RE-DESIGN FOR CHANGE: TOWARDS DYNAMIC AND SUSTAINABLE RESIDENTIAL BUILDINGS

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Summary

In this era in which we have to face up new environmental challenges, residential post-war housing projects of the 1970's are characterised by their outdated comfort and excessive energy consumption. These buildings are currently renovated so that the operational energy consumption is pushed down to near-zero and passive standard levels adding the best technical solutions available. However, neither future building upgrade or periodic alterations or transformations – due to e.g. demographic changes or future policy revisions of the European Energy Performance of Buildings Directives – neither the end-of-life of building products are anticipated. To tackle environmental and financial impacts associated with these life cycle interventions this paper introduces an alternative 'dynamic' renovation approach based on a 4 Dimensional Design Strategy (4D). By incorporating the *time parameter* as variable design parameter, future scenarios can better be anticipated. The results for a case study of apartment blocks of the 70s in Brussels illustrate that a dynamic approach is a required complementary renovation approach in order to ensure a sustainable material and waste management during the total life cycle of buildings.

Keywords: Dynamic (re-)design, sustainable material & waste management, LCC, LCA

1 Introduction

In 1956 Fernand Brunfaut came up with the plan to develop a utopian urban residential district on the occasion of the World Exposition in 1958 in Brussels. Today, a global renovation of this 'Model City' is urgent to bring the neighbourhood back to contemporary standards. The case study – one of the *medium-rise blocks* on this urban district – is a representative example of the abundant post-war apartment blocks constructed after the Second World War as a modern response to acute housing shortage in Europe. Many of these buildings are at present facing a long list of structural, functional, socio-economical and financial problems. Poor insulation and high energy costs, low building standards and the urgent need for building upgrade make these buildings important targets in the European attempts to reduce the environmental impacts of the existing building stock. In addition, due to evolving socio-economic standards the apartment types in this building do no longer conform to modern wide-ranging family mixes or to improved living and comfort standards. The building lay-out, plan organisation and fitting-out of the medium-rise buildings were not designed to be extensively adapted in the future – in analogy with most buildings today.

Fig. 1 *Building block at Model City before renovation*

Fig. 2 *Building block at Model City after renovation*

Therefore, during renovation works in 2008–2013 the building structure had to be entirely stripped and refitted with new apartment layouts to revitalise the building to today's norms and standards. The building envelope was replaced in order to respond to *minimum* energy performance requirements applicable at the time of the building permit submission. Nevertheless, with upcoming revisions of the energy performance directives these non-upgradable measures are rather irrelevant when compared to forthcoming low energy renovation projects. Furthermore, due to our fast-changing society with its unpredictable social-cultural, financial and environmental needs, the future will be calling for new building changes. Therefore, *complementary renovation approaches* are required that renew the energy performance of the post-war building stock, while dealing with *socio-economical* and *environmental* issues as regards the future building life cycle.

2 Towards a dynamic residential building stock

In order to identify the need for change in buildings, a preliminary survey was held amongst the main stakeholders involved with renovation of (social) residential blocks [1]. Architects, social housing companies and members of the Flemish federation for social housing (VMSW) were invited to respond a questionnaire concerning the need for maintenance and building alterations during buildings' life cycles. The results revealed a large interest for building solutions that can be easily *altered* or *upgraded* along the way, especially for the *building envelope* and the *internal fitting-out*. However, a multi-criteria analysis of conventional residential building solutions pointed out shortcomings regarding the ability to deal with changing conditions (like future technical upgrade or alterations of the building organisation) without generating large waste streams and consuming new building materials [2]. For example, when we consider the renovated building blocks at the Model City, any future alteration of apartment lay-outs will be as difficult and material-consuming to make as it was during renovation, due to amongst others the (new) rigid partitioning applied between and within apartments.

Therefore, an alternative design approach which introduces the *time parameter* is proposed in the context of this study. *4Dimensional design* (4D) refers to a design attitude to conceive building artefacts from a life cycle perspective, therefore integrating the fourth dimension, i.e. *time*, from the initial stage of design [3]. In order to reduce the accumulating *environmental* and *financial* life cycle impacts, 4D design strategies aim to prolong the useful life of buildings, components and materials. Consequently, for the case study, the alternative is to reorganise the building structure according to the *frame and generic space* approach [4]. In this approach, *permanent* building parts need to be defined to constitute the *frame* within which change – the unspecified *generic* space – can take place. The structural layer (i.e. concrete skeleton frame) and the service distribution layer (i.e. new centralised technical shafts) are combined as the *frame* in which the fitting-out can be adapted easily [1]. At component level, the Hendrickx-Vanwalleghem (HV) approach is applied to design building layers with a high turnover, i.e. internal partitioning and building envelope. This approach consists of composing construction systems with a minimum number of basic elements with combination rules allowing for the conversion of each artefact to a different configuration by means of adding, removing or transforming the basic elements it is made of – like Meccano kit-of-parts [3]. To enhance the reuse potential, *durable* building elements (i.e. resistant against wear-and-tear of multiple (dis)assembly, handling and transport) are assembled using *reversible* connections according to 'Design for Disassembly' principles [1]. These solutions for the new fitting-out offer a higher potential of *reuse* and *recycling* and enable to make alterations without consuming new materials and adding waste streams as in conventional construction.

