of this study. (Figure 4)

The dwellings fall under two big periods :

From 1830 to 1914: predominance of individual housing (small, bourgeois and aristocratic), whose spatial organization will be based on the spatial organization of the "maison bourgeoise".

From 1920 to 1930: emergence of apartment building (building modest, standard and / or high status) that takes his real development after 1930.

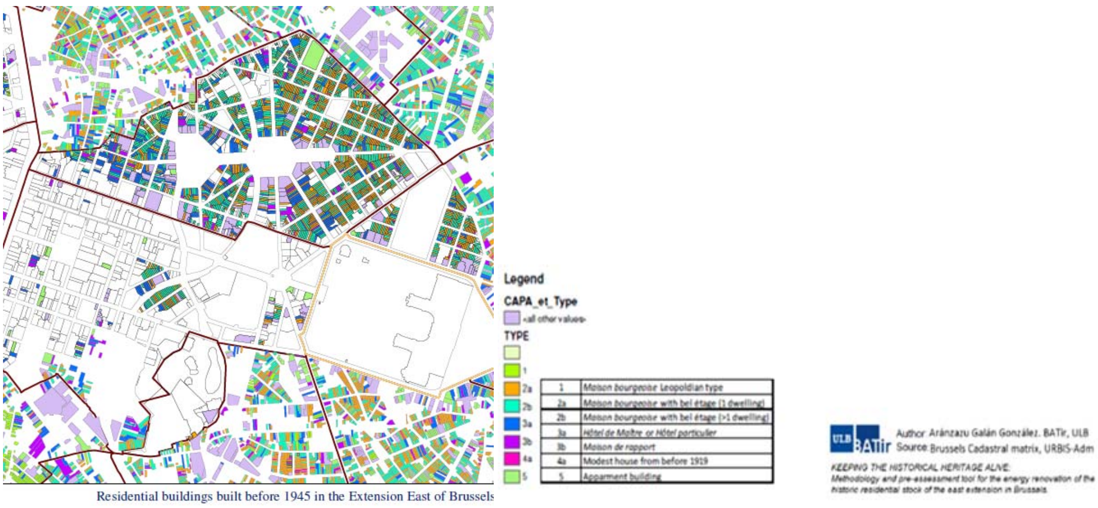
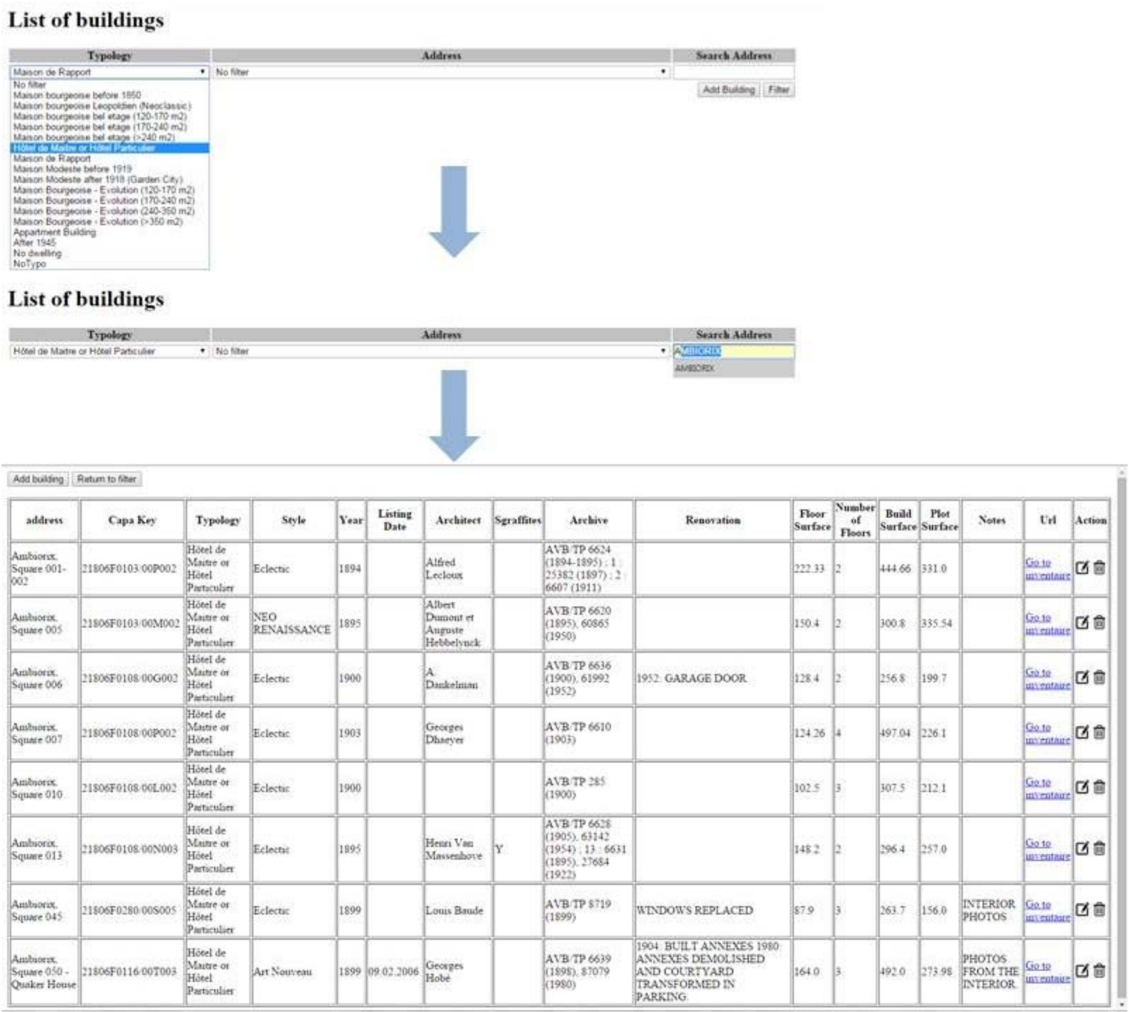


