

Louvain School of Management

**To what extent can demountable
partition wall systems become
economically competitive compared to
conventional wall systems when
evaluated through a Life Cycle Costing
approach?**

Author(s): Joris Antoine
Supervisor(s): Julie Hermans
Academic year 2025-2026
Dissertation for the Master of Business Engineering
Master subject and focus: Energy Management

DECLARATION

The declaration below is **mandatory and must appear on the first page (after the front page) of your master's thesis.**

STATEMENTS ON YOUR USE OF GENERATIVE AI

Confirm the following statements:

Statements on responsible use of generative AI	Your answer
The content of my/our master's thesis is my/our original output, even if I/we used generative AI to help prepare it.	☒ Yes ☐ No
I/we master the theories, tools and methods that I/we use for the thesis.	☒ Yes ☐ No
I/we verified that the output presented in the thesis is accurate and valid, and that it contains no hallucination, no false reference, etc.	☒ Yes ☐ No
I/we acknowledge that I/we master the final output and that I am/we are able to explain it and answer questions about it.	☒ Yes ☐ No
I/we made sure not to provide generative AI tools with access to confidential data or information	☒ Yes ☐ No

SIGNATURE

Sign your declaration:

Author last name, first name(s)	Date	Signature
1 Joris Antoine	02/08/2026	

NOTE

For this document, DeepL has been used to propose formulations, but the text is original, except the extracts explicitly mentioned as coming from other sources, which are mentioned in footnotes.

Supervisor: Julie Hermans

Use of AI:

DeepL, ChatGPT and Claude were used for the following purposes:

- Improve the linguistic quality of the text by suggesting alternative phrasing, enhancing clarity, and correcting spelling, grammar, and syntax errors.
- Assisting with the translation of the thesis text from French into English while preserving its intended meaning.
- Providing suggestions for structuring and reorganising certain sections to improve readability and logical flow.
- Discussing and refining the interpretation and presentation of the results

All outputs produced by the AI have been carefully reviewed to verify their consistency, accuracy, and reliability

Abstract

The construction sector generates significant amounts of waste, making circular construction and the reuse of building components increasingly important. Among building elements, interior partition walls offer considerable reuse potential due to their frequent replacement during a building's lifetime.

This thesis evaluates the economic competitiveness of demountable partition wall systems compared with conventional alternatives through a Life Cycle Costing (LCC) approach. Developed in collaboration with Buildwise, the study compares six partition wall systems representing three levels of demountability and two finishing materials, plaster and wood. A simulation model was developed over a 60-year study period under three refurbishment scenarios representing different levels of building adaptability. Semi-structured interviews with construction professionals were also conducted to assess the practical relevance of the model.

The results demonstrate that demountable partition wall systems can become economically competitive when assessed through a Life Cycle Costing approach. However, this competitiveness is not guaranteed and depends on several interacting factors, including the level of demountability, the compatibility of the selected finishing materials with Design for Disassembly principles, the complexity of the wall assembly and the labour requirements associated with refurbishment and end-of-life operations. The findings also highlight that material selection should not rely solely on initial construction costs but rather on the long-term economic performance of partition wall systems over their entire life cycle. More broadly, the study suggests that the wider adoption of reusable partition wall systems will depend not only on their technical and economic performance but also on the evolution of market conditions, regulatory frameworks and professional practices.

Acknowledgments

Before presenting this thesis, I would first like to express my sincere gratitude to my supervisor, Julie Hermans, for her guidance, support and valuable feedback throughout this research. Her advice and availability have been instrumental in shaping this thesis and helping me successfully complete this work.

I would also like to sincerely thank Jan Roekens for his support throughout this research, for his willingness to share his expertise, and for the valuable insights and resources he provided. His guidance and practical knowledge of the construction sector greatly contributed to the development of this thesis.

My sincere thanks also go to the professionals who agreed to participate in the interviews. Their time, experience, and openness provided essential practical perspectives that significantly enriched this research.

Finally, I would like to express my deepest appreciation and thanks to my family for their unconditional encouragement, patience, and unwavering support throughout my academic journey. Their faith in me has been a constant source of motivation during the completion of this Master's thesis.

This thesis marks the conclusion of my studies at UCLouvain and represents an important milestone in my academic and professional journey. I am grateful to everyone who contributed, directly or indirectly, to making this achievement possible.

Table of content

ABSTRACT.....	2
ACKNOWLEDGMENTS	3
1 INTRODUCTION.....	1
1.1 CONTEXT.....	1
1.2 MOTIVATIONS	2
1.3 RESEARCH QUESTION.....	3
1.4 STRUCTURE OF THE THESIS.....	4
2 THEORY	4
2.1 CIRCULAR ECONOMY IN THE CONSTRUCTION SECTOR.....	5
2.1.1 <i>From the Linear Economy to the Circular Economy</i>	5
2.1.2 <i>The R-Strategies</i>	6
2.2 REUSE OF BUILDING COMPONENTS	7
2.3 INTERIOR PARTITION WALLS AS A CASE FOR CIRCULAR CONSTRUCTION	7
2.4 DESIGN FOR DISASSEMBLY	9
2.5 ECONOMIC ASSESSMENT OF CIRCULAR CONSTRUCTION	10
2.6 LIFE CYCLE COSTING	10
2.6.1 <i>Definition of Life Cycle Costing</i>	10
2.6.2 <i>Key Concepts of Life Cycle Costing</i>	11
2.7 REVIEW OF EXISTING RESEARCH.....	12
2.7.1 <i>Existing Research and Remaining Challenges</i>	12
2.7.2 <i>Increasing Need for Life-Cycle Decision Support</i>	13
3 EMPIRICAL RESEARCH	14
3.1 METHODOLOGY	14
3.1.1 <i>Buildwise</i>	14
3.1.2 <i>Expert interviews</i>	14
3.1.3 <i>Case study description</i>	15
3.1.4 <i>Baseline scenario development</i>	16
3.1.5 <i>Scope</i>	17
3.1.6 <i>Cost data collection</i>	18
3.1.7 <i>Overview of the Excel Model and Main Assumptions</i>	20
3.2 EXPERT FEEDBACK.....	22
3.3 RESULTS	23
3.3.1 <i>Construction costs results presentation</i>	24
3.3.2 <i>End of life cost results presentation</i>	24
3.3.3 <i>Scenario results presentation</i>	25
4 DISCUSSION	29
4.1 INTERPRETATION OF RESULTS	29
4.1.1 <i>Understanding construction cost differences</i>	29
4.1.2 <i>The influence of finishing materials on construction and refurbishment costs</i>	31
4.1.3 <i>Influence of Finishing Materials on End of life Costs</i>	32
4.1.4 <i>The Impact of Demountability on End-of-Life Costs</i>	33
4.1.5 <i>Comparison of the Three Refurbishment Scenarios</i>	34
4.2 MAIN FINDINGS.....	35
4.3 MANAGERIAL IMPLICATIONS	36
4.4 CONTRIBUTION TO RESEARCH	37
4.5 LIMITATIONS AND FUTURE RESEARCH DIRECTIONS	38
4.6 CONCLUSION	40
5 BIBLIOGRAPHY.....	43
6 APPENDICES.....	47

List of figures:

Figure 1: Illustration of Linear Economy Model (Dung & Hong, 2021).....	5
Figure 2: Illustration of Circular Economy Model (Taburiaux & Taburiaux, 2025).....	6
Figure 3: Example of an interior gypsum partition wall (Buildwise, n.d.)	8
Figure 4: Helicopter view of the complete model (Author, 2026).....	20
Figure 5: Net Present Value of the construction costs per m ² for the six partition wall systems	24
Figure 6: Net Present Value of end-of-life costs per m ² for the six partition wall systems	25
Figure 7: Net Present Value of Refurbishment costs per m ² under Baseline Scenario 1	25
Figure 8: Total life cycle costs per m ² under Baseline Scenario 1	26
Figure 9: Net Present Value of Refurbishment Costs per m ² under Baseline Scenario 1	27
Figure 10: Total life cycle costs per m ² under Baseline Scenario 2.....	27
Figure 11: Net Present Value of Refurbishment costs per m ² under Baseline Scenario 3.....	28
Figure 12: Total life cycle costs per m ² under Baseline Scenario 3.....	28
Figure 13: Net Present Value of end-of-life costs per m ² for the six partition wall systems with pattern.....	33
Figure 14: Layered composition of a conventional wall with plaster finish.....	59
Figure 15: Layered composition of a conventional wall with wood finish.....	60
Figure 16: Layered composition of a hybrid wall with plaster finish	61
Figure 17: Layered composition of a hybrid wall with wood finish.....	61
Figure 18: Layered composition of a demountable wall with plaster finish.....	62
Figure 19: Layered composition of a demountable wall with wood finish.....	62
Figure 20: Screenshot of financial assumptions used in LCC model	64
Figure 21 : Screenshot of construction costs worksheet used in model	65
Figure 22: Screenshot of demolition activities used in model	65
Figure 23: Screenshot of construction costs calculations.....	66
Figure 24: Screenshot of replacement costs calculations.....	66
Figure 25: Screenshot of refurbishment costs calculations	67
Figure 26: Screenshot of end of life cost calculations	68
Figure 27: Screenshot of disassembly factor calculation	69

List of tables:

Table 1: Characteristics of the Baseline Scenarios	17
Table 2: Acronyms Used for the Partition Wall Systems	23
Table 3: Average Construction Cost per Wall Layer by Cost Category (€/m ²).....	30
Table 4: Construction and Refurbishment Cost Components of the Four Finishing Layers (€/m ²).....	31
Table 5: Demolition Cost Components for Three End-of-Life Demolition Actions (€/m ²)	32
Table 6: Waste Processing Costs by Waste Stream and Collection Method (€/m ³)	33
Table 7: Non-discounted end of life labor costs for walls with plaster finish (€/m ²)	34
Table 8: Non-discounted end of life labor costs for walls with wood finish (€/m ²)	34

1 Introduction

1.1 Context

The construction sector plays a fundamental role in economic development by providing the infrastructure and buildings required to support modern societies. However, it is also associated with significant environmental challenges. The sector is one of the largest consumers of raw materials worldwide and is responsible for substantial waste generation throughout the construction, renovation and demolition phases of buildings (Akanbi et al., 2018; Ossio et al., 2023). In the European Union, construction and demolition activities account for approximately 35% of total waste generation, making the sector one of the largest waste producers (European Commission, n. d.). In Belgium, this figure reached in 2022 42% of total waste production, corresponding to nearly 26 million tonnes of waste annually (Statbel, 2025). As concerns regarding resource depletion and waste generation continue to grow, improving material efficiency and extending the useful life of construction products have become key objectives for both policymakers and industry stakeholders.

In response to these challenges, the concept of the circular economy has gained increasing attention in both policy and academic discussions. Unlike the traditional linear economic model, often described as “take-make-dispose”, the circular economy aims to maintain the value of products, materials and resources for as long as possible while minimizing waste generation (Buildwise, n.d.). Within the construction sector, this objective can be pursued through several strategies, including reuse, repair, refurbishment and recovery of building components. By extending the service life of materials and reducing the need for virgin resources, these approaches contribute to a more sustainable use of resources throughout the built environment (Ossio et al., 2023; Buildwise, n.d.).

Among these strategies, the reuse of building components has emerged as a promising solution for improving material circularity in construction. However, the successful implementation of reuse practices depends largely on how buildings and their components are designed. Conventional construction systems are often assembled in a manner that makes dismantling difficult, resulting in the loss of valuable materials at the end of their use phase. To overcome this limitation, the concept of Design for Disassembly (DfD) has been developed. DfD promotes the design of buildings and components that can be dismantled without significant damage, thereby facilitating their future recovery, reuse and reintegration into new construction projects (Rios et al., 2015).

Within this context, interior non-bearing partition walls constitute a particularly relevant case study. Unlike many structural building elements, partition walls are frequently modified during a building’s lifetime, especially in office and commercial environments where spatial requirements evolve over time. Changes in occupancy, organizational structures or building

functions often lead to the relocation, removal or replacement of existing partitions before they reach the end of their technical service life. Therefore, the present research investigates how circular construction principles can be implemented in practice through the economic assessment of interior partition wall systems. More specifically, the study compares three categories of partition walls: conventional, hybrid and fully demountable systems. Within each category, both plaster/gypsum-finished and wood-finished wall configurations are analysed. In addition, three refurbishment scenarios representing different frequencies of interior modifications are considered in order to evaluate how refurbishment frequency influences the economic performance of the different wall systems over their life cycle.

