Vrije Universiteit Brussel
Faculty of Engineering
Department of Architectural Engineering

Scenario based life cycle costing

an enhanced method for evaluating the financial feasibility of transformable building (graphical summary)

Waldo Galle

The present document is a graphical summary of the thesis *Scenario based life cycle costing* submitted in fulfilment of the requirements for the award of the degree of Doctor in Engineering Sciences and publicly defended at the Vrije Universiteit Brussel on September 9th, 2016.

Supervised by prof. Niels De Temmerman and prof. Ronald De Meyer

Transformable building is an innovative construction and design strategy. It aims for an adaptable building stock and fosters the resource efficient management of building components.

Its use of reversible connections such as bolts and screws instead of mortar and glue, and the compatibility and accessibility of its components facilitate material reuse during future refurbishments.

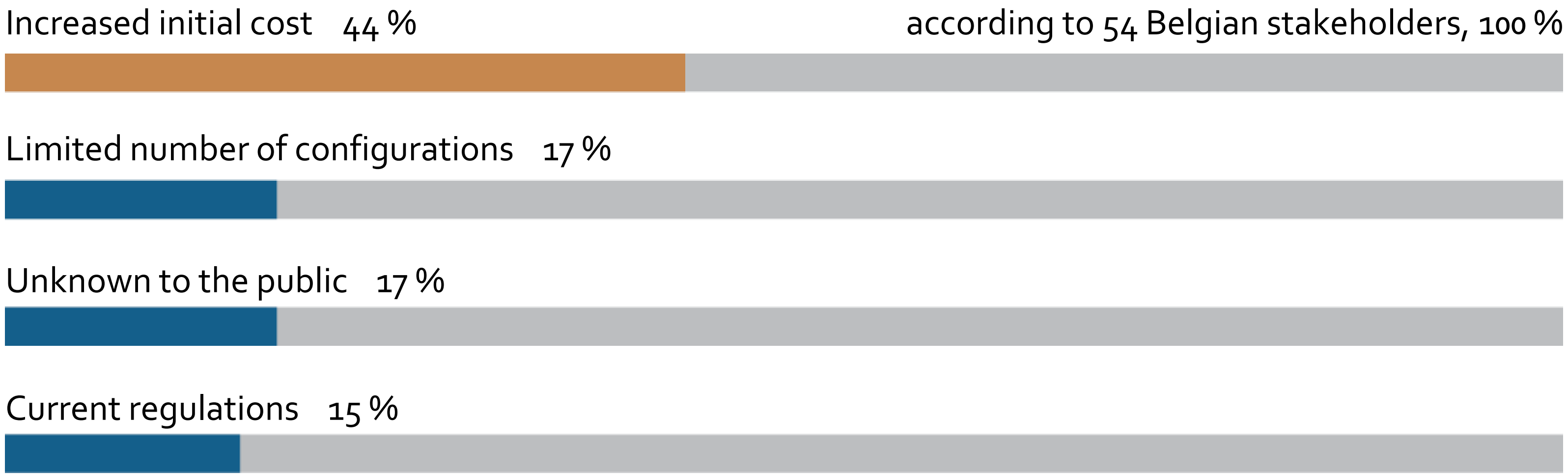
Project ABT/DAMEN OFFICES, Delft by Bierman Henket architecten 2001.
Source Leupen B. et al. (2005). *Time-based Architecture.* 010. 236-239.
Photo Bierman Henket architecten, www.biermanhenket.nl.

Although the reduced environmental impact of future material reuse has already been demonstrated during life cycle assessments, transformable building is restricted to small-scale and specific building projects.

Amongst architects, constructors and material producers, an increased investment cost is cited the most often as an important impediment to the widespread implementation of transformable building.

State of affairs

Today, few transformable buildings are realised because of several perceptions.



Survey Vandenbroucke, M. et al. (2013). Opportunities and obstacles of implementing transformable architecture, in *Proc. of the Int. Conf. on Sustainable Building*, Guimarães.

But today the financial consequences of transformable building are hardly known. An explorative literature review illustrates this insightfully. Amongst the collected strengths, weaknesses, opportunities and threats, several contradictions arise.

The feared increase of the investment cost contradicts the expected life cycle savings. And although transformable building is technically feasible, the use of demountable building components is associated with various financial uncertainties.

Swot analysis

The financial consequences of transformable building are hardly known.