Figure 4. Map of Building typologies of Leopold Quarter

The hypothesis of this paper is that by a deep analysis of the building typologies, the designer could have a better understanding of the particularities of the stock. After the building stock definition, a more practical approach is required. Figure 5 shows the tool developed in this research to classify all the dwellings embodied in the studied building stock. Even when the retrofitting measures will be developed for the whole stock, all the buildings of the area are classified using GIS tools. This will enable the implementation of the final database in the future.

The filters system, allows an easy comparison of the dwellings facilitating the selection of those that will be consider as case of study.

Maps of every individual topic could be provided, depending of the interest of the user, as well as individual databases.



address	Capa Key	Typology	Style	Year	Listing Date	Architect	Sgraffites	Archive	Renovation	Floor Surface	Number of Floors	Build Surface	Plot Surface	Notes	Url	Action
Ambiorix, Square 001-002	21806F0103/00P002	Hôtel de Maitre or Hôtel Particulier	Eclectic	1894		Alfred Lecloux		AVB/TP 6624 (1894-1895) : 1 ; 25382 (1897) : 2 ; 6607 (1911)		222.33	2	444.66	331.0		Go to inventaire	
Ambiorix, Square 005	21806F0103/00M002	Hôtel de Maitre or Hôtel Particulier	NEO RENAISSANCE	1895		Albert Dumont et Auguste Hebbelynck		AVB/TP 6620 (1895), 60865 (1950)		150.4	2	300.8	335.54		Go to inventaire	
Ambiorix, Square 006	21806F0108/00G002	Hôtel de Maitre or Hôtel Particulier	Eclectic	1900		A. Dankelman		AVB/TP 6636 (1900), 61992 (1952)	1952: GARAGE DOOR	128.4	2	256.8	199.7		Go to inventaire	
Ambiorix, Square 007	21806F0108/00P002	Hôtel de Maitre or Hôtel Particulier	Eclectic	1903		Georges Dhaeyer		AVB/TP 6610 (1903)		124.26	4	497.04	226.1		Go to inventaire	
Ambiorix, Square 010	21806F0108/00L002	Hôtel de Maitre or Hôtel Particulier	Eclectic	1900				AVB/TP 285 (1900)		102.5	3	307.5	212.1		Go to inventaire	
Ambiorix, Square 013	21806F0108/00N003	Hôtel de Maitre or Hôtel Particulier	Eclectic	1895		Henri Van Massenhove	Y	AVB/TP 6628 (1905), 63142 (1954) ; 13 : 6631 (1895), 27684 (1922)		148.2	2	296.4	257.0		Go to inventaire	
Ambiorix, Square 045	21806F0280/00S005	Hôtel de Maitre or Hôtel Particulier	Eclectic	1899		Louis Baude		AVB/TP 8719 (1899)	WINDOWS REPLACED	87.9	3	263.7	156.0	INTERIOR PHOTOS	Go to inventaire	
Ambiorix, Square 050 - Quaker House	21806F0116/00T003	Hôtel de Maitre or Hôtel Particulier	Art Nouveau	1899	09.02.2006	Georges Hobé		AVB/TP 6639 (1898), 87079 (1980)	1904: BUILT ANNEXES 1980: ANNEXES DEMOLISHED AND COURTYARD TRANSFORMED IN PARKING	164.0	3	492.0	273.98	PHOTOS FROM THE INTERIOR	Go to inventaire	