This master's thesis was carried out in collaboration with Buildwise, the Belgian innovation centre for the construction industry, whose mission is to support construction professionals through research, knowledge sharing and the development of innovative solutions for the built environment (Buildwise, n.d.). The collaboration was established within the framework of Buildwise's ongoing research activities on circular construction and the economic assessment of reusable and demountable building systems.

1.2 Motivations

Although the environmental benefits of reuse and circular construction practices are increasingly recognised (Minunno et al., 2020), their adoption within the construction sector remains limited. Several studies identify economic considerations as one of the main barriers to the implementation of circular economy principles in construction (Munaro & Tavares, 2023; Osei-Tutu et al., 2022). As construction decisions are largely driven by financial performance and investment viability, understanding the economic implications of circular construction solutions has become essential.

Not all building components, however, offer the same potential for circularity. Some elements, such as cast-in-place reinforced concrete, are inherently difficult to dismantle and reuse because they were not designed according to Design for Disassembly principles and this is not economically sustainable (Salama, 2017). By contrast, demountable partition wall systems are specifically designed to facilitate disassembly, reconfiguration and component reuse, making them economically promising candidates for the implementation of circular construction principles (Rios et al., 2015). Their frequent replacement during building refurbishments, despite often remaining technically functional, further increases their reuse potential.

Consequently, demountable partition wall systems have attracted growing attention from both researchers and industry stakeholders, including Buildwise. Several demountable solutions currently exist, relying on different construction techniques and finishing materials. Although these systems demonstrate clear technical feasibility (Juunoo, n.d.; Wonderwalls, n.d.), the extent to which they provide economic benefits throughout multiple life cycles remains

insufficiently understood. A comprehensive economic comparison is therefore needed to determine under which conditions these systems can become economically competitive (Jansen et al., 2020).

Among the different finishing materials available for partition wall systems, gypsum and wood were selected because they represent two of the most commonly used interior finishing solutions. Their different installation methods, labour requirements and reuse potential make them particularly relevant for assessing how material choice influences the economic performance of conventional and demountable wall systems.

This study therefore aims to develop a Life Cycle Costing model comparing six partition wall systems with different levels of demountability. Beyond its academic contribution, this project thesis is intended as a decision-support tool for practitioners. By comparing alternative wall solutions under different refurbishment scenarios, it provides architects, developers and other construction professionals with objective economic information to support the selection of partition wall systems throughout the building life cycle.

1.3 Research Question

The main objective of this research is to evaluate the economic competitiveness of demountable partition wall systems compared to conventional wall systems using a Life Cycle Costing approach. More specifically, based on Buildwise's expertise, the study selected six wall systems and analyses their performance under three identified refurbishment scenarios. Each case guiding the following specific sub-questions:

SQ1: How do the life cycle costs of demountable partition wall systems compare with those of conventional wall systems?

SQ2: At what refurbishment frequency does an adaptable partition wall system become more cost-effective than a conventional partition wall system over its life cycle.

SQ3: How do labour and material costs affect the total life cycle cost of different building material alternatives? (With case studies: gypsum boards and wood)

SQ4: How to calculate a good estimation of disassembly costs for demountable wall systems?

Those sub-questions support the main research question :

“To what extent can demountable partition wall systems become economically competitive compared to conventional wall systems when evaluated through a Life Cycle Costing approach?”

1.4 Structure of the thesis

Following the introduction, the thesis is organised as follows. The first part presents the theoretical foundations required to understand the research topic.

The second part presents the empirical research. First, the methodology adopted for this study is described, including the case study, the semi-structured interviews, the selected wall systems, the data sources, the assumptions made and the development of the simulation-based cost assessment model. Particular attention is given to the refurbishment scenarios used to evaluate the economic performance of conventional and demountable partition wall systems throughout their life cycle. The results obtained from both the interviews and the Life Cycle Costing model are then presented and compared across the different wall systems and refurbishment scenarios.

The final part is dedicated to the discussion and conclusion of the research. The results are interpreted in light of the research objectives, allowing for a better understanding of the conditions under which demountable partition wall systems may become economically competitive. The implications of the findings for practitioners and decision-makers are subsequently discussed, followed by an assessment of the study's limitations and recommendations for future research.

2 Theory

This first part of the thesis presents the theoretical foundations required to understand the research developed in the following chapters. It provides a review of the main concepts related to circular construction and establishes the conceptual framework on which the study is based.

The literature review is organised into six sections, following a progressive approach that moves from the broad context of the construction sector towards the specific concepts underlying this research. It begins by presenting the growing importance of the circular economy, it then introduces the concept of reuse of building components before focusing on interior partition walls as a particularly relevant application for circular construction. The following sections discuss the principles of Design for Disassembly (DfD) and building adaptability, before presenting the economic concepts required to evaluate circular construction solutions through a Life Cycle Costing (LCC) approach. Finally, the chapter concludes with a synthesis of the existing literature and identifies the research gap that motivates the present study.

2.1 Circular Economy in the Construction Sector

2.1.1 From the Linear Economy to the Circular Economy

For many decades, economic development has largely relied on a linear production model, commonly described as a "take-make-dispose" system. Under this model, natural resources are extracted, transformed into products, used for a limited period and ultimately discarded as waste. While this approach has supported industrial growth and improved living standards, it has also resulted in increasing resource consumption and waste generation, raising concerns regarding its long-term sustainability (Ellen MacArthur Foundation, 2013; Geissdoerfer et al., 2017).



Figure 1: Illustration of Linear Economy Model (Dung & Hong, 2021)

In response to these challenges, the concept of the circular economy has progressively emerged as an alternative to the traditional linear model. Although the concept originates from several schools of thought, it was largely popularised by the Ellen MacArthur Foundation and is now widely recognised as a key framework for achieving more sustainable patterns of production and consumption. While numerous definitions have been proposed, they all converge towards the same objective: maintaining the value of products, materials and resources within the economy for as long as possible while minimising waste generation (Ellen MacArthur Foundation, 2013; Geissdoerfer et al., 2017). Geissdoerfer et al. (2017) define the circular economy as *"a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing and narrowing material and energy loops."* Similarly, the Ellen MacArthur Foundation (2013) describes it as an economic system that is *restorative and regenerative by design*.

Within the built environment, these principles have led to the emergence of circular construction, an approach that seeks to optimise resource use throughout the entire life cycle of buildings by promoting more sustainable design, construction and end-of-life practices (Ossio et al., 2023; Van Stijn et al., 2021; Buildwise, n.d.).



Figure 2: Illustration of Circular Economy Model (Taburiaux & Taburiaux, 2025)

2.1.2 The R-Strategies

To operationalise the principles of the circular economy, the literature commonly refers to the hierarchy of R-strategies. Originally centred on the three well-known principles of Reduce, Reuse and Recycle, this framework has progressively evolved into more comprehensive classifications. Although several versions coexist in the literature, the 10R framework proposed by Reike et al. (2018) and further adopted by Jansen et al. (2020) is now among the most widely recognised approaches for describing circular resource management.

The ten strategies are organised according to their ability to preserve the value of products, components and materials, from the highest to the lowest level of value retention. In descending order of desirability, they are Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover (Reike et al., 2018; Jansen et al., 2020). At the top of the hierarchy, Refuse aims to avoid unnecessary resource consumption altogether, while Reduce seeks to minimise the use of virgin materials and waste generation. Reuse, which occupies one of the highest positions, keeps products in use for their original purpose with little or no transformation. Repair and Refurbish extend product lifetimes by restoring or improving their functionality, whereas Recycle recovers raw materials once higher-value options are no longer feasible. Finally, Recover, typically through energy recovery (waste incineration), represents the least preferred option as it results in the greatest loss of material value (Reike et al., 2018).

This hierarchy reflects the principle that the less a product is transformed, the more of its economic, functional and environmental value is retained. Consequently, strategies located at the top of the hierarchy are generally considered more effective in supporting the transition towards a circular economy than end-of-life solutions such as recycling or energy recovery.

Among these strategies, reuse occupies one of the highest positions within the hierarchy and is widely recognised as one of the most effective strategies for supporting the transition towards a circular construction sector (Minunno et al., 2020). As this thesis focuses on reusable interior partition wall systems, the following section specifically examines the concept of reuse and its application within the construction sector.

2.2 Reuse of Building Components

Reuse refers to the practice of employing a building component again for the same or a similar purpose without significantly altering its original form (Akanbi et al., 2018; Bertino et al., 2021). Unlike recycling, which transforms products into secondary raw materials before they can be used again, reuse preserves the functional characteristics of building components while avoiding additional manufacturing processes (Minunno et al., 2020; Sakthibala et al., 2025).

As a result, reuse provides several environmental, economic and social benefits. Extending the service life of building components reduces the demand for virgin materials, limits waste generation and creates new business opportunities related to material recovery, refurbishment and resale (Akanbi et al., 2018; Nußholz et al., 2019). According to Poncelet (2022), reuse also contributes to the development of local employment and circular business models while becoming increasingly attractive in the context of material shortages and rising construction costs. Nevertheless, despite these recognised advantages, only around 1% of construction products are currently reused after their first application, illustrating the considerable untapped potential of this strategy (Poncelet, 2022).

Despite growing interest from both researchers and policymakers, the implementation of reuse remains limited. The literature identifies several barriers, including fragmented supply chains, regulatory constraints, uncertain economic profitability, limited market demand and insufficient information regarding the quality and availability of reclaimed materials (Munaro & Tavares, 2023; Osei-Tutu et al., 2022). Furthermore, many existing buildings were not originally designed to allow components to be removed without damage, making recovery operations technically challenging and economically unattractive.

Overcoming these barriers requires considering reuse from the earliest stages of a building's life cycle. Practical measures such as reuse inventories, material traceability, dismantling tests and specialised marketplaces facilitate the identification, recovery and reintegration of reusable building components into new construction projects (Poncelet, 2022). More broadly, collaboration between stakeholders and design approaches that facilitate future disassembly are increasingly recognised as essential drivers for expanding reuse within the construction sector (Munaro & Tavares, 2023; Bertino et al., 2021).

2.3 Interior Partition Walls as a Case for Circular Construction

Interior partition walls are non-load-bearing building elements used to divide the interior space of a building into separate rooms or functional areas. Unlike structural walls, they do not contribute to the load-bearing system of the building and can therefore be modified or replaced without affecting its structural integrity. In addition to organising interior spaces, partition walls fulfil several functional requirements, including acoustic insulation, privacy, fire resistance and

aesthetic integration within the building (Mateus et al., 2013). Their non-structural nature makes them particularly adaptable to changing user requirements throughout a building's life cycle.



Figure 3: Example of an interior gypsum partition wall (Buildwise, n.d.)

The particular interest of interior partition walls within circular construction can be better understood through Stewart Brand's theory of Shearing Layers (Brand, 2007). According to this concept, buildings are composed of several layers that evolve at different rates over time, ranging from the long-lasting structure to rapidly changing interior elements. While structural components may remain in place for many decades, the Space Plan layer, which includes interior partition walls, is frequently modified to accommodate changing organisational, functional or architectural requirements. As a result, partition walls generally experience much shorter replacement cycles than most other building elements, despite often remaining technically functional.

This characteristic gives interior partition walls significant potential for reuse. Since they are regularly removed during refurbishment works rather than because they have reached the end of their technical service life, many of their components retain a considerable functional value (Brand, 2007). Recovering and reusing these elements therefore represents an opportunity to reduce the demand for virgin materials, limit construction waste generation and extend the service life of existing building products, in line with the principles of the circular economy discussed in the previous sections (Akanbi et al., 2018; Minunno et al., 2020). Mateus et al. (2013) further emphasise that lightweight partition systems offer greater flexibility and adaptability than traditional construction solutions, making them particularly suitable for buildings expected to undergo frequent interior modifications.