STRENGTHS	WEAKNESSES
longer service lives and lower life cycle costs	higher investment and life cycle costs
increased market value	counter-productive innovation risks
technical feasibility	resistance to reuse
OPPORTUNITIES	**THREATS**
changing needs and continuous alterations	few innovation incentives for constructors
sustainability evaluations and policy measures	inert construction sector structure and scale
complementary innovation	strongly intervening government
solid sector structure and scale	persistence of change

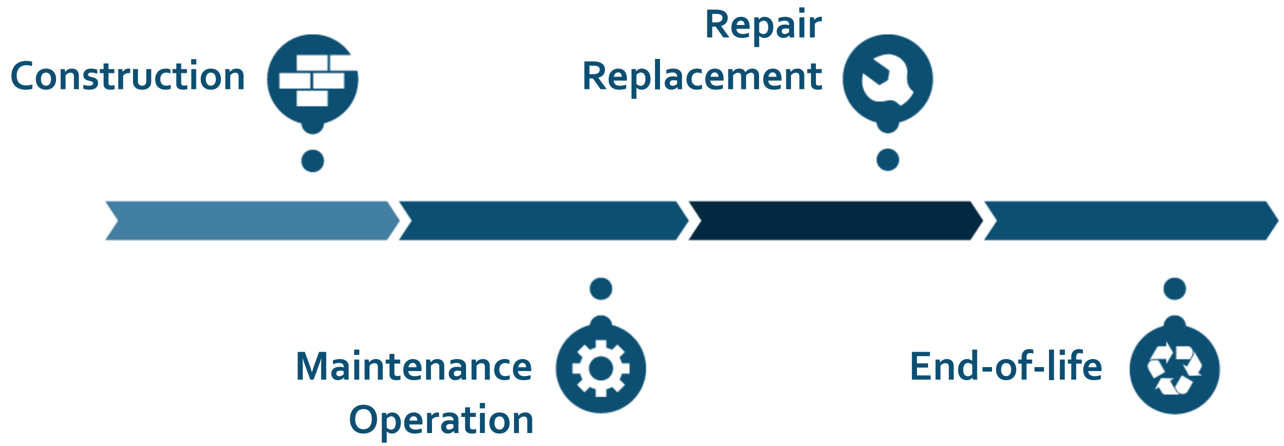
Literature review Galle W., De Troyer F. and De Temmerman N. (2015). The strengths, weaknesses, opportunities and threats of open and transformable building related to its financial feasibility. In *Proc. of the Int. conf. on the Future of Open Building*. Zürich: ETH-Zürich.

Because transformable building has the ambition to generate material savings during as well as at the end of an asset's service life, life cycle costing is considered a purposeful framework for evaluating its financial consequences.

Moreover, the focus of life cycle costing on building elements such as walls, floors, doors and windows resembles closely conventional budget calculations while its long-term perspective matches the increasingly common environmental life cycle assessments.

Point of departure

Life cycle cost analysis can bring insight in the long-term consequences of design choices.



Although disregarded in conventional life cycle cost analyses, it is expected that the dynamic nature of transformable buildings, their specific costs and the related uncertainty have an important impact on the analysis outcomes. For this reason, the present research proposes a transformation integrated life cycle costing method.

By integrating in the analyses a building's changing specifications, this method empowers advisors and designers to promote and implement transformable building in an informed and well-conceived way.

Problem statement

Transformable building includes 3 challenges for life cycle cost analysis.

For integrating the dynamic nature of transformable buildings in life cycle cost analysis, the present research proposes five new features. Together they constitute scenario based life cycle costing, an enhanced method for evaluating the financial feasibility of transformable building.

Moreover, understanding that long-term evaluations such as life cycle cost analyses have hardly any predictive value, discrete what-if analyses, continuous sensitivity analyses and probabilistic risk analyses of large series of design alternatives are indispensable and therefore enabled with the proposed features.

Preview

In reaction to those challenges the present research proposes five new features.