Figure 5. Building catalogue tool

3.2 Scenarios of Sustainable retrofitting

All the seven typologies integrated in the neighbourhood are studied and simplified in schemas that highlight, in a first step, the typology characteristics. As an example, the "Maison Bourgoise" is selected. This typology is characterised by a plan with two or three rooms in a row and 4 or 5 floor levels.

An example of this representation system is given below (Figure 6). All this methodology is focused to built the layout of the tool that will offer a friendly front-end to the user that could quickly identify the typology he is working in. The special features of each building will be identified in ulterior combos, so the dwelling is fully defined.

In a second step, Critical information is gathered:

- Real-life legal situation (implying ability/inability to initiate retrofitting): owning a whole house, owning a flat in a house, owning a flat in an apartment block, owning a whole apartment block, etc. There can be different strategies depending on whether the whole or part of the dwelling could be retrofitted.

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- Legal status: is the building (or part of) listed? Different strategies would be taken into account depending on the elements that could not be changed.
- Building system typologies :
  - Materials (thickness, U values, humidity issues, air tightness, etc.)
  - Bulk and compactness (heated net volume VP, heat loss surface AT, compactness: this provides indicators in terms of big/small and possible energy conservation upgrade.
  - Orientation, m^2 of windows + useful solar gains + potential for Energy retrofitting: this provides an indicator of the Energy Retrofitting measures that could b tackled.
- For each criterion, min/max and average values will be defined (according to sample) + scenarios to maximize them in order to have a complete and holistic view of the retrofitting process.

Figure 6. Spatial definition schemas of dwelling type

Based on the description of each dwelling type and its main building components, various scenarios of retrofitting are proposed. They focus mainly on improving the energy performance of each dwelling type in a step by step methodology. Each of the scenarios is analyzed one by one including a data sheet where it would appear the energy consumption before the intervention, the cost of the intervention and the new energy consumption after the intervention.

