METHODOLOGICAL ISSUES IN EVALUATING INTEGRAL SUSTAINABLE RENOVATIONS

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ABSTRACT

Ongoing research in Europe related to sustainable renovation mainly focuses on improving the energy performance of buildings. These studies have a limited scope regarding sustainability as operational energy is often the only focus. A screening of current practices in Flanders moreover shows that renovations are often limited to small interventions, whereby a long term vision is missing. We are convinced that a more integral approach is necessary to strive for sustainable renovation. This research aims at supporting the construction sector in the challenge for an increased renovation rate with more in depth transformations of the existing housing stock in Flanders. The objective is moreover to stimulate a transition from energy-focused renovations towards integral sustainable renovations from a life cycle perspective. In this context, the research aims among others at developing a number of affordable and innovative 'open-renovation-systems', with the focus on interventions such as splitting, combining, wrapping and extending residential buildings. To compare and analyze these renovation systems, a method to evaluate the environmental and financial impact of the renovation interventions over their whole life cycle is being developed. This evaluation method is based on the LCA (life cycle assessment) and LCC (life cycle costing) methodology. This paper focuses on two methodological issues in evaluating the environmental impact of renovation interventions: the allocation of the environmental impact of existing structures and materials to the life cycle before and after renovation, and the role of the estimation of the building lifespan (before and after renovation) in decision taking. The results of the analyzed case study show that the chosen allocation approach does not influence the overall conclusions regarding renovation or demolition followed by new construction. However, the case study reveals that the estimation of the second building lifespan can affect the results in a significant manner.

Keywords: Life Cycle Assessment (LCA), sustainable renovation, allocation, building lifespan

INTRODUCTION

The construction sector faces an important challenge in order to achieve the European objectives concerning sustainability and energy consumption. These objectives require a 20% reduction of the greenhouse gas emissions from 1990 levels by 2020 [1]. As buildings account for a major share in greenhouse gas emissions (i.e. more than 35% in the EU [2]), improving the energy efficiency of buildings is an important priority although the greenhouse gas emissions during the production of materials should not be ignored. Therefore, important priorities are energy-efficient newly built houses and thorough renovations of the existing housing stock. As the amount of newly built houses is limited compared to the existing buildings (i.e. little more than 1% of the building stock per annum in the EU [2]), renovation plays a major role in achieving these objectives. Ongoing research in Europe related to sustainable renovation mainly focuses on improving the energy performance of buildings and transforming existing buildings into nearly zero energy buildings ([3] - [6]). These studies have a limited scope regarding sustainability as operational energy is the only focus. Some studies enlarge the scope by including embedded energy and by following an energy-based life cycle approach [7]. Some researchers (e.g. Thiers and Peuportier [8]) even evaluate a wide range of environmental impacts, but still limit their scope to energy improvement measures. However, once the energy demand is reduced, the choice of materials and resulting maintenance, repair and replacement scenarios become relatively more important.

A screening of current practices in Flanders confirms that renovations are often limited to small interventions to improve the energy performance. In Flanders, we are mainly dealing with a privative housing ownership whereby renovations are ad hoc solutions for ad hoc questions. These interventions are often expensive and time consuming because of their specificity. Examples in other contexts show that a different approach is possible. In the Netherlands, for example, prefabricated industrial building systems are more and more used, resulting in faster and cheaper renovations. In addition, current renovations of residential buildings in Flanders often miss a long term vision. Flexibility and adaptability are important keywords because of the household changing needs over time, such as family expansion and contraction and evolving comfort requirements. To deal with these changing needs and to avoid spatially underused buildings, interventions as splitting, combining and extending buildings will often be used in the future. Therefore, there is a need for affordable and adaptable building systems with a low environmental impact. The aim of this paper is to analyze some methodological issues in evaluating renovation measures in the overall aim to strive for sustainable solutions. More specifically two issues are analyzed in detail: (1) the allocation of the existing structures and materials over the two building life cycles (i.e. before and after renovation), and (2) the role of the estimation of the building lifespan (before and after renovation) in decision taking.