Feature 1
diverging scenarios

Feature 2
life cycle interventions

Feature 3
geometric discounting technique

Feature 4
analytical life cycle costing procedure

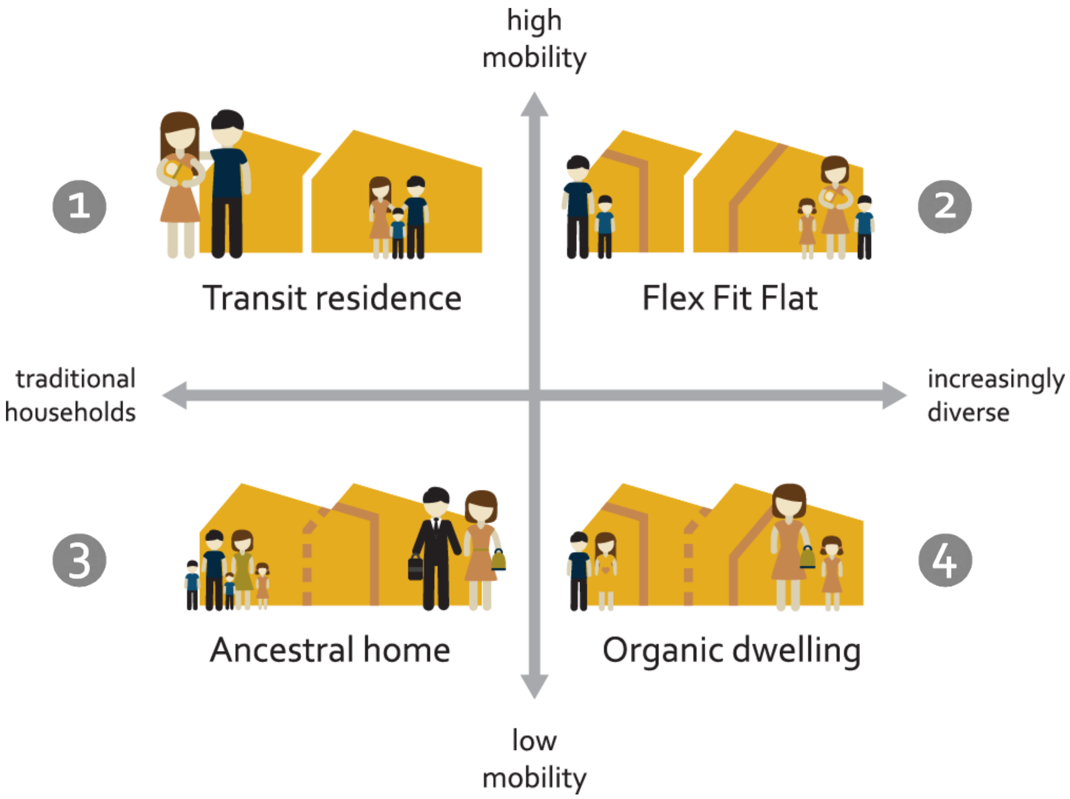
Feature 5
building modelling protocol

First, diverging life cycle scenarios are introduced. These imaginable futures reflect our unpredictable and continuously changing requirements and standards.

For creating effective scenarios a comprehensive framework is built. It allows identifying key drivers for change, their effect on user satisfaction and the real and life cycle options each design alternative offers. For the successful implementation of these scenarios the added-value of scenario planning for building design and life cycle costing is extensively discussed.

Feature 1

Diverging scenarios are stories reflecting a building's uncertain future.