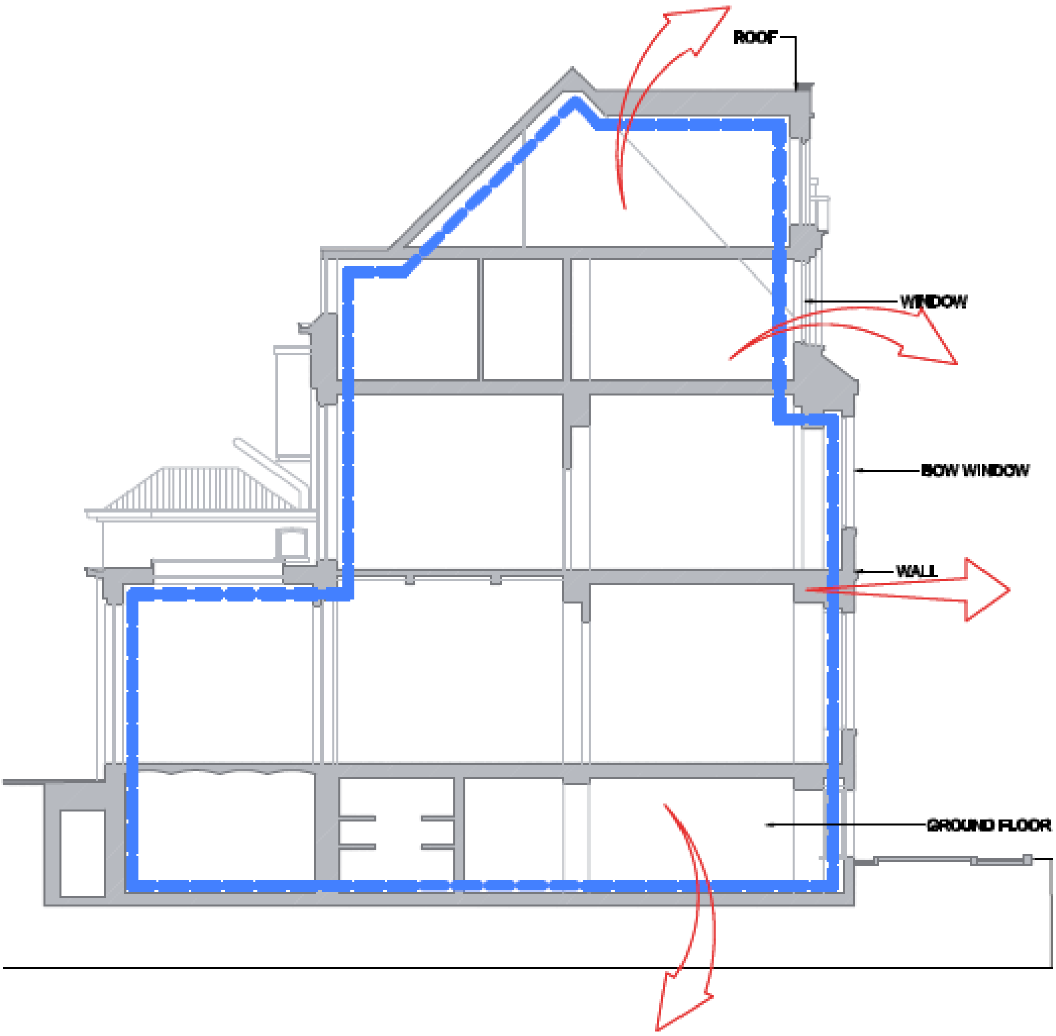

Figure 7. Thermal envelope and heat transfer

1. Scenarios for envelope retrofitting (Figure 8)

The envelope retrofitting scenarios are defined based on a trend analysis performed on the renovation of housing awarded at Exemplary Buildings initiated by Brussels Environment. They are proposed by phases, knowing that today, only few Brussels owners can finance all of the retrofitting works in one phase. The retrofitting steps are proposed in a hierarchical manner, taking into account the state of the dwelling, the influence on the energy performance and the extent of work required. The scenarios for the retrofitting of the services are proposed in the same way, taking into account the existing technical services and the possible densification of the dwelling. The scenarios propose improve strategies for existing technical services that include electricity generation, heat generation, hot water storage, heat distribution, lightning and ventilation.

All the possible scenarios defined are explored individually and in relation with the other scenarios. As aforementioned, the target is to deliver a full picture of the retrofitting process and that means to take into account that the intervention in one of the components impact in the others in one or other way. By coding these impacts by the traffic light colours we can deliver a schema of the elements we have to include in our intervention to achieve the expected energy efficiency outcomes.

This retrofitting guide sheets could be consider as a risk analysis of the interventions catalogued by element that shows the problems that could create to work in the building in a fragmented way.