METHOD

The European standards EN15804 [9] and EN15978 [10] recommend the use of a life cycle assessment (LCA) for the evaluation of construction materials and buildings. The life cycle of a building consists of several phases, mainly classified as the production, construction, use and end-of-life (EOL). At any moment during the life cycle of a building, it can be decided to (1) consolidate, (2) renovate or (3) demolish the building and build a new one. An important issue related to the preferred choice between the three options from an environmental point of view, is how to account for the environmental impact of the existing building. Two main approaches can be distinguished when analysing the renovation of a building: (1) excluding the environmental impact of the existing building from the comparison and (2) using annual depreciation and hence allocating part of the environmental impact of the first phase to the second building life cycle. The two approaches might influence the preferred option and hence a carefully selected methodology is important. In this context, an analysis of both approaches has been made based on a literature study and a case study in the Belgian context. Since the current dwelling stock in Belgium consists of 32% terraced buildings, of which 65 % is built before 1945 [11], this dwelling type is selected for the case study. The calculations are based on a small not insulated working-class terraced house of 99m² as defined by Allacker [12]. The results are briefly summarised in the subsequent section.

RESULTS

Results literature study

The “exclude the past” approach, consisting in allocating the impact of the existing building entirely to the first life cycle (i.e. before renovation), is used by several researchers. Quantis [13] applied this approach to identify under which conditions rehabilitation and retrofit of a building is preferred over demolition and new construction from an environmental perspective. Their arguments for this approach are the following: (1) the choice to rehabilitate a building has no impact on the production of existing materials which is the result of past decisions (2) there is a lack of information concerning the type, quantity and original impacts of the remaining materials, which could have been produced when the industrial systems were radically different [13]. When using this approach, one should also decide how to allocate the impact of the parts that are demolished. Several approaches are again possible: allocating the impact to the first life cycle or allocating it to the renovated house (at the start of the second life cycle), or allocating it partially to both. Hansen et al. [14] for example stated that the impact related to the removal and waste of the existing building elements can mostly be allocated to the previous service life. Their argument is that the removed building elements often had such a long service life that it is justified to allocate them to the previous service life. However, for the elements that are still useful and with a long expected remaining service life, they argued to allocate part of the impacts to the previous phase.

"W/E-adviseurs" [15] used the depreciation approach for the allocation of the impact of the existing building. In this study the research question focused on the preference between the improvement of an existing office or demolition and new construction. "W/E-adviseurs" [15] preferred this methodology because the first approach does not consider the building age, which means that there is no difference between a building of 10 or 100 years, although the demolition of a building after 10 years can be seen as destruction of environmental capital. The main idea of this approach is to determine which building parts are not yet at the end of their predicted life cycle. The environmental impact of these elements (i.e. due to production and EOL) is partially allocated to the second life cycle according to the ratio of remaining life span to the predicted life span. The new life cycle of the building consists of three types of impact: (1) the partial impact of the components that not yet reached the originally predicted service life at the moment of their replacement, (2) the impact of maintenance and replacement of the parts that remain in use and (3) the life cycle impact of the new components and materials.

In the depreciation approach, the estimation of the life span of the original building is crucial as it determines the ratio of the environmental impact allocated to the second life cycle. When the goal of the research is to compare the impact of 'lifespan extension due to renovation' with 'demolition and new construction', this life span estimation is an important issue. The uncertainty on the lifespan is however high, and hence many studies include sensitivity analyses. In [15] appears that for the considered offices the assumptions concerning the life span of a building have a significant influence on the results. Certainly for demolition followed by new construction, the expected lifespan is important when both the new construction and the residual load of the existing building have to be allocated to a short period, which may lead to different conclusions.

The first study [13] concluded that, if the renovated building has the same energy performance as newly-built houses, the renovation scenario remains environmentally favourable even after a century. When the newly-built house is more energy efficient than the renovated building, the newly-built house can be preferred although this can take decades. The outcome of this study is that preferences depend on the remaining building life span. It can be more environmentally preferable to renovate a building without major energy improvements when the remaining life span is relatively short. Several previous LCA studies pointed out that the operational energy use has a major share in the total environmental impact of a building over its whole life span. The estimation of the operational energy use is hence an important aspect when comparing renovation and demolition followed by new construction but is not further addressed in this paper.