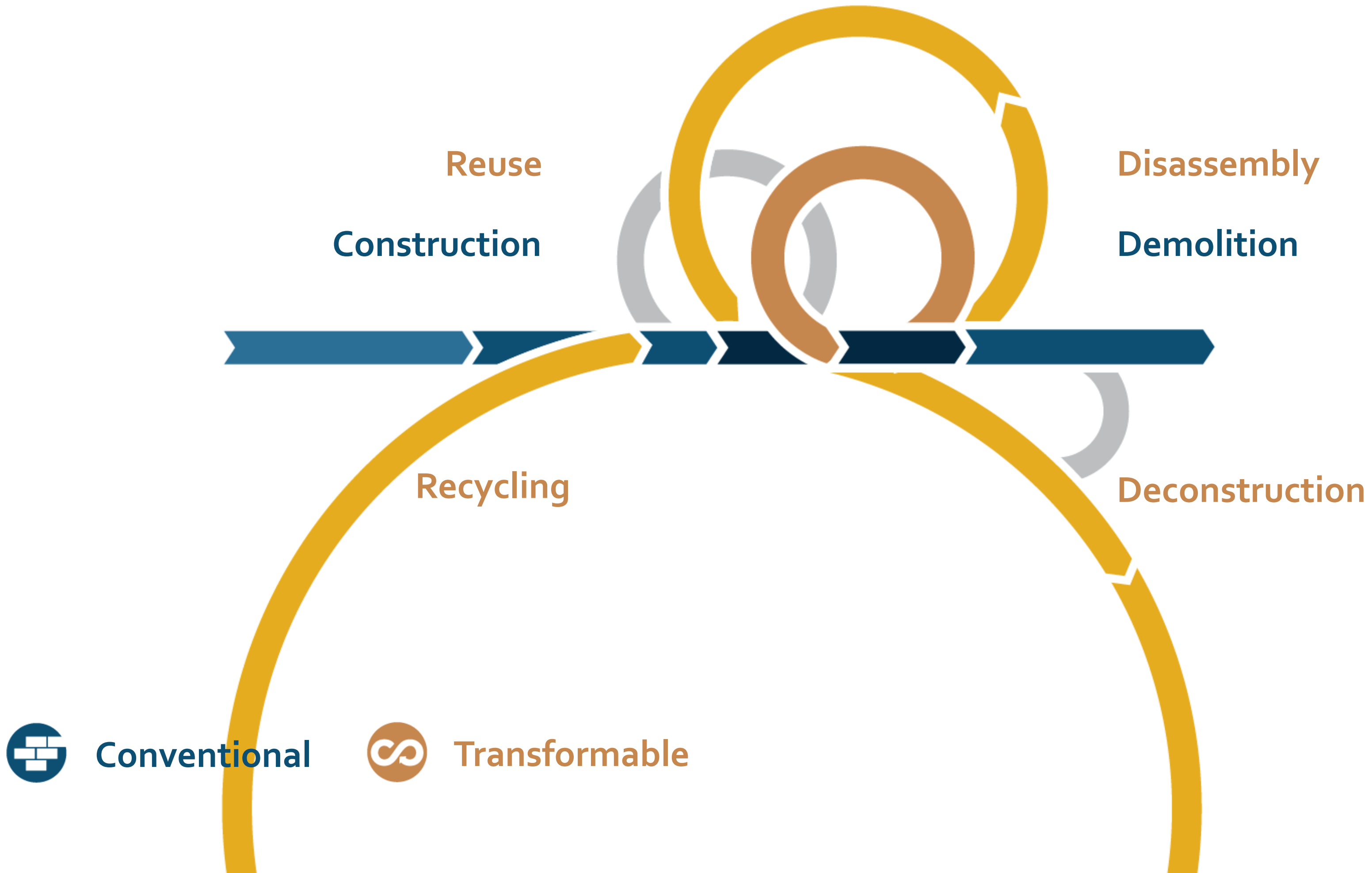


Second, the financial impacts of transformable building are identified. Therefore, a series of life cycle interventions is defined.

In addition to life cycle stages such as construction, use and end-of-life, life cycle interventions such as assembly, disassembly and reuse allow setting up circular service life models. These models allow quantifying the life cycle costs that result from transformable building. Special attention is given to the reuse of building elements, their recycling and residual value.

Feature 2

Life cycle interventions allow describing linear and circular service lives of building elements.



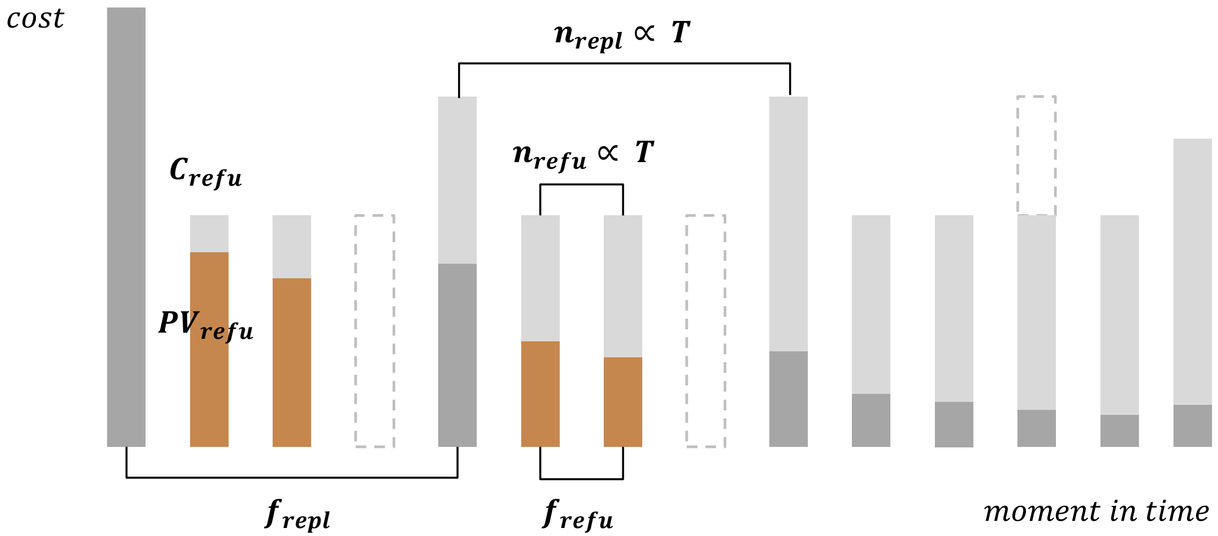
Third, the identified costs are discounted to their moment of occurrence. This allows comparing design alternatives that entail costs at different moments in time.