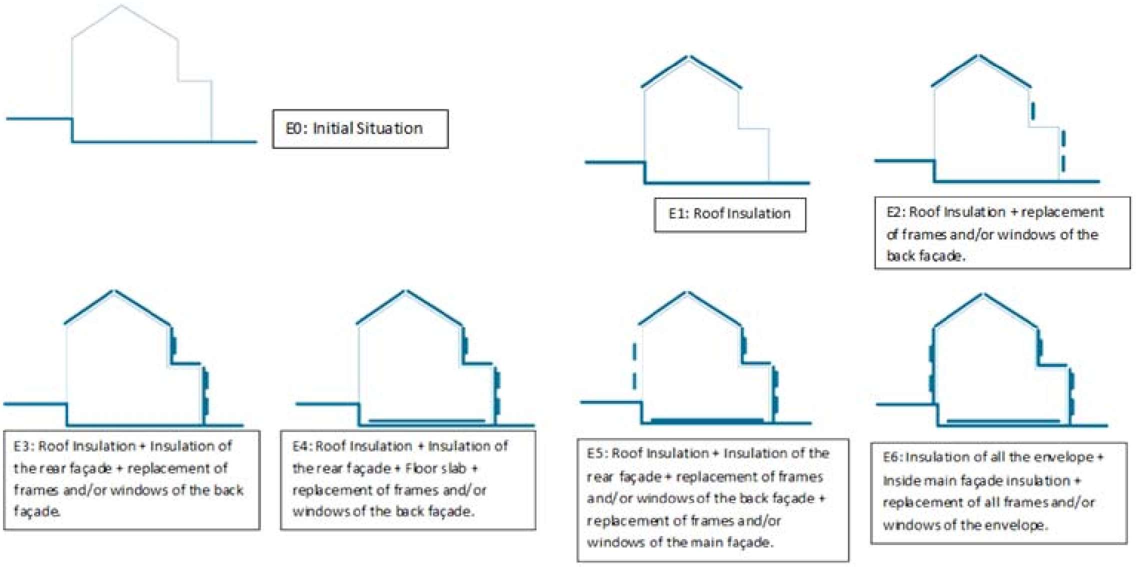

Figure 8. Envelope retrofitting scenarios schemas.


Figure 9. Retrofit guidance sheet

All the previous databases are included in the TCS matrix and represent the basis of its working methodology.

4 FUTURE IMPLEMENTATION

The final tool presents multiple ways of implementation: the first one is the scope of the project. Due to the large number and different typologies of the buildings in Brussels, the case study has been restricted to those of a much defined period and typology. The methodology to create the databases allows, however, the implementation of the formers.

Some assumptions have also been done in the measures for the retrofitting. Only those related with ventilation and heating has been taken into account. As well, in the retrofitting scenarios, not all the possibilities of occupation have been taken into consideration.

Finally, some improvements would be done to the tool in regards to its calibration. Till now, as aforementioned, the scenarios are based on a literature review on the studied building stock, investigated through best practice examples, industry overview and experience with refurbishment specialists. These scenarios will be enriched with the possibility to have reliable data in the behaviour of old mass masonry walls by working in the Energy House of the University of Salford. The data drawn from the 1:1 scale model of an old mass masonry wall house built by the School of Built Environment in a controlled environment, would be include in the tool as to calibrate the validity of the results.

5 CONCLUSIONS

The paper presents a methodology to approach the retrofitting of the built environment by the definition and analysis of the existing dwelling typologies and their components.

By integrating this assessment of the existing built environment with strategies for its retrofitting, the research explores to increase the guaranties of success since the design phase. By addressing the problem from different axes and including the heritage value and identity of the building, the research will provide a retrofitting roadmap for the ancient building stock of Leopold Quarter in Brussels to meet the energy performance of buildings directive standards while preserving its heritage value.

The outcomes of the research will be gathered in a common database that would have the form of a tool. This tool is oriented to the design professionals so they can have an overview of the integrated strategy based in the quantification of the energy efficiency upgrade, cost optimal energy performance and heritage value preservation.

6 ACKNOWLEDGEMENTS

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