Two main approaches to partition wall construction can generally be distinguished. **Conventional partition wall systems** are typically designed as permanent building elements and often rely on construction techniques such as plastering, joint filling, adhesive bonding or non-reversible mechanical fixings that make dismantling difficult without damaging the individual components. As a result, walls are generally demolished rather than carefully disassembled at the end of their use phase. By contrast, **demountable partition wall systems**

are based on dry construction techniques and reversible mechanical connections that allow wall components to be removed, relocated and potentially reused with limited damage (Mateus et al., 2013; Rios et al., 2015). Their capacity to accommodate changing spatial requirements while preserving the integrity of building components makes them particularly relevant within a circular construction perspective.

The increasing interest in demountable partition wall systems reflects a broader shift from designing buildings solely for their initial use towards designing them for future adaptability and material recovery. This design philosophy forms the basis of the Design for Disassembly concept, which is presented in the following section.

2.4 Design for Disassembly

Design for Disassembly (DfD) is a design approach that considers the future disassembly of a building from the earliest stages of the design process. Instead of treating demolition as the inevitable end-of-life scenario, DfD anticipates that building components may one day need to be separated, relocated or replaced. Consequently, the ability to dismantle a building becomes an integral design objective rather than an operation considered only at the end of its service life (Crowther, 2005). This approach represents a shift from designing buildings solely for construction towards designing them for multiple life cycles.

To support this objective, Design for Disassembly relies on several design principles intended to facilitate future dismantling operations. Crowther (2005) highlights the importance of simplifying building assemblies, reducing unnecessary complexity and considering the sequence in which components will eventually be removed. Building on these principles, Rios et al. (2015) identify practical design solutions such as the use of reversible mechanical connections instead of adhesives or welded joints, modular and prefabricated elements, standardised components and adequate documentation describing materials and assembly methods. Together, these principles make disassembly operations more predictable, efficient and technically feasible.

By facilitating the separation of building components with limited damage, Design for Disassembly creates favourable conditions for recovering materials in a condition suitable for further use. In contrast to conventional construction techniques, where dismantling often results in the destruction of components, DfD preserves the functional integrity of building elements and therefore increases the opportunities for reuse within future construction projects (Rios et al., 2015). For this reason, Design for Disassembly is increasingly recognised as a key enabler of circular construction, bridging the gap between the theoretical principles of reuse and their practical implementation in the built environment.

2.5 Economic Assessment of Circular Construction

The transition towards circular construction has traditionally been driven by environmental considerations, with numerous studies demonstrating the potential of reuse, recycling and design for disassembly to reduce resource consumption, waste generation and greenhouse gas emissions (Minunno et al., 2020; Mangialardo & Micelli, 2018).

However, environmental benefits alone are not sufficient to ensure the large-scale adoption of circular construction practices. Decisions regarding the selection of construction systems are also influenced by economic considerations, as clients, contractors and investors must justify the financial viability of alternative solutions. As highlighted by Jansen et al. (2020), the transition towards a circular economy requires not only environmentally preferable solutions but also economically competitive business models. Likewise, Akanbi et al. (2018) argue that evaluating building components over their entire life cycle is essential to capture the long-term economic implications of circular strategies such as reuse.

Despite the growing use of Life Cycle Costing (LCC), investment decisions in the construction sector remain largely driven by the minimisation of initial investment costs rather than by the total cost incurred over a building's entire life cycle. When life cycle cost considerations are included, they generally focus on conventional cost categories such as operation, maintenance and replacement costs. However, the economic implications of future building adaptations, such as changes in user requirements, functional transformations or space reconfigurations, are rarely incorporated into economic assessments. As a result, investment decisions often overlook the potential long-term economic benefits associated with designing buildings for future adaptability (Woodward, 1997).

This need is particularly relevant for building components designed for multiple life cycles. Although reusable or demountable systems may involve different initial investment costs compared with conventional solutions, they may also generate savings through reduced replacement needs, lower waste management costs and the recovery of residual value at the end of their service life. Consequently, evaluating only the initial construction cost provides an incomplete basis for decision-making. Instead, Jansen et al. (2020) suggest that we should focus on an assessment considering costs over the entire life-cycle.

2.6 Life Cycle Costing

2.6.1 Definition of Life Cycle Costing

Life Cycle Costing (LCC) is a methodology developed to evaluate the total economic performance of an asset throughout its entire life cycle. Rather than focusing solely on the initial investment, LCC considers all relevant costs incurred from construction to the end of the

analysis period, thereby providing a more comprehensive basis for comparing alternative design solutions (International Organization for Standardization [ISO], 2008).

According to the ISO 15686-5 standard, Life Cycle Costing supports decision-making by identifying the solution that minimises the total cost over a predefined study period rather than simply selecting the option with the lowest acquisition cost. This perspective is particularly relevant in the construction sector, where many costs arise long after the initial construction phase and may significantly influence the overall economic performance of a building or one of its components (International Organization for Standardization [ISO], 2008). Buildwise similarly highlights that adopting a life cycle perspective enables stakeholders to better account for future maintenance, replacement and end-of-life costs when comparing conventional and circular construction solutions. Life Cycle Costing therefore provides a framework for integrating these future expenditures into a single economic assessment (Buildwise, n.d.)

2.6.2 Key Concepts of Life Cycle Costing

Applying the Life Cycle Costing methodology requires the definition of several key concepts that determine how costs are evaluated throughout the study period.

First, a distinction must be made between initial costs and life cycle costs. While the former correspond to the expenditure required to construct or acquire a building component, the latter encompass all costs incurred during the selected study period, including maintenance, replacement, refurbishment, end-of-life operations and any residual value remaining at the end of the analysis (International Organization for Standardization [ISO], 2008). Considering these additional cost categories is particularly important when comparing conventional and circular construction systems, as their economic performance may evolve differently over time (Buildwise, n.d.).

A second important concept is the service life of a building component. Since construction products rarely share the same lifespan, some components may require several interventions or replacements during the study period, whereas others remain in service throughout the entire analysis. Consequently, the frequency of replacement cycles becomes a major determinant of long-term economic performance (Akanbi et al., 2018; Van Stijn et al., 2021).

Finally, Life Cycle Costing also recognises that certain building components may retain an economic value after their first period of use. This residual value reflects the possibility that products or materials can still generate economic benefits through reuse, remanufacturing or recycling instead of being treated solely as waste (International Organization for Standardization [ISO], 2008; Bertino et al., 2021).

Because these different costs occur at different moments throughout the life cycle, they cannot be directly compared. Life Cycle Costing therefore relies on the principle of discounting,

through which future costs and revenues are converted into their present value using a discount rate. This allows all economic flows occurring during the study period to be expressed on a common monetary basis and combined into a single economic indicator, commonly referred to as the Net Present Value (NPV) (International Organization for Standardization [ISO], 2008).

$$NPV = Q \sum PV(t, C)$$

$$PV(t, C) = C \cdot \left(\frac{1 + r'_g}{1 + r'_d} \right)^t$$

NPV= Net present value

Q= quantity

PV= present cost value

C= current cost value

r'g= growth rate

r'd= discount rate

t= the moment of occurrence of the cost

Source: Formula provided by Jan Roekens (Buildwise)

2.7 Review of Existing Research

2.7.1 Existing Research and Remaining Challenges

Life Cycle Costing (LCC) has become an increasingly established methodology for evaluating the economic performance of construction systems from a whole-life perspective. Consequently, an increasing number of studies have adopted this methodology to support decision-making within the context of circular construction.

Existing research illustrates the diversity of LCC applications in the construction sector. Akanbi et al. (2018) integrated LCC into a Building Information Modelling (BIM)-based framework to evaluate the construction, reuse and end-of-life costs of reusable building components, demonstrating the potential of digital tools to support life-cycle decision-making. Van Stijn et al. (2021) combined LCC with circularity indicators to assess how design choices promoting adaptability and reuse influence the long-term economic performance of building components. At the material level, Biolek and Hanák (2019) applied LCC to compare alternative façade insulation systems, while Ahmed and Tsavdaridis (2018) combined LCC and Life Cycle Assessment (LCA – environmental assessment) to compare lightweight flooring systems. Together, these studies demonstrate that Life Cycle Costing provides a more comprehensive basis for comparing construction alternatives than considering initial construction costs alone.

Research has also progressively moved towards the assessment of circular partition wall systems. In one of the most comprehensive studies on this topic, Buyle et al. (2019) compared seven conventional and demountable internal wall assemblies within a Belgian context using both LCA and LCC. Their findings showed that demountable wall systems can become

economically and environmentally competitive when reuse is effectively implemented, while also highlighting the influence of refurbishment frequency and end-of-life assumptions on life-cycle performance. This study represents an important step towards understanding the economic implications of circular partition systems and demonstrates the relevance of life-cycle-based decision-making.

Despite these important contributions, several research opportunities remain. Most existing studies have primarily been developed as scientific case studies evaluating predefined construction systems under a specific set of assumptions. Comparatively less attention has been devoted to translating these methodologies into practical decision-support tools capable of comparing commercially available partition wall systems using industry-based cost data and project-specific refurbishment scenarios. Building upon the Life Cycle Costing framework developed in collaboration with Buildwise, the present research applies this methodology to six representative partition wall systems reflecting different levels of demountability in predefined refurbishment scenarios. In parallel, the study analyzes the impact of different finishing materials which are platster and wood. Beyond assessing their long-term economic performance, the study also aims to provide a practical decision-support model capable of assisting professionals in the construction sector during the material selection process.

2.7.2 Increasing Need for Life-Cycle Decision Support

Beyond the scientific literature, recent regulatory developments further reinforce the need for life-cycle-based assessment in the construction sector. The revised Energy Performance of Buildings Directive (EPBD) introduces the progressive assessment of the whole-life Global Warming Potential (GWP) of new buildings, making life-cycle considerations an increasingly important aspect of building design and procurement within the European Union (European Commission, n.d.). Although this requirement primarily concerns environmental performance, it reflects a broader shift towards decision-making based on whole-life building performance rather than initial construction costs alone.

As life-cycle assessment becomes progressively integrated into regulatory frameworks and procurement practices, construction professionals will increasingly require practical tools capable of comparing alternative design solutions from both environmental and economic perspectives. Within this context, Life Cycle Costing can complement environmental assessment by providing decision-makers with objective economic information over the entire building life cycle. The model developed in this research contributes to this objective by offering a structured approach for comparing alternative partition wall systems according to their long-term economic performance.

3 Empirical research

3.1 Methodology

3.1.1 Buildwise

As presented in the introduction, this research was carried out within the framework of Buildwise's ongoing activities on circular construction, with a particular focus on the economic assessment of reusable and demountable partition wall systems.

More specifically, this research was conducted in close collaboration with Jan Roekens, researcher at Buildwise, who was actively involved in the development of this research topic and designed the base of the model. Throughout the thesis, regular exchanges with Mr. Roekens contributed to refining the research objectives, discussing methodological choices and validating several modelling assumptions. His expertise also provided valuable insights into current practices, available technical data and the practical challenges associated with reusable partition wall systems.

The collaboration with Buildwise gave access to technical documentation, cost data and professional expertise that formed the basis for the development of the simulation-based life cycle cost model presented in this thesis.

3.1.2 Expert interviews

To complement the simulation-based analysis, two semi-structured interviews were conducted with experienced professionals who are regularly involved in construction projects requiring technical, material and cost-related decision-making. The objective was to confront the developed Life Cycle Costing model with professional experience and assess its practical relevance.

The first interview was conducted with Julien Bernar, Managing Director of BMGT, a Belgian landscaping and hardscaping company that works closely with residential developers such as Matexi. In addition to his professional activities, he is also involved in private real estate development projects. The second interview involved Gregory Chauviaux, real estate developer of ANROCH company, responsible for managing and coordinating residential construction projects, particularly in the Namur region.

During the interviews, the experts were presented with the objectives of the research and the simulation model developed in collaboration with Buildwise. Discussions focused on the realism of the modelling assumptions, the plausibility of the refurbishment scenarios, the relevance of the selected cost categories and the potential usefulness of such a decision-support tool in professional practice. The interviews also explored how material selection decisions are

currently made in construction projects and whether a life cycle cost perspective could support these decisions.

Although these interviews do not constitute a formal validation of the model, they provide valuable practitioner feedback regarding its credibility, realism and potential applicability within the construction sector. The interviews are provided in **Appendix 1: Interview Julien Bernar** and **Appendix 2: Gregory Chauviaux**.