Therefore, the geometric discounting technique is developed and validated. Without ignoring the complexity of the circular service lives of building elements, geometric discounting forms the basis for automated life cycle cost calculations, comprehensive uncertainty analyses and thus well-conceived design choices.

Feature 3

The geometric discounting technique is developed to facilitate the life cycle cost calculations.

$$PV_{refu} = C_{refu} \sum_{i=0}^{n_{repl}-1} \sum_{j=1}^{n_{refu}} \left(\frac{1+r_g}{1+r_d}\right)^{i \cdot f_{repl} + j \cdot f_{refu}}$$

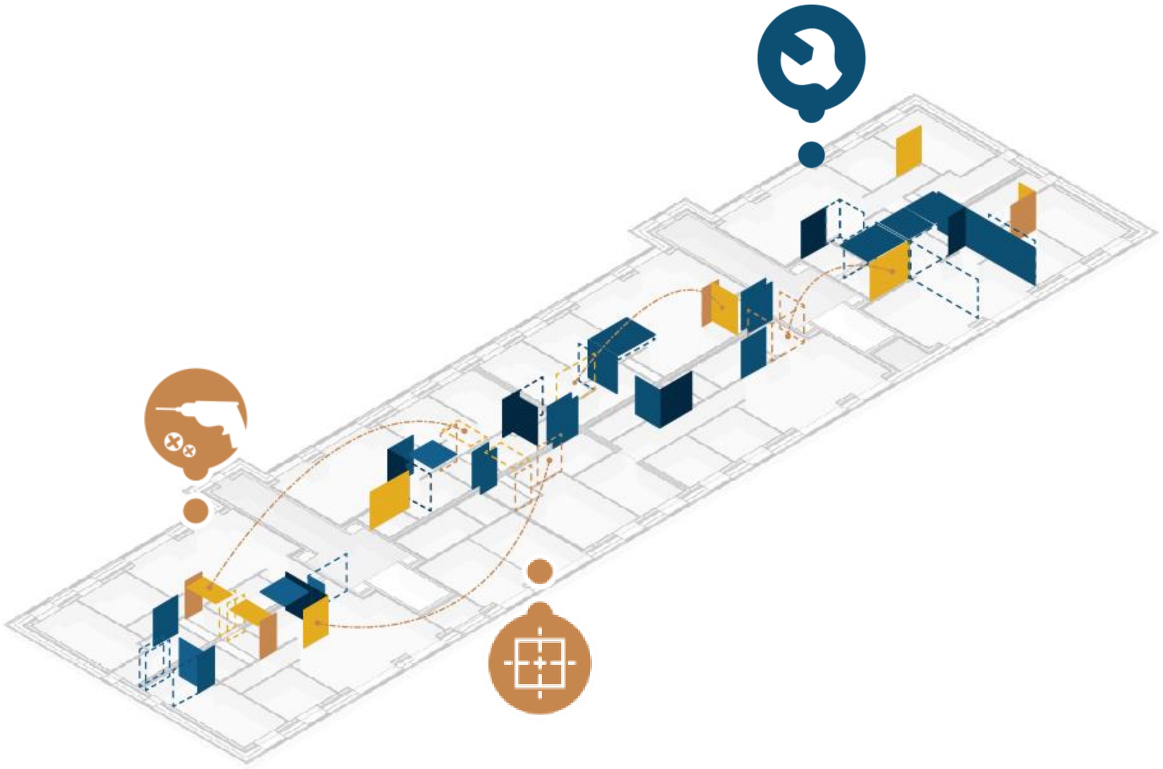


Fourth, the life cycle cost calculations are set up. To take into account the varying element quantities that result from the introduced scenarios, an analytical method is proposed.