Results of case study

Four scenarios are analysed and compared in the terraced house case study: (1) consolidation (i.e. further use of the existing building without any upgrading), (2) energetic renovation, (3) thorough renovation and (4) demolition followed by new construction. A description of the scenarios is given in Table 1. The analysis was also done for a timber frame construction, but the results are similar with the fourth scenario and are therefore not discussed in this paper.

SCENARIO	Energetic renovation	Thorough renovation	Demolition and new construction
INTERVENTIONS	New condensing gas boiler		
	• Outer wall: exterior insulation of 10 cm EPS inclusive exterior plaster • Roof: 17,5 cm rockwool between collar beams and twills • Windows: double glazed and PVC profiles	• Demolition of non-structural parts (only foundation, outer walls, floors and common walls are reused) • New inner walls in timber frame • Composition of the building skin is the same as in the scenario with an energetic renovation	• Foundation and common walls are reused • The floor plan and the composition of the inner walls are the same as in the scenario with a thorough renovation • Insulation: *Outer wall* : 22 cm rockwool *Floor on grade* : 15 cm PUR *Roof* : 17,5 cm rockwool between collar beams and twills *Windows* : double glazed and PVC profiles

Table 1: Description of the analysed scenarios

The environmental impact calculation is based on the MMG LCA method, developed by OVAM [16]. Figure 1 shows the yearly environmental cost of the four scenarios, based on the depreciation approach. The assumption is made that the predicted building lifespan for the first phase was 90 years and that the intervention takes place 20 years before the foreseen end of life, i.e. at a building age of 70 years. The same analysis is made for a predicted lifespan for the first phase between 60 and 200 years. The life span of the new phase is a parameter from 15 years to 120, in steps of 15 year.

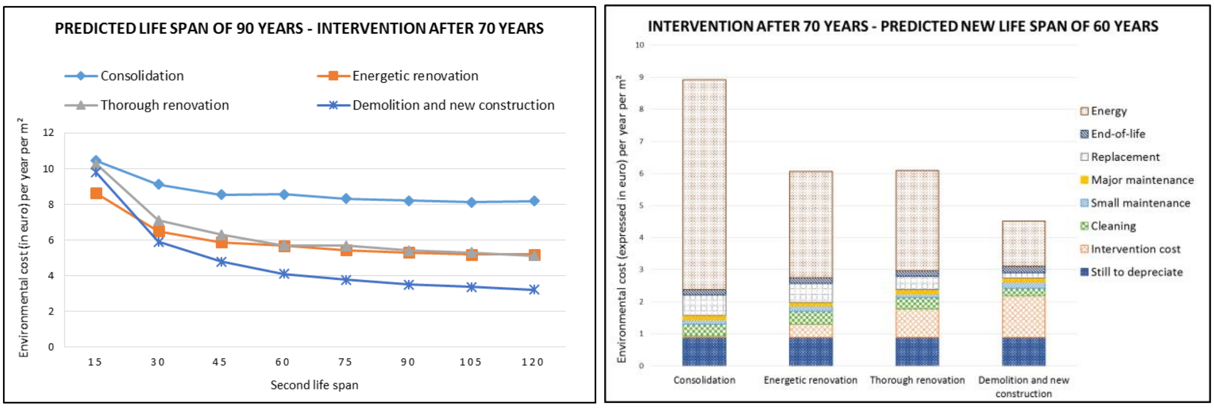

Figure 1: Environmental cost of the four scenarios per year per m² floor, in function of the duration of the second building lifespan, considering a first predicted lifespan of 90 years and an intervention after 70 years (left) and environmental cost of the four scenarios per year per m²floor, divided per life cycle phase, considering a first predicted lifespan of 90 years, an intervention after 70 years and a second lifespan of 60 years (right).