3.1.3 Case study description

This research focuses on the economic comparison of six interior non-bearing partition wall systems composed of materials commonly used in the construction sector. Rather than analysing an existing building, the study compares alternative construction solutions that fulfill the same functional purpose while differing in their level of demountability and reuse potential. To ensure a meaningful comparison, all selected wall systems provide similar technical performances in terms of acoustic performance, allowing the analysis to focus on differences in construction techniques and life cycle costs rather than functional performance.

The six wall systems can be grouped into three categories representing different levels of demountability. For each of the categories we will compare a plaster finish solution with a wood finish solution. The first category consists of two conventional wall systems assembled using traditional construction methods and not designed for future disassembly or reuse:

- **Conventional Wall with plaster finish:** Hollow sand-lime masonry wall insulated with PUR insulation boards and finished on both sides with painted plaster. **(CWP)**
- **Conventional Wall with wood finish:** Gypsum block wall insulated with PUR insulation boards and finished on both sides with wooden cladding. **(CWW)**

The second category consists of two hybrid wall systems. Although these systems are not fully demountable, they incorporate construction features that allow a higher degree of disassembly than conventional walls. Some components can be recovered or reused during refurbishment operations, while other elements remain permanently integrated into the wall system.

- **Hybrid Wall with plaster finish:** Metal stud partition wall with rock wool insulation, OSB boards and screw-fixed gypsum plasterboards finished and painted. **(HWP)**
- **Hybrid Wall with wood finish:** Metal stud partition wall with rock wool insulation, OSB boards and wooden cladding on both sides. **(HWW)**

The third category consists of two fully demountable partition wall systems based on commercially available solutions developed by JUUNOO, a Belgian company specialising in modular interior partition systems. JUUNOO applies the principles of DfD through a patented telescopic metal stud system combined with dry construction techniques and reversible

mechanical connections. This design enables partition walls to be installed, dismantled and reconfigured without significantly damaging the individual components, thereby facilitating their potential reuse over multiple refurbishment cycles (JUUNOO, n.d.).

- **Demountable Wall with plaster finish:** Juunoo telescopic metal stud system with rock wool insulation and removable screw-fixed gypsum plasterboards. **(DWP)**
- **Demountable Wall with wood finish:** Juunoo telescopic metal stud system with rock wool insulation and removable (velcro) laminated wood finishing panels. **(DWW)**

Visual representations of the six wall setups are provided in **Appendix 3**: Visual representation of the six wall setups for visual understanding of their different layer compositions.

These six wall systems were selected because they represent different construction approaches while providing comparable technical performances. This diversity makes them particularly suitable for assessing how different design approaches influence the economic performance of partition wall systems over their life cycle.

The comparison considers the four main cost components included in the Life Cycle Costing model: construction costs, replacement costs, refurbishment costs and end-of-life costs. By evaluating each wall system across these cost components, the study aims to determine under which conditions demountable partition wall systems can become economically competitive compared with conventional construction solutions.

3.1.4 Baseline scenario development

The economic performance of partition wall systems depends not only on their initial construction costs but also on how frequently they are modified throughout a building's lifetime. Since buildings are subject to different levels of spatial adaptation depending on their function and occupancy, a single refurbishment frequency would not provide a representative assessment of the potential benefits of demountable construction systems.

To account for this variability, three baseline scenarios were developed. Rather than representing exact real-life situations, these scenarios simulate three different levels of building adaptability over the 60-year study period. During each refurbishment event, partition walls are assumed to be either demolished or dismantled, depending on the wall system (conventional or demountable), before being reconstructed or reassembled according to the characteristics of the selected construction solution.

Scenario 1 represents a highly adaptable building in which spatial layouts are frequently modified. This scenario is representative of environments such as commercial spaces, where changes of tenants, business activities or interior layouts regularly require the relocation or

reconstruction of partition walls. Consequently, refurbishment events occur at relatively short intervals, allowing the analysis under intensive transformation conditions.

Scenario 2 represents a building with a moderate level of spatial adaptation, such as a typical office building. Although the internal layout may evolve over time to accommodate organisational changes, these transformations occur less frequently than in commercial buildings. This intermediate scenario represents a balanced level of refurbishment.

Scenario 3 represents a relatively stable building in which spatial modifications are limited. In this case, partition walls remain in place for long periods and refurbishment mainly occurs during major building renovations or changes of use, such as the conversion of office space into residential units. This scenario reflects conditions under which the opportunities for dismantling and reusing partition walls are expected to be less frequent.

The objective of these baseline scenarios is to establish a first comparative framework for evaluating how refurbishment frequency influences the economic competitiveness of conventional, hybrid and fully demountable partition wall systems. By exposing each wall system to the same sequence of refurbishment events within a given scenario, the analysis isolates the influence of demountability on life cycle costs.

For the purpose of this research, refurbishment frequencies are distinguished between the inner layer and the outer layers of the partition wall systems. The outer layer correspond to the most exterior layers on each side, these mainly represent the renewal of wall finishes without altering the overall layout. Whereas the inner layers comprise all remaining wall layers and are affected whenever the building layout is modified. The refurbishment frequencies adopted for both the inner and outer layers are summarised in Table 1: Characteristics of the Baseline Scenarios.

Scenario	Building context	Inner layer refurbishment	Outer layer refurbishment
Scenario 1	Commercial building	Every 6 years	Every 3 years
Scenario 2	Office building	Every 10 years	Every 5 years
Scenario 3	Stable building	Every 40 years	Every 20 years

Table 1: Characteristics of the Baseline Scenarios

3.1.5 Scope

This study is limited to the economic assessment of interior non-bearing partition wall systems. Other building components, such as structural elements, façades, roofs and technical installations, are outside the scope of this research, as they are subject to different functional

requirements and life cycle characteristics. In addition, business-related considerations, such as market access, branding and commercial strategy, are outside the scope of this research.

The analysis focuses exclusively on the economic dimension of circular construction through a Life Cycle Costing approach. Environmental benefits, such as reducing waste generation and preserving material value and technical performances such as structural behaviour, fire resistance or acoustic performance are not evaluated either.

The cost assessment focuses on the life cycle stages considered to be the most relevant for comparing conventional and demountable partition wall systems, namely construction, replacement, refurbishment and end-of-life. Other cost categories commonly included in Life Cycle Costing studies, such as maintenance and repair, were deliberately excluded from the analysis because they are primarily influenced by the finishing materials and their specific maintenance regimes rather than by the systems' demountability. Including these costs would introduce differences unrelated to the research objective and detract from the cost components most directly affected by the level of demountability and reuse potential of the wall systems.

Finally, the conclusions of this study are limited to the six wall systems analysed and the assumptions adopted within the simulation model. Consequently, the results should not be interpreted as universally applicable to all construction systems or building contexts.

3.1.6 Cost data collection

The reliability of the simulation model developed in this study depends directly on the quality of the cost data used as input. Since all subsequent calculations and comparisons are based on these values, particular attention was paid to collecting, verifying and, where necessary, estimating the different cost parameters.

The primary source of cost data was the ASPEN cost database provided by Buildwise (ASPEN, 2020). This database contains detailed cost information for a wide range of construction materials and activities commonly used in both new construction and renovation projects. For each building component, costs are systematically divided into three categories: material costs, labour costs and equipment costs. In addition, the ASPEN documentation also provides demolition costs for the different construction materials, allowing both installation and end-of-life activities to be incorporated into the Life Cycle Costing model. Since all cost data were obtained from the ASPEN document, which is based on 2020 prices, the reference year of the study was set to 2020.

The technical service life of the various building components was obtained from the OVAM report *Technical Service Life of Building Components* (OVAM, 2018). This report compiles

reference service lives for a wide range of construction materials, providing a consistent basis for modelling replacement events throughout the 60-year study period.

Unlike conventional wall systems, the cost data required for the JUUNOO-based wall systems were not fully available in the ASPEN database. To obtain the material costs of these demountable systems, JUUNOO was first contacted directly. The company subsequently redirected the study to one of its official distribution partners, Eurabo, from whom the prices of the different components composing the JUUNOO wall systems were obtained (Eurabo, n.d.).

Estimating the labour costs of the JUUNOO wall systems proved to be considerably more challenging, as no publicly available reference data existed. For the wall system finished with laminated wood panels, labour costs were estimated using an installation video published by JUUNOO (JUUNOO, 2021). The video presents a side-by-side comparison between the installation of a conventional drywall partition and a JUUNOO demountable partition. According to the video, the construction of a conventional plasterboard wall, including the installation of the metal studs, plasterboards and finishing works, requires approximately 2 hours and 36 minutes, whereas a 9 m² JUUNOO wall is assembled in approximately 20 minutes, including around 10 minutes for installing the telescopic metal studs and 10 minutes for mounting the finishing wood panels. Since this video was produced for commercial purposes and aims to demonstrate the speed of the JUUNOO system, the installation time was considered likely to represent optimal working conditions. Following discussions with Jan Roekens from Buildwise, a conservative approach was therefore adopted by multiplying the reported installation time by three in order to better represent the performance of a contractor with no previous experience of the JUUNOO technology. The resulting installation time was then combined with an hourly labour rate of €40 per hour. This labour rate was based on industry information published by Vertuoza (Vertuoza, n.d.) and was independently confirmed through discussions with Julien Bernar. Based on these assumptions, labour costs per square metre were calculated for the JUUNOO wall system finished with laminated wood panels. In addition, no equipment costs were assigned to this wall system, as the installation process does not require any specialised equipment.

For the JUUNOO wall system finished with gypsum plasterboards, a different approach was adopted. Since the installation of the telescopic metal stud for the wall with plaster finish system remains identical as the installation of the telescopic metal stud for the wall with wood finish, the labour cost estimated for the JUUNOO supporting structure with wood finish was retained. However, the installation of the gypsum plasterboards and their finishing was assumed to follow conventional construction practices. Consequently, the corresponding labour, material and equipment costs were directly taken from the ASPEN database (ASPEN, 2020).

For all cost data that were not collected in the reference year (2020), the original values were converted to their 2020 equivalent using the Belgian ABEX construction price index (Association belge des Experts, n.d.)

3.1.7 Overview of the Excel Model and Main Assumptions

This section provides an overview of the Excel-based Life Cycle Costing model designed by Buildwise and used throughout this research. Rather than describing every calculation performed within the model, it presents its main components and the principal assumptions underlying the analysis. The objective is to provide the reader with a clear understanding of the overall modelling approach adopted to compare the six partition wall systems. More detailed descriptions of the different worksheets, calculation procedures and modelling assumptions are provided in **Appendix 4: Complete explanation of the Excel-based LCC model**. Figure 4 presents a helicopter view of the complete model and illustrates the logic applied to calculate the life cycle costs of each wall system.