This calculation method considers the reuse of building elements separately from other life cycle interventions such as replacements and reoccurring refurbishments. The resulting calculation outcomes allow comparing objectively the life cycle cost of design alternatives in various scenarios.

Feature 4

During the life cycle cost calculations buildings are considered as warehouses of elements.

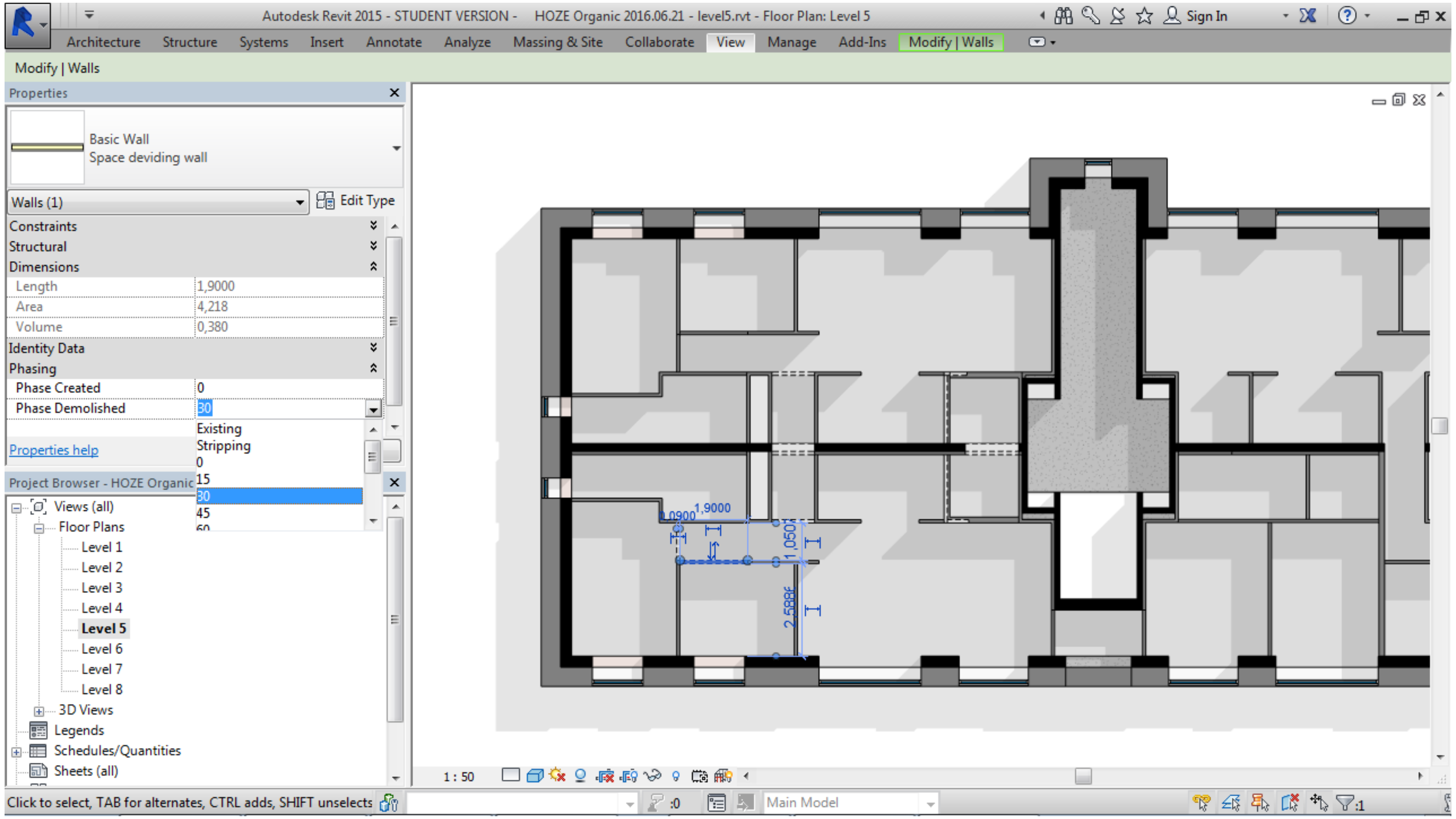


Fifth, a building modelling protocol is composed. It guarantees that the discounted costs are correctly included in the life cycle cost calculations.

Therefore, it includes three fundamental modelling principles, defines the required model parameters and discusses the different implications of those parameters. In the present research the protocol is implemented in a conventional spreadsheet environment while the use of a building information model is explored too.