3 Evaluation of a dynamic renovation approach

To compare effects of a *dynamic* renovation approach compared to a *static* one, *environmental* and *financial* benefits/drawbacks are evaluated over a remaining building *life cycle* of 45 years after renovation – with alterations regularly taking place. In this study the *production* phase (building materials), *construction* phase (assembly works), *use* phase (maintenance, replacements, alterations), *end-of-life* phase (removal, waste treatment) and all *transport* phases are incorporated for the assessment of environmental impacts (Life Cycle Assessment (LCA)) and financial costs (Life Cycle Costing (LCC)). The ReCiPe environmental impact method is applied for its suitability in the West-European context. Next, the *present value* of building solutions is calculated in order to discount all future financial costs and gains to their present value at the time of renovation. Two graphs (**Fig. 3** and **Fig. 4**) are representing the *environmental* (LCE) and *financial* (LCF) *life cycle impacts/costs* for a range of *scenarios* for (non-load-bearing) *internal partitioning*.

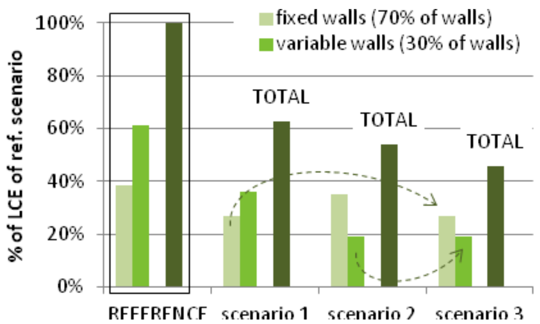

Fig. 3 *Environmental life cycle impacts (LCE) of scenarios of internal partitioning*

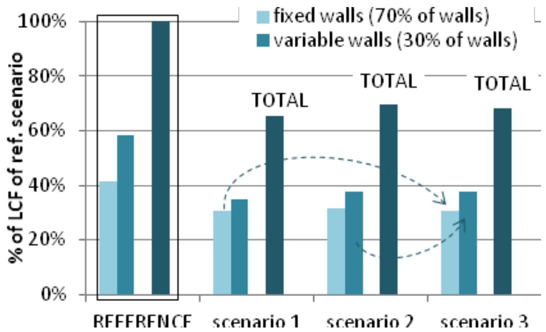

Fig. 4 *Financial life cycle impacts (LCF) of scenarios of internal partitioning*

A *reference scenario* (partitioning made of masonry in analogy with today's renovation) is compared with conventional *drywall* partitioning (*scen. 1*), the proposed *dynamic* partitioning (*scen. 2*) and the combination of *drywall* and *dynamic* partitioning (*scen. 3*). When forming new apartment typologies in the new (flexible) plan, 70 % of the internal partitioning remains unchanged (*fixed* walls) whereas 30 % needs to be moved every 10 years (*variable* walls). For the *static* partitioning (i.e. ref. scen. and scen.1) frequent plans alterations cause these 30 % to be entirely removed and replaced. In contrast, the reversibility of connections and durability of building elements in the *dynamic* proposal enable to dismantle the partitioning and reuse it in a new configuration. The graph for the environmental evaluation reveals that dynamic solutions (scen. 2) comprise important life cycle impact reductions for *variable walls*, in which opportunities of multiple (dis)assembly can be fully exploited. However, a small increase of the initial environmental impacts and investment costs of dynamic solutions compared to drywalls – due to higher material and assembly impacts/costs [1] – results in higher life cycle impacts/costs for the *fixed* walls compared to scenario 1. Therefore, the *combination* of static (scen. 1) and dynamic partitioning (scen. 2) for respectively fixed and variable walls decreases the environmental life cycle impact of the reference scenario with about 50 %. In this third scenario the more labor intensive dismantling and re-assembling steps compared to demolition and replacement of walls are responsible for lower gains in financial terms, but still present a reduction of life cycle financial costs of approximately 30 % compared to the reference scenario with rigid masonry walls.

4 Conclusions

In each renovation project an evaluation should be made of the flexibility of the *building structure*, in order to determine if alterations can be made during renovation concerning the general *building composition and organisation* in order to increase future opportunities for change (e.g. centralisation of technical services for flexible plan layouts). When this approach at building level is combined with a dynamic design approach for building layers with a high expected turnover rate, environmental and financial life cycle impacts/costs related to frequent building update, upgrade or building alterations can be reduced. Hence, a compromise is sought between static and dynamic solutions when introducing them in the (existing) building stock. Reversible jointing, a careful choice of durable materials and a multi-layer composition of building systems are adjustments in the conventional building system design which in the long run create wide ranged benefits regarding minimisation of resource consumption and building waste production.

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