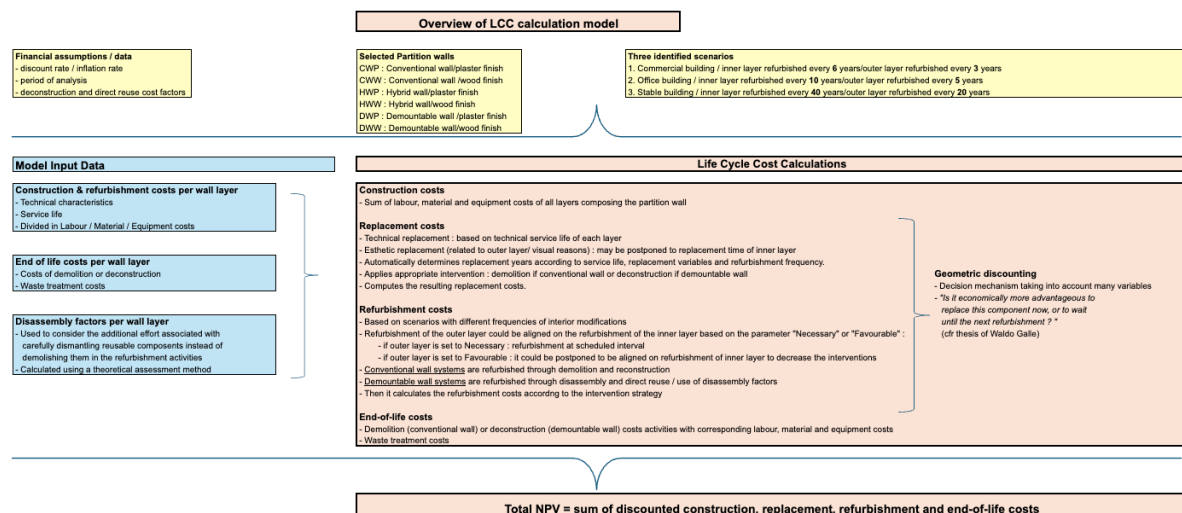


Figure 4: Helicopter view of the complete model (Author, 2026)

A bigger scaled version of this helicopter view is available in **Appendix 5 : Helicopter view of the complete model**

i) Financial assumptions

The Excel model relies on a set of financial assumptions that serve as the basis for all Life Cycle Costing calculations. These include the discount rate, the inflation rate and the 60-year study period adopted throughout the analysis. In addition, the model incorporates several cost factors to estimate life-cycle activities for which no direct cost data were available. These factors express the costs of activities such as deconstruction or direct reuse relative to the demolition or initial construction costs respectively. Although alternative assumptions could

influence the numerical results, the selected values were chosen to represent realistic construction practices.

ii) Model input data

The model centralises all input data required for the calculations. For each wall layer, collected construction and refurbishment costs are divided in labour, material and equipment costs. The End-of-Life Costs per Wall Layer represents all cost data associated with the final stage of the life cycle, i.e. the costs of demolition or deconstruction activities and the corresponding waste treatment costs for each material stream. Finally, a Disassembly Factors per Wall Layer is used to estimate the additional labour required to carefully dismantle reusable components instead of demolishing them. It is calculated using the theoretical Disassembly Potential Measurement Method developed by Van Vliet et al. (2021) to which the reader is referenced to in **Appendix 4**: Complete explanation of the Excel-based LCC model.

iii) Life Cycle Costing Calculations

The core of the Excel model consists of the Life Cycle Costing calculations, which determine the Net Present Value (NPV) of each partition wall system.

Construction costs are first calculated by summing the labour, material and equipment costs of every wall layer composing the selected partition wall system. This provides the initial construction cost per square metre. **Replacement costs** are then determined according to the technical service life assigned to each wall layer. The model distinguishes between technical replacement, based on the technical service life of each material, and esthetic replacement, which applies to the exterior finishing layer and is due to visual reasons. This esthetic type of replacement allows the outer layer to be postponed to the replacement time of inner layers when scheduled shortly afterwards. Based on the service life and replacement settings, the model automatically determines the timing of replacement interventions before applying either demolition or deconstruction depending on the wall category. The corresponding replacement costs are then calculated. **Refurbishment costs** are estimated based on the selected refurbishment scenario, representing different frequencies of interior modifications. Depending on the decision setting assigned to the outer layer (Necessary or Favourable), its refurbishment may either occur at the scheduled interval or be postponed to coincide with the refurbishment of the inner layer, thereby reducing the number of interventions. Once the intervention timing has been determined, conventional wall systems are refurbished through demolition and reconstruction strategy, whereas demountable wall systems follow a strategy based on disassembly and direct reuse. The refurbishment costs are then calculated according to the selected intervention strategy. Finally, **end-of-life costs** represent the last stage of the analysis. At the end of the study period, the model applies either demolition or deconstruction activities before assigning the corresponding waste treatment costs for each material stream.

The replacement and refurbishment calculations are supported by a **geometric discounting** decision mechanism based on the work of Galle (2016). Rather than automatically replacing materials as soon as they reach the end of their technical service life, this mechanism evaluates whether it is economically preferable to replace a component immediately or postpone the intervention until the next refurbishment. To support this decision, the model simultaneously considers several parameters, including the technical service life of the material, its replacement variables, the refurbishment frequency and the refurbishment decision variables.

The overall Net Present Value (NPV) of each partition wall system is finally obtained by summing the discounted construction, replacement, refurbishment and end-of-life costs.

3.2 Expert Feedback

The semi structured interviews were conducted to confront the proposed Life Cycle Costing model with professional practice and to assess whether its assumptions and overall structure were considered realistic by practitioners regularly involved in material selection decisions. Beyond evaluating the model itself, the interviews also provided an opportunity to better understand the current decision-making process in the construction sector and the practical challenges associated with the adoption of reusable building components.

A first observation emerging from both interviews is that material selection remains primarily driven by initial investment costs. Although both experts acknowledged the importance of considering costs over the entire life cycle, they explained that long term considerations are rarely integrated into decision making because of the uncertainty surrounding the future evolution of buildings. Julien Bernar particularly insisted on this point, explaining that practitioners generally focus on meeting the immediate requirements of a project, as it is difficult to anticipate how a building will be used or transformed several decades later. Gregory Chauviaux expressed a similar opinion, noting that professionals are also frequently faced with technically equivalent solutions without having sufficient information to determine which option will be the most advantageous over the long term. These observations support the relevance of developing decision support tools capable of integrating future building transformations into the material selection process.

Both experts also expressed genuine interest in the research topic and considered the proposed model to be relevant for professional practice. They agreed that the overall structure of the model is coherent, that the calculation logic is easy to understand and that the three refurbishment scenarios represent realistic levels of building flexibility. Gregory Chauviaux further highlighted that the model could facilitate discussions with clients by providing an objective economic comparison between alternative wall systems, and while Julien Bernar considered that this type of tool is likely to become increasingly useful as circular construction practices continue to develop.

The interviews also enabled the refinement of certain modelling assumptions, especially the inflation rate which was first set to 0,7%. As both experts considered this value too conservative, the inflation assumption was revised to 3% in the final version of the model.

Beyond the validation of the model, the interviews also highlighted several barriers to the wider adoption of reusable partition systems. Both experts agreed that reuse cannot become common practice without changes extending beyond the technical performance of the wall systems themselves. Gregory Chauviaux mainly emphasised the logistical dimension, explaining that dismantling, transporting and storing reusable components must remain economically viable. He also pointed out that reuse will only become practical if a sufficiently developed market exists, allowing supply and demand for reusable materials to meet efficiently. Julien Bernard on the other hand insisted that the sector still requires recognized standards and certification procedures to increase confidence in reused materials, while their adoption will also depend on a broader change in practices and mindsets within the construction industry.

Overall, the interviews confirmed the plausibility of the proposed modelling approach while strengthening its practical relevance.

3.3 Results

This section presents the results obtained from the Life Cycle Costing simulation model developed for the six partition wall systems. The objective of this chapter is to present the results in a descriptive manner by highlighting the main trends observed in the simulation outputs. The interpretation of these findings and their relationship to the research question are examined later in the Discussion chapter.

Given the large number of figures and repeated comparisons presented throughout this chapter, the following acronyms presented in *Table 2* are used for the six wall systems to improve the readability of the graphs and the accompanying text:

Acronym	Wall system
CCP	Conventional wall with plaster finish
CWW	Conventional wall with wood finish
HWP	Hybrid wall with plaster finish
HWW	Hybrid wall with wood finish
DWP	Demountable wall with plaster finish
DWW	Demountable wall with wood finish

Table 2: Acronyms Used for the Partition Wall Systems

A consistent colour scheme is also used throughout the figures to distinguish wall setups with plaster finishes (**beige**) from those with wood finishes (**orange-brown**).

The complete composition of each wall system is presented in **Appendix 3**: Visual representation of the six wall setups to which the reader is referred for a detailed description of the construction systems considered in this study.

Before presenting the results obtained for each baseline scenario, it is useful to examine the cost categories that remain identical throughout the analysis. Since construction costs and end-of-life costs are independent of the refurbishment frequency adopted in the different scenarios, their Net Present Values (NPVs) remain unchanged across all three baseline scenarios.

3.3.1 Construction costs results presentation

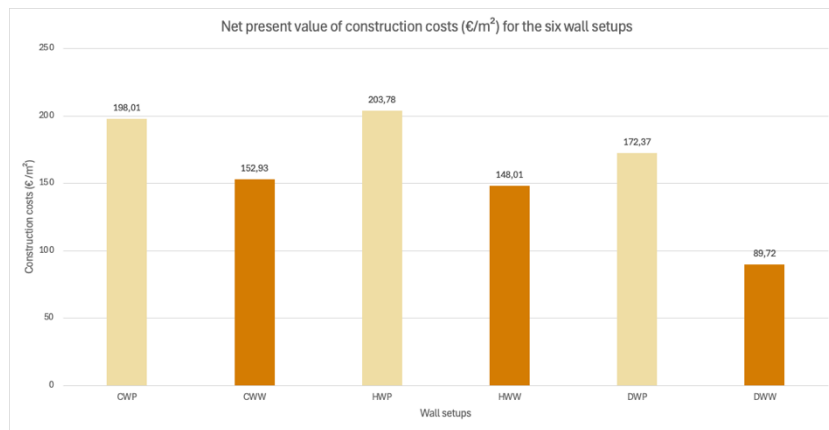


Figure 5: Net Present Value of the construction costs per m² for the six partition wall systems

Among the six wall systems illustrated in Figure 5, **HWP** exhibits the highest construction cost, with an NPV of **203,78 €/m²**, closely followed by **CWP** at **198,01 €/m²**. **DWP** occupies an intermediate position with a construction cost of **172,37 €/m²**, while **CWW** and **HWW** present lower values of **152,93 €/m²** and **148,01 €/m²**, respectively. The lowest construction cost is observed for **DWW**, with an NPV of **89,72 €/m²**, making it the least expensive wall system at the construction stage.

3.3.2 End of life cost results presentation

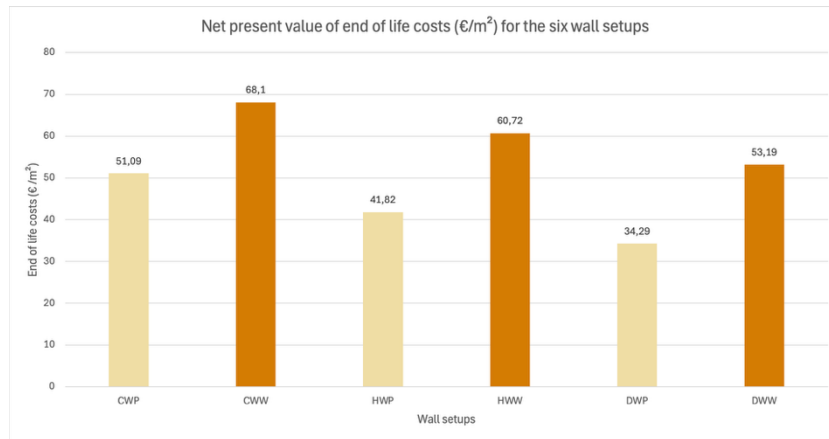


Figure 6: Net Present Value of end-of-life costs per m² for the six partition wall systems

Figure 6 shows that the highest end-of-life cost is observed for **CWW**, with an NPV of **68,1 €/m²**, followed by **HWW** at **60,72 €/m²**. **DWW**, **CWP** and **HWP** present intermediate values ranging from approximately **41,82 €/m²** to **53,19 €/m²**, while **DWP** records the lowest end-of-life cost at **34,29 €/m²**.