Feature 5

A modelling protocol explains how to create a suitable building information model.

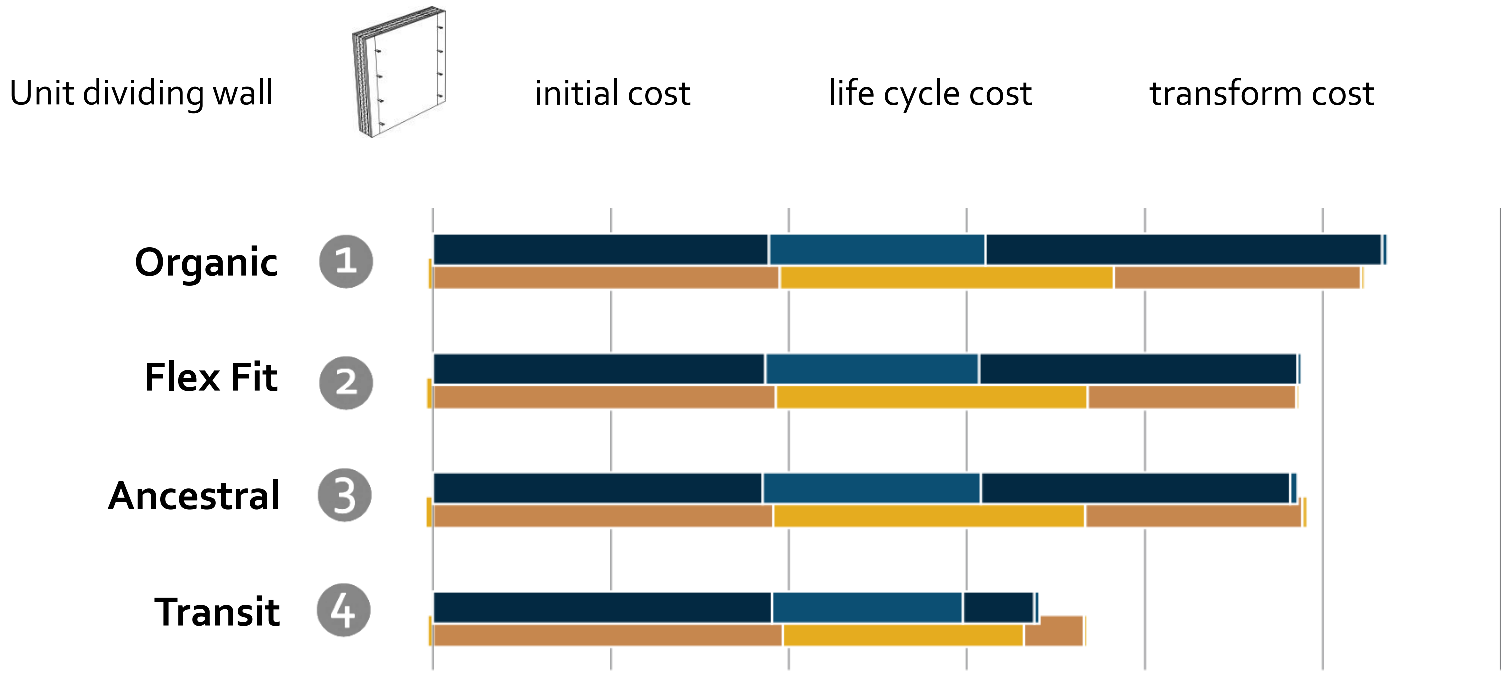


To illustrate the added-value of the developed scenarios, calculation methods and modelling protocol an in-depth case study is conducted.

It assesses the transformable renovation of the HoZe apartment building, including various element alternatives such as conventional and transformable unit dividing walls. It shows how scenario based life cycle costing allows comparing long-term costs, identifying boundary conditions, understanding design improvements and exploring investment risks. Consequently, this case study acts as the method's proof of concept.

Proof of concept

With the developed method the life cycle cost of each alternative can be compared in every scenario.