The results reveal that for this case study the environmental load for the second phase is only marginally influenced by the originally predicted lifespan of the existing building. The results per life cycle phase for a first predicted lifespan of 90 years are shown in Figure 1. The energy consumption is responsible for a major share of the environmental cost. The environmental cost of the existing components that has to be allocated in this case is just a small share of the yearly cost. The EOL cost of the parts that are removed is included in the intervention cost.

The "exclude the past" approach was also used to analyse the case study. For this approach, it is assumed that the EOL of the demolished parts is allocated to the new building life cycle, as in the depreciation approach. In Figure 2, the results are compared with the one from the depreciation approach for a thorough renovation (left) and demolition and new construction (right). The results reveal that the choice of the allocation approach has, in this case, no influence on the conclusions. Concerning the depreciation method, the estimation of the second building lifespan can affect the results significantly, certainly if the remaining life span of the building is relatively short. Furthermore, when the second lifespan is shorter than, in this case, 22 years, the yearly environmental costs are lower for renovation than demolition and newly-built, due to the higher investment cost for newly-built that has to be amortized over a short period. The same analysis is made for an energetic renovation with a similar energy efficiency to newly-built construction, which shows that renovation remains environmental preferable when the second lifespan is shorter than approximately, in this case, 70 years. However, even with this improved energy efficiency the choice of allocation approach has no influence on the conclusions.

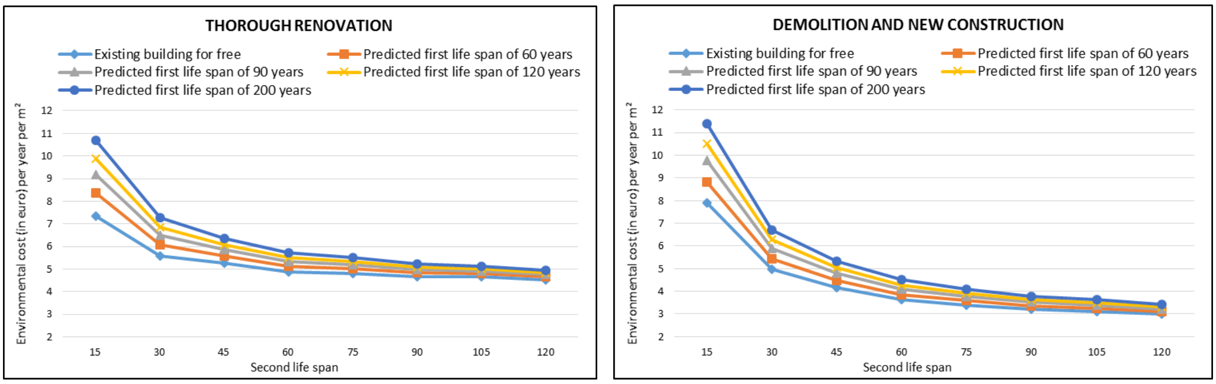

Figure 2: Environmental cost per year per m² of the thorough renovation (left) and demolition and new construction (right) for an intervention after 70 year, using both allocation approaches. For the depreciation approach, several predicted life spans for the first life cycle are compared.

Finally we also considered the possibility of even not taking the EOL of the existing building into account. As the impact of the EOL is small compared to the total impact of the life cycle phases (i.e. approximately 2% for renovation and 3.5% for newly-built when considering a second life span of 60 years), allocating it or not to the existing structure does not change the overall results.

CONCLUSION AND FURTHER RESEARCH

In this paper two main approaches for allocating the environmental impact of the existing building are compared via a case study: (1) allocating the environmental impact of the existing building entirely to the first life cycle, whether or not taking the EOL during the intervention into account and (2) allocation based on annual linear depreciation. The results of the case study show that the choice of allocation approach does not influence the overall conclusions regarding renovation or new construction. However, the estimation of the second building lifespan and differences in energy efficiency can affect the results significantly. Simulating the effect of originally estimated life spans, different ages of intervention and different ratios of energy cost versus investment cost is required in future.

ACKNOWLEDGEMENTS

This paper is part of a doctoral research funded by the Agency for Innovation by Science and Technology (IWT).

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