3.3.3 Scenario results presentation

This section focuses on the cost categories that are directly influenced by the three baseline scenarios. For each of these scenarios, the refurbishment and the total life cycle costs are presented. Refurbishment costs are expected to vary according to the frequency of building modifications simulated in each scenario and therefore constitute the main source of variation between the different analyses. The total life cycle costs combines all life cycle components and provides the overall economic performance of each wall system under the corresponding refurbishment conditions. The results are presented separately for each baseline scenario before being compared and interpreted in the Discussion chapter.

i) Scenario 1 results (*Commercial building with high frequency of refurbishment*)

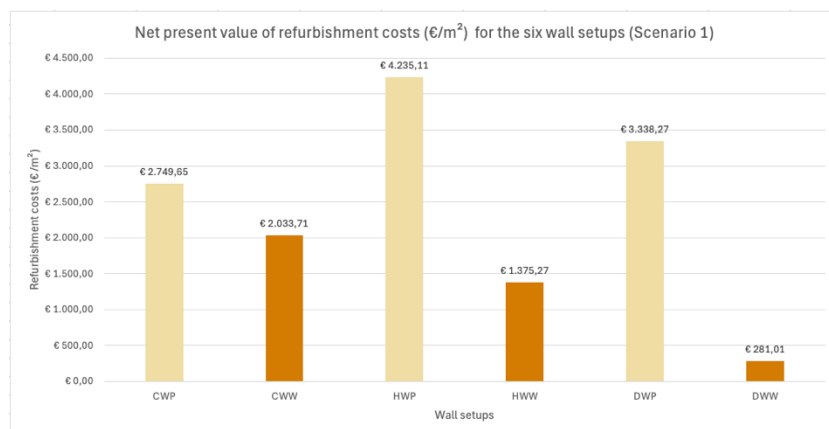


Figure 7: Net Present Value of Refurbishment costs per m² under Baseline Scenario 1

Among the six solutions illustrated in Figure 7, **HWP** records the highest refurbishment cost, reaching **4235,11 €/m²**, followed by **DWP** (**3338,27 €/m²**) and **CWP** (**2749,65 €/m²**). **CWW** and **HWW** present intermediate values of **2033,71 €/m²** and **1375,27 €/m²**, respectively. By contrast, **DWW** exhibits by far the lowest refurbishment cost, with an NPV of only **281,01 €/m²**, representing a substantial difference compared with all other wall systems.

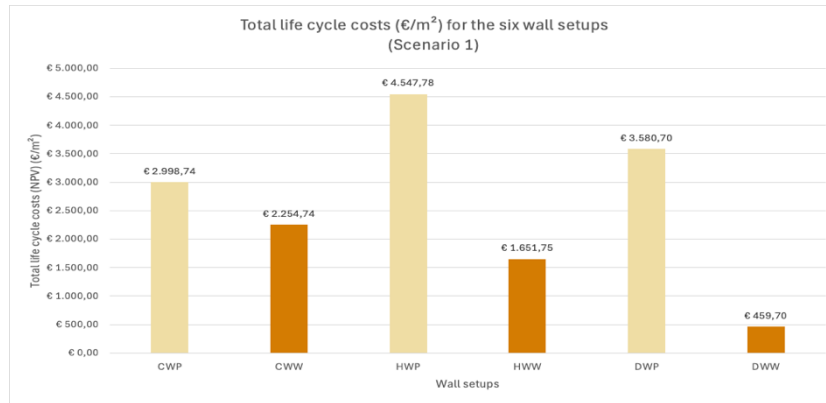


Figure 8: Total life cycle costs per m² under Baseline Scenario 1

The ranking of the wall systems presented in Figure 8 closely follows the one observed for the refurbishment costs shown above. **HWP** presents the highest total life cycle costs, amounting to **4547,78 €/m²**, followed by **DWP** (**3580,7 €/m²**) and **CWP** (**2998,74 €/m²**). **CWW** and **HWW** achieve costs of **2254,74 €/m²** and **1651,75 €/m²**, respectively. Once again, **DWW** records the lowest total life cycle cost, with a total NPV of **459,7 €/m²**.

A comparison between Figures 7 and 8 further indicates that refurbishment costs constitute a major component of the total life cycle costs in **Baseline Scenario 1**. Consequently, the overall ranking of the wall systems in terms of total life cycle costs closely mirrors the ranking observed for the refurbishment costs.

ii) Scenario 2 results (*Office building with medium frequency of refurbishment*)

The second baseline scenario represents an intermediate level of building adaptability, with refurbishment events occurring less frequently than in Scenario 1.

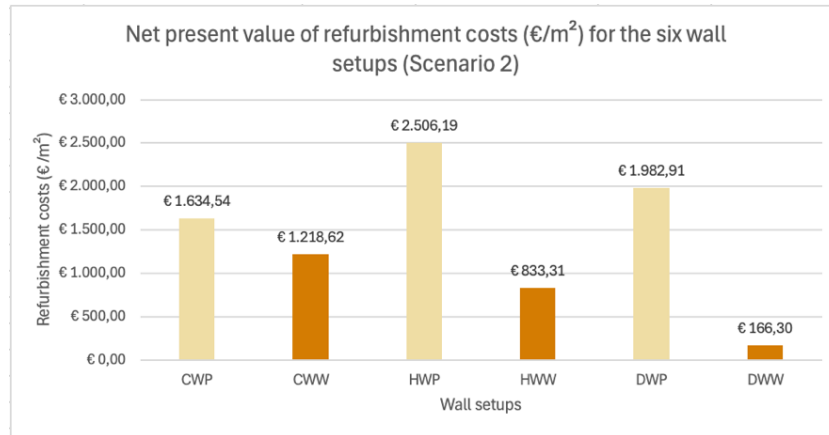


Figure 9: Net Present Value of Refurbishment Costs per m² under Baseline Scenario 1

As expected, refurbishment costs presented in Figure 9 are lower for all wall systems than those observed in Scenario 1 due to the reduced frequency of refurbishment events. Nevertheless, the overall ranking of the six wall systems remains unchanged.

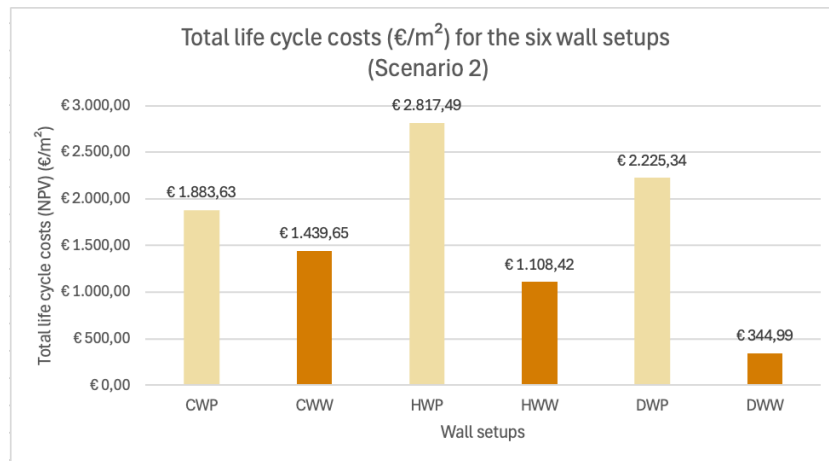


Figure 10: Total life cycle costs per m² under Baseline Scenario 2

Figure 10 presents the total life cycle costs per square metre under **Baseline Scenario 2**. Once again, the overall ranking remains identical to that observed for the refurbishment costs. **HWP** exhibits the highest total LCC (**2817,49 €/m²**), followed by **DWP** (**2225,34 €/m²**) and **CWP** (**1883,63 €/m²**). **CWW** and **HWW** reach total NPVs of **1439,65 €/m²** and **1108,42 €/m²**, respectively, whereas **DWW** remains the least expensive wall system with a total NPV of only **344,99 €/m²**. Similar to Scenario 1, the close correspondence between the refurbishment costs and the total LCC indicates that refurbishment remains the dominant component of the overall life cycle costs. However, its relative contribution is lower than in Scenario 1, which is expected given the lower refurbishment frequency.

iii) Scenario 3 results (*Stable building with low frequency of refurbishment*)

The third baseline scenario represents the lowest level of building adaptability, with refurbishment events occurring only occasionally throughout the 60-year study period.

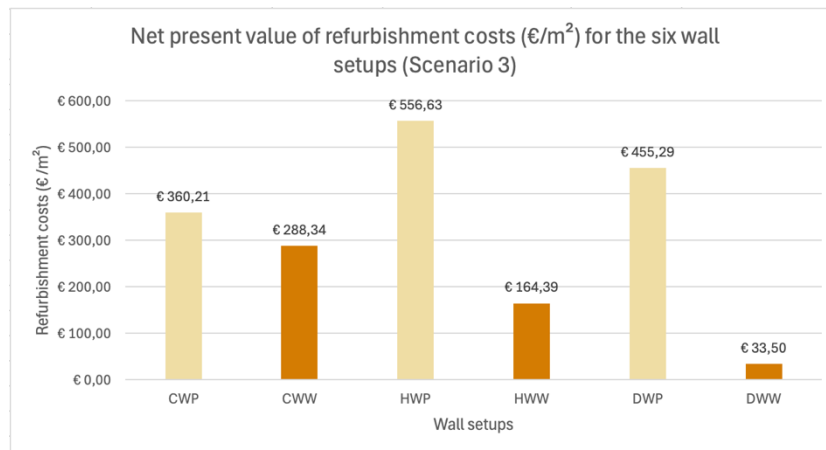


Figure 11: Net Present Value of Refurbishment costs per m² under Baseline Scenario 3

As anticipated, looking at Figure 11 refurbishment costs decrease further for all wall systems compared with Scenarios 1 and 2, reflecting the lower frequency of refurbishment events. The same ranking is observed despite the reduction in costs. **HWP** records the highest refurbishment cost at **556,63 €/m²**, while **DWW** once again records the lowest refurbishment cost at only **33,5 €/m²**.

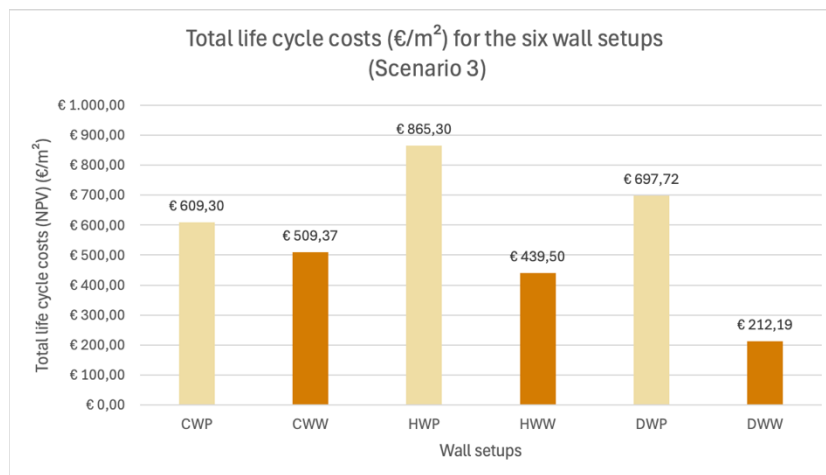


Figure 12: Total life cycle costs per m² under Baseline Scenario 3

Similar to the previous scenarios, the overall ranking of the wall systems follows that of the refurbishment costs. According to Figure 12, **HWP** exhibits the highest total life cycle costs (**865,3 €/m²**), followed by **DWP** (**697,72 €/m²**) and **CWP** (**609,3 €/m²**). Then again **CWW** at **509,37 €/m²**, and **HWW** **439,5 €/m²**, **DWW** remains the least expensive wall system with a total NPV of **212,19 €/m²**. Although the ranking continues to reflect the refurbishment costs, their contribution to the total life cycle costs is considerably smaller than in the previous two scenarios. As a result, refurbishment costs no longer dominate the total NPV to the same extent, even though they remain an important cost component.

iv) Impact of the Finishing Material on Life Cycle Costs

Within each construction category (conventional, hybrid and demountable), a consistent pattern is observed with respect to the finishing material. In each category, the wall system finished with wood exhibits lower construction costs, lower refurbishment costs and lower total life cycle costs than its counterpart finished with plaster. This relationship is consistent across all three baseline scenarios.

An opposite trend is observed for the end-of-life costs. Within each construction category, the wall system finished with wood consistently presents higher end-of-life costs than its plaster-finished counterpart.

4 Discussion

4.1 Interpretation of results

This section discusses the main findings of the study and explains the economic mechanisms underlying the observed results.

It should be noted, however, that the interpretations presented in this section are specific to the case study developed in this research. The results are based on the six partition wall systems analysed, the assumptions adopted in the economic model and the selected refurbishment scenarios. Consequently, the conclusions drawn should not be considered directly applicable to all partition wall systems or building contexts, but rather as insights derived from the specific conditions investigated in this study.

4.1.1 Understanding construction cost differences

At first glance, one could reasonably expect fully demountable partition wall systems, which rely on more advanced construction techniques and are specifically designed according to Design for Disassembly principles, to present higher construction costs than conventional wall systems. However, the results obtained in this study do not follow this expected trend. On the contrary, the **DWW wall setup exhibits the lowest construction cost among the six wall systems analysed**, with a Net Present Value of 89,72 €/m², considerably lower than all the other wall configurations (*Figure 5*).

To better understand this result, Table 3 presents the average labour, material and equipment costs per wall layer for each wall system. The results show that DWW exhibits one of the highest average material costs per wall layer (19,55 €/m²), which could suggest that its innovative construction technology relies on more expensive materials than the other wall systems. Despite this, DWW remains the least expensive wall system to construct. This seemingly contradictory result is explained by its exceptionally low average labour cost per wall layer. At only 2,88 €/m², its average labour cost is substantially lower than any other wall setup's average labour costs. **The savings achieved through installation therefore outweigh**

the higher material costs, resulting in the lowest overall construction cost among the six wall systems.

A second interesting observation concerns the comparison between the conventional and hybrid partition wall systems which have the highest construction costs. **As shown in Figure 5, the construction costs of both wall categories are remarkably similar despite their different configurations.** The plaster-finished systems, CWP and HWP, exhibit construction costs of 198,01 €/m² and 203,78 €/m², respectively, while the wood-finished systems, CWW and HWW, amount to 152,93 €/m² and 148,01 €/m².

These similarities may appear surprising. As illustrated in Table 3, the average labour and material costs are systematically higher for the conventional wall systems than for their hybrid counterparts. For instance, CWP presents labour and material costs of 35,96 €/m² and 13,55 €/m², compared with only 26,02 €/m² and 7,87 €/m² for HWP. A similar pattern can be observed for the wood-finished wall systems, where both labour and material costs are also higher for CWW than for HWW.

The explanation lies in the composition of the wall systems. Although the individual layers of the hybrid wall systems are generally less expensive than those of the conventional wall systems, hybrid wall systems contain a greater number of layers. The hybrid wall setups consist of six layers, whereas the conventional wall setups contain only four. Consequently, **the lower average construction cost per wall layer is largely offset by the additional layers that need to be installed, resulting in very similar overall construction costs between the two wall categories.**

Wall setup	Labour cost	Material cost	Equipment cost
CWP	35,96 €/m ²	13,55 €/m ²	0 €/m ²
CWW	17,3 €/m ²	20,94 €/m ²	0 €/m ²
HWP	26,02 €/m ²	7,87 €/m ²	0,07 €/m ²
HWW	12,8 €/m ²	11,87 €/m ²	0 €/m ²
DWP	29,43 €/m ²	13,55 €/m ²	0,11 €/m ²
DWW	2,88 €/m ²	19,55 €/m ²	0 €/m ²

Table 3: Average Construction Cost per Wall Layer by Cost Category (€/m²)

An additional observation emerging from the analysis concerns the relative importance of construction costs within the overall life cycle cost of partition wall systems. As also highlighted in previous Life Cycle Costing studies, the initial construction cost represents only a fraction of the total costs incurred over the building life cycle. Consequently, comparing wall systems solely on the basis of their construction costs may lead to incomplete conclusions regarding their overall economic performance. A comprehensive Life Cycle Costing approach is therefore essential to capture the full range of costs associated with construction, refurbishment and end-of-life activities.

4.1.2 The influence of finishing materials on construction and refurbishment costs

A general trend observed throughout the results is that, consistently, within each wall category, **partition wall systems incorporating wood finishes systematically exhibit lower construction and refurbishment costs than those using gypsum-based finishes.**

This difference can be explained by examining the construction and refurbishment cost components of the four finishing layers used in the analysed wall systems. As shown in Table 4, **both gypsum-based finishing layers (Plaster coating and Gypsum cladding) are characterised by substantially higher labour costs than the two wood-based finishing layers (Finishing wooden plates – Juunoo and Wood cladding)** for both construction and refurbishment activities. This is **mainly due to the installation process**, which requires several additional operations for plaster coating and gypsum cladding, including joint filling, plastering, sanding and painting. Whereas, wood finishing panels are installed as finished products and therefore require fewer installation steps, resulting in considerably lower labour costs. However, Table 4 also shows that the two **wood-based finishing layers are associated with substantially higher material costs than the gypsum-based finishing layers.** While both wood finishing layers require material costs of €24.03/m², the material costs of the gypsum-based finishing layers are approximately €12/m².

Wall setup	4 finishing layers	Construction costs			Refurbishment costs		
		Labour	Material	Equipment	Labour	Material	Equipment
CWP	Plaster coating	45,29€/m ²	12,22€/m ²	0€/m ²	49,31€/m ²	12,22€/m ²	0€/m ²
HWP DWP	Gypsum cladding	55,24€/m ²	12,04€/m ²	0,21€/m ²	62,49€/m ²	12,71€/m ²	0,21€/m ²
DWW	Finishing wooden plates – Juunoo	2,14€/m ²	24,03€/m ²	0€/m ²	2,42€/m ²	24,03€/m ²	0€/m ²
CWW HWW	Wood cladding	15,58€/m ²	24,03€/m ²	0€/m ²	16,96€/m ²	24,03€/m ²	0€/m ²

Table 4: Construction and Refurbishment Cost Components of the Four Finishing Layers (€/m²)

How, then, can gypsum-finished wall systems systematically exhibit higher construction and refurbishment costs than wood-finished wall systems when each finishing type is more expensive in either labour or material?

The explanation lies in the relative magnitude of the two cost components. Although wood-based finishing layers are associated with higher material costs, gypsum-based finishing layers

require considerably more labour for both installation and refurbishment. **Since the difference in labour costs is substantially greater than the difference in material costs, the labour component has a stronger influence on the total cost. Consequently, wall systems incorporating wood finishes consistently present lower construction and refurbishment costs than those incorporating gypsum-based finishes.**

4.1.3 Influence of Finishing Materials on End of life Costs

As highlighted in the results section, an opposite trend is observed for the end-of-life costs. While partition wall systems incorporating wood finishes systematically exhibit lower construction and refurbishment costs, they consistently present higher end-of-life costs than their gypsum-based counterparts within each wall category.

This trend can be explained by examining the different cost components included in the end-of-life stage. End-of-life costs are determined by two main elements. First, demolition costs define the labour and equipment costs required to remove the finishing layer. Second, waste processing costs determine the material costs associated with treating the resulting waste streams.

Table 5 presents the demolition cost components associated with the different demolition actions used to model the removal of the finishing layers. A clear difference can be observed in the labour costs required for demolition. Removing the wood cladding requires labour costs of 31.16 €/m², approximately twice as high as those associated with removing gypsum plastering (14.96 €/m²) or screwed plasterboard cladding (15.58 €/m²). By contrast, equipment costs remain negligible, with only mechanical removal of gypsum plastering requiring a small equipment cost of 0.65 €/m².

Wall setup	Demolition actions	Demolition prices		
		Labour	Material	Equipment
HWP DWP	Plasterboard cladding — demolition of screwed plasterboard panel	15,58 €/m ²	0 €/m ²	0 €/m ²
CWP	Mechanical removal of gypsum plastering	14,96 €/m ²	0 €/m ²	0,65 €/m ²
CWP HWP DWP	Breaking off multiplex board cladding	31,16 €/m ²	0 €/m ²	0 €/m ²

Table 5: Demolition Cost Components for Three End-of-Life Demolition Actions (€/m²)

Table 6 presents the waste processing costs associated with wood and gypsum waste streams. Although these costs appear relatively high when expressed per cubic meter, they become negligible once converted to a square metre basis because the finishing layers are very thin. Consequently, the material cost associated with waste processing represents only a very small share of the total end-of-life cost.

Overall, the results indicate that end-of-life costs are driven almost entirely by labour costs, while material and equipment costs have only a marginal influence. **Since removing wood finishing layers requires substantially more labour than removing gypsum-based finishing layers, partition wall systems incorporating wood finishes systematically exhibit higher end-of-life costs.**

Different waste stream	Material processing prices	
	Mixed (demolition)	Sorted (deconstruction)
Wood	25 €/m ³	3 €/m ³
Gypsum	43 €/m ³	24 €/m ³

Table 6: Waste Processing Costs by Waste Stream and Collection Method (€/m³)

4.1.4 The Impact of Demountability on End-of-Life Costs

An observation emerging from the results concerns the relationship between the degree of demountability and the end-of-life costs. Within both finishing categories, a clear pattern can be identified: **the more demountable the partition wall system, the lower its end-of-life costs.** This trend can be observed for both gypsum-finished walls (CWP → HWP → DWP) and wood-finished walls (CWW → HWW → DWW), where each increase in demountability is associated with a reduction in end-of-life costs (*Figure 13*).

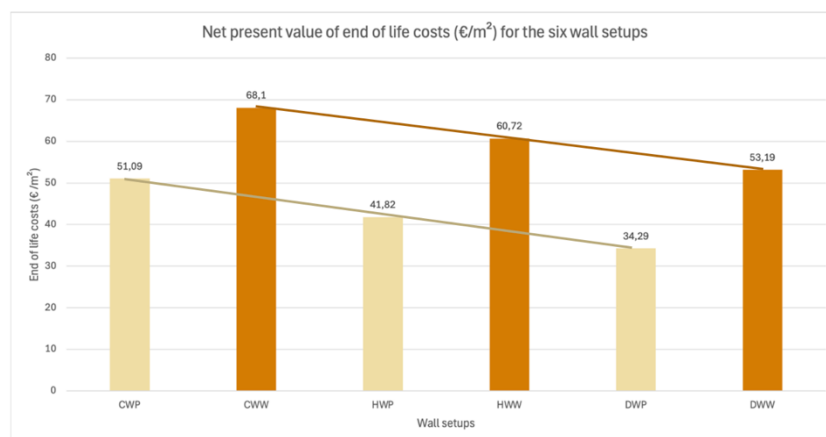


Figure 13: Net Present Value of end-of-life costs per m² for the six partition wall systems with pattern

This trend can first be explained by the labour required during demolition. As discussed in the previous section, labour costs represent the main component of the end-of-life costs. As illustrated in Table 7 and 8, **the non-discounted end-of-life labour costs decrease**

consistently as the level of demountability increases, regardless of the finishing material. This indicates that dismantling increasingly demountable wall systems requires less labour than demolishing conventional solutions. Consequently, the reduction in labour requirements constitutes the main driver behind the lower end-of-life costs observed for demountable partition wall systems.

Non discounted end of life labor costs for walls with plaster finish (labour + waste treatment)	
CWP	79,81 €/m ²
HWP	73,74 €/m ²
DWP	60,37 €/ m ²

Table 7: Non-discounted end of life labor costs for walls with plaster finish (€/m²)

Non discounted end of life labor costs for walls with wood finish (labour +waste treatment)	
CWW	111,83 €/m ²
HWW	108,02 €/m ²
DWW	94,64 €/m ²

Table 8: Non-discounted end of life labor costs for walls with wood finish (€/m²)

A second explanation relates to the way materials are handled at the end of a building's life. As wall systems become more demountable, their different components can be separated more easily, resulting in cleaner and more homogeneous waste streams. Such waste streams are simpler to manage and generally require less treatment than mixed demolition waste, thereby reducing end-of-life costs.

4.1.5 Comparison of the Three Refurbishment Scenarios

A comparison of the three refurbishment scenarios reveals a remarkably consistent ranking of the six partition wall systems. Regardless of the refurbishment frequency considered, the order of the refurbishment costs remains unchanged throughout the analysis. From the highest to the lowest refurbishment cost, the ranking is consistently: **HWP → DWP → CWP → CWW → HWW → DWW**.

This stable ranking also highlights the **strong influence of the finishing material**. In each scenario, the wall systems incorporating gypsum plaster finishes systematically present the highest refurbishment costs. Once these systems have been ranked, the remaining positions are occupied by the wood-finished wall systems, with the conventional solution (CWW) exhibiting higher refurbishment costs than the hybrid solution (HWW), while the fully demountable solution (DWW) consistently remains the least expensive. This pattern can largely be explained

by the labour costs associated with the different finishing materials. As discussed previously, gypsum plaster finishes require substantially higher labour inputs during refurbishment activities than wood-based finishes, making them systematically more expensive across all wall categories.

A second observation concerns the effect of refurbishment frequency. As expected, increasing the number of refurbishment interventions leads to higher refurbishment costs for all wall systems. However, although the absolute costs increase from one scenario to the next, this increase does not modify the relative economic performance of the different wall systems. In other words, more frequent refurbishments amplify the refurbishment costs of every wall configuration while preserving the same ranking across all three scenarios.

4.2 Main findings

1. The economic competitiveness of demountable partition wall systems depends on both their level of demountability and the compatibility of the selected finishing materials with Design for Disassembly principles.

Although both gypsum- and wood-based partition wall systems can be designed for disassembly, the results show that their economic performance differs considerably. This difference is primarily explained by the finishing techniques associated with each material. Gypsum boards require several labour-intensive operations, including joint filling, plastering, sanding and painting, which increase construction, refurbishment and replacement costs while reducing the economic benefits of demountability. In contrast, wood cladding is inherently compatible with dry and reversible construction methods, allowing components to be installed, removed and reused with considerably less labour. These findings suggest that maximising the economic benefits of Design for Disassembly requires not only demountable structural systems but also finishing materials that are themselves compatible with circular construction principles.

2. Contrary to initial expectations, increasing refurbishment frequency did not alter the relative economic competitiveness of the analysed wall systems.

One of the most surprising outcomes of the Life Cycle Costing analysis is that the relative ranking of the six wall systems remained unchanged across all three refurbishment scenarios. While more frequent refurbishments naturally increased the total life cycle costs of every solution, they did not modify their relative economic competitiveness. This suggests that the comparative performance observed in this study is robust across the refurbishment scenarios considered and is primarily determined by the characteristics of the wall systems themselves.

3. Wall system complexity, particularly the number of construction layers, emerged as an important determinant of economic performance.

Beyond material selection and demountability, the analysis highlights the influence of wall system complexity on life cycle costs. Systems composed of a greater number of construction layers generally require additional installation, dismantling and replacement operations, leading to higher labour requirements throughout the building life cycle. The comparison between conventional and hybrid wall systems illustrates that even when individual materials are less expensive, the cumulative impact of additional layers can offset these savings and reduce overall economic competitiveness. Although this observation cannot be generalised to every construction system, it suggests that reducing unnecessary complexity may improve both economic performance and the ease of future disassembly.

4. Material selection should be based on a life cycle perspective rather than on initial construction costs alone, requiring a shift from short-term project thinking towards long-term building thinking.

The interviews revealed that material selection is still largely driven by initial construction costs and the immediate requirements of individual projects. The professionals interviewed acknowledged that they rarely consider how a building may evolve over the next forty to sixty years because future adaptations remain difficult to predict during the design phase. However, the Life Cycle Costing simulations demonstrate that evaluating wall systems solely on their construction costs provides only a partial assessment of their economic performance. By integrating construction, replacement, refurbishment and end-of-life costs, the proposed model provides a more representative evaluation of long-term competitiveness. Adopting such an approach therefore requires not only a different decision-support tool but also a broader change in mindset, encouraging professionals to consider buildings as evolving assets whose future transformations should already influence present-day design decisions.

5. The transition towards reuse depends on more than technical performance.

The interviews highlighted that several external barriers continue to limit the widespread adoption of reuse practices, including the limited availability of secondary material markets, the absence of standards and certification procedures, logistical challenges and the need for changes in current design practices. Demountable partition wall systems therefore represent only one component of the transition towards circular construction, which also requires supportive organisational, regulatory and market conditions.

4.3 Managerial implications

Beyond its academic contribution, this research provides a practical business decision-support tool for professionals involved in the construction sector. Rather than recommending a specific

partition wall system, the proposed Life Cycle Costing model enables decision-makers to compare different wall solutions by considering not only their initial construction costs, but also their refurbishment, replacement and end of life costs. Although the model was developed using six specific partition wall systems, its methodology can easily be adapted to other wall configurations, cost assumptions or refurbishment scenarios. It therefore provides a structured framework to support more informed and transparent decision-making throughout the building life cycle for professionals. While the model has demonstrated its practical applicability, it should be regarded as a research prototype rather than a fully developed professional tool. With further refinement, it has the potential to become a practical decision-support tool for construction professionals. Future developments could focus on improving its usability through a more intuitive interface, consistent language throughout the workbook, a dedicated user guide, user training and increased automation. Such improvements would facilitate its adoption and integration into professional decision-making processes.

The Life Cycle Costing model developed as part of this research is available at the following link:

<https://docs.google.com/spreadsheets/d/18jlYaTswvKOILfNrFhsQlWx6G1Lx7Wfv/edit?usp=sharing&ouid=113340432282120294471&rtpof=true&sd=true>

4.4 Contribution to research

This research contributes to the existing literature on circular construction and Life Cycle Costing in several ways.

First, the findings reinforce previous research highlighting the importance of adopting a life-cycle perspective when evaluating circular construction solutions. While numerous authors have emphasised that circular construction has primarily been assessed from an environmental perspective (Mangialardo & Micelli, 2018; Minunno et al., 2020), this study confirms the relevance of complementing these assessments with an economic evaluation based on Life Cycle Costing. In line with Jansen et al. (2020) and Akanbi et al. (2018), the results demonstrate that considering only the initial construction cost provides an incomplete basis for decision-making, as refurbishment frequency, end-of-life costs and residual value can substantially influence the overall economic performance of partition wall systems.

This research confirms and further extends the findings of Buyle et al. (2019), who demonstrated the economic potential of demountable partition wall systems through a Life Cycle Costing approach. Building on this work, the present study broadens the analysis by comparing six representative partition wall systems reflecting different levels of demountability across multiple refurbishment scenarios. Beyond assessing the long-term economic

performance of these systems, the research develops a structured Life Cycle Costing approach that enables the comparison of alternative partition wall solutions under different project conditions. In addition, the results provide new empirical insights into the influence of finishing materials on the reuse potential and economic performance of partition wall systems, highlighting the advantages of wood-based finishes over conventional gypsum-based solutions in a circular construction context.

Beyond these theoretical contributions, the main contribution of this research is managerial. Whereas previous studies have primarily focused on scientific case studies developed under predefined assumptions, this research translates Life Cycle Costing principles into a practical decision-support model that can support material selection in real construction projects. Rather than recommending a single partition wall system, the proposed model enables practitioners to compare alternative solutions according to their construction costs, refurbishment costs, end-of-life costs and residual value under different refurbishment scenarios. Although the model was developed using six representative partition wall systems, its methodology can easily be adapted to alternative wall configurations, different cost assumptions or project-specific scenarios. In this sense, the principal contribution of this research lies not only in the economic results obtained, but also in providing a structured and reproducible framework that supports more informed decision-making and establishes a foundation for the future development of more advanced digital decision-support tools for the construction sector.

4.5 Limitations and future research directions

Although this research contributes to the understanding of the economic viability of demountable partition wall systems, several limitations should be considered when interpreting its findings. At the same time, these limitations highlight opportunities for future research to further develop the proposed Life Cycle Costing model, strengthen its practical applicability and extend the current knowledge on circular construction practices.

1. Scope of the analysed wall systems

The first limitation concerns the range of partition wall systems included in the analysis. The research was focused on six specific partition wall systems, which limits the extent to which the results can be generalised to all partition wall solutions available on the market. Furthermore, the two fully demountable wall systems analysed in this research are both based on the construction technology developed by JUUNOO. While using an existing commercial system strengthens the practical relevance of the study, it also means that the results may not be representative of other demountable partition wall technologies currently available.

To address this limitation, future research could extend the analysis by applying the proposed Life Cycle Costing model to a wider variety of partition wall systems. Applying the model to additional manufacturers, construction techniques and material combinations would further validate its applicability and provide a broader evidence base for assessing the economic performance of circular partition wall systems.

2. Simplifying Assumptions and estimated cost data

A second limitation concerns the simplifying assumptions adopted throughout the Life Cycle Costing model. Several assumptions were required to ensure a consistent comparison between the different wall systems, including the use of multiplication factors to estimate deconstruction and direct reuse activities, refurbishment scenarios, as well as key economic parameters such as the discount rate and inflation rate. Although these assumptions were necessary to establish a comparable analytical framework, different assumptions could lead to different economic outcomes.

A related limitation concerns the availability of cost data. Although the majority of the costs used in this research were obtained from professional construction cost databases, certain cost components had to be estimated due to the absence of reliable market data. These estimates were based on the best information available and were intended to reflect realistic construction practices as closely as possible. Nevertheless, estimated values may differ from the actual costs observed in real construction projects and therefore introduce a degree of uncertainty into the results.

Future research could further refine the methodological assumptions and strengthen the economic database supporting the model. As more projects involving demountable partition wall systems are completed, future studies could validate and refine the assumptions underlying the model, progressively replace estimated values with observed project data, and incorporate a broader range of cost sources, thereby improving the accuracy and reliability of the model.

3. Scope of the Life Cycle Costing Model

The proposed Life Cycle Costing model does not include every cost and value component that may occur throughout the life cycle of partition wall systems. In particular, maintenance and repair costs were excluded from the analysis in order to keep the model focused on the cost components most relevant to the comparison of the selected wall systems. Furthermore, the model does not account for the potential residual value that demountable partition wall systems may retain at the end of a building's life compared with conventional wall systems. Although these aspects were beyond the scope of this research, their omission means that the proposed model does not capture the full economic implications associated with long-term building adaptability and material recovery.

Future research could therefore broaden the scope of the model by integrating additional cost and value components, including maintenance and repair costs, transportation and storage costs associated with reusable components, and the residual value generated through their resale on secondary markets. Such developments would provide a more comprehensive representation of the long-term economic performance of partition wall systems and further improve the model's usefulness as a decision-support tool.

4. Economic Perspective Only

Finally, this research evaluates partition wall systems exclusively from an economic perspective. Although Life Cycle Costing provides valuable insights into their long-term financial performance, other important aspects, such as environmental impacts or social considerations, were not included in the assessment. Consequently, the results should be interpreted as one element of the decision-making process rather than as a complete evaluation of the overall sustainability of partition wall systems.

Beyond the development of the Life Cycle Costing model itself, future research could adopt a broader ecosystem perspective by investigating the organisational, institutional and behavioural factors influencing the adoption of reusable construction solutions. Although this research demonstrates the economic potential of demountable partition wall systems, the large-scale implementation of reuse also depends on the willingness of architects, contractors, clients, manufacturers and policymakers to adopt circular construction practices. Better understanding the interactions between these stakeholders could provide valuable insights into the barriers and drivers shaping the transition towards a more circular construction sector.

5. Future development of the proposed model

Beyond the research directions discussed above, future work could focus on transforming the proposed Life Cycle Costing model into a user-friendly digital decision-support tool. While the present model was intentionally developed as an Excel-based research prototype to evaluate the economic competitiveness of partition wall systems, integrating its methodology into dedicated software applications or Building Information Modelling (BIM) environments would considerably enhance its practical applicability. Such developments could automate data entry, facilitate scenario analyses, improve accessibility for construction professionals and ultimately support the integration of life cycle thinking into routine material selection decisions.

4.6 Conclusion

This research was conducted in collaboration with Buildwise with the objective of evaluating the economic competitiveness of demountable partition wall systems compared with conventional wall systems using a Life Cycle Costing approach. To achieve this objective, six

representative wall systems reflecting different levels of demountability were analysed under three refurbishment scenarios. In addition to the Life Cycle Costing assessment, semi-structured interviews with construction professionals were conducted to complement the quantitative analysis and provide practical insights into the applicability of the proposed model. The following section revisits each of the research sub-questions before providing a final answer to the main research question.

SQ1: How do the life cycle costs of demountable partition wall systems compare with those of conventional wall systems?

The results show that demountable partition wall systems are not systematically more cost-effective than conventional solutions. Their economic competitiveness depends largely on both their level of demountability and the compatibility of the selected finishing materials with Design for Disassembly principles. While some demountable systems achieved the lowest life cycle costs, others remained less competitive than conventional alternatives.

SQ2: At what refurbishment frequency does an adaptable partition wall system become more cost-effective than a conventional partition wall system over its life cycle?

Contrary to the initial hypothesis, increasing refurbishment frequency did not modify the relative economic ranking of the analysed wall systems. Although