Conventional Transformable

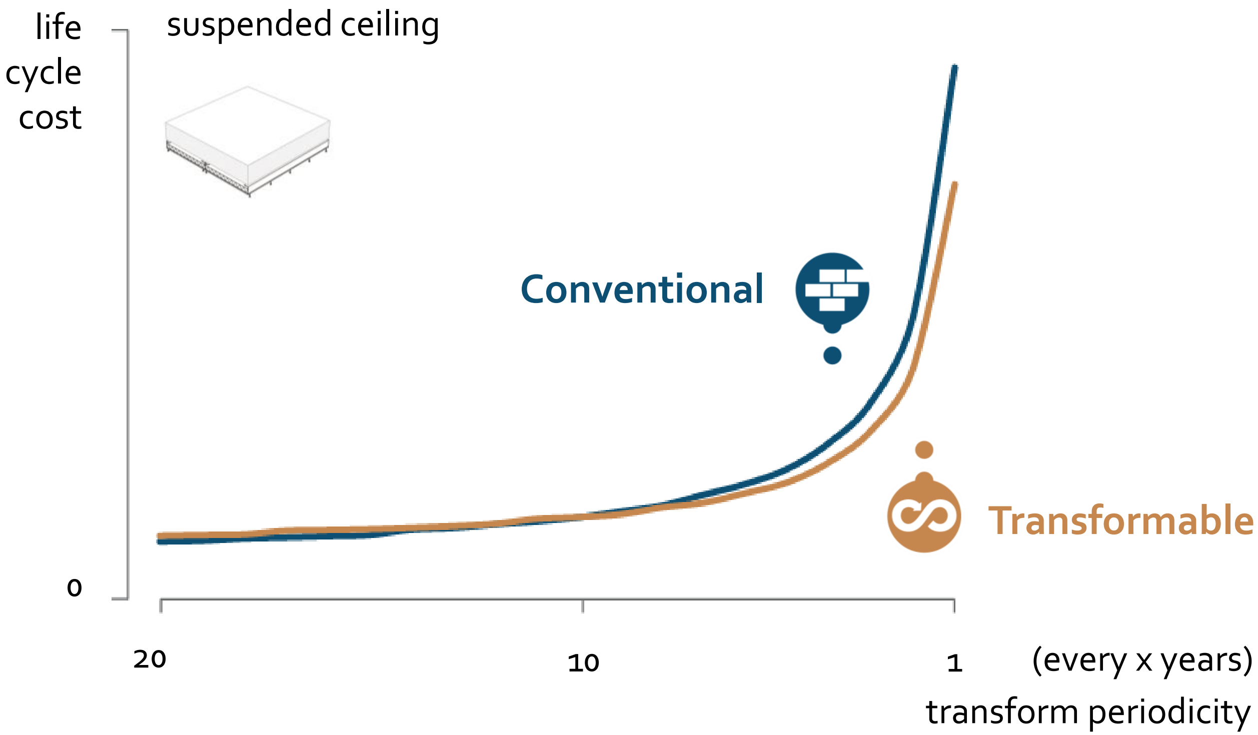
To frame the feared initial cost increase and gain better insight in the financial feasibility of transformable building the present research proposes scenario based life cycle costing.

Additional elaboration, validation and benchmarking of the proposed method and its features remain nevertheless necessary. They are needed to advance the method in accordance with the ongoing transition towards a circular economy as well as to adjust its features to alternative implementation opportunities.

Waldo Galle
Vrije Universiteit Brussel

Proof of concept

And many sensitivity, what-if and probabilistic uncertainty analyses can be conducted.



Conventional Transformable

Disclaimer

The present document is a graphical summary of the thesis *Scenario based life cycle costing* submitted in fulfilment of the requirements for the award of the degree of Doctor in Engineering Sciences and publicly defended at the Vrije Universiteit Brussel on September 9th, 2016. The research preceding the thesis was possible thanks to a PhD Fellowship of the Research Foundation – Flanders FWO.

The thesis discusses the fundamental development and set-up of scenario based life cycle cost analyses. It is not intended to provide a definitive guide to the application of these analyses. Users are therefore recommended to take professional advice to ensure that any proposals they may have for the analyses' use comply with relevant legislation and standards. They should note that neither the author nor the host institutions can be held responsible for any loss, damage or expense arising from the use of the analyses developed in the thesis.

Readers are invited to share their comments with the author. Also suggestions for improvements and information regarding errors are welcome as they might assist the further development of scenario based life cycle costing.

Subject to availability, a printed copy of the thesis *Scenario based life cycle costing* can be obtained upon motivated request. You can contact the author by e-mail at waldo.galle@vub.ac.be.

Reference to this document:

Galle W. (2016) Scenario based life cycle costing: an enhanced method for evaluating the financial feasibility of transformable building (graphical summary). Vrije Universiteit Brussel, Brussels. 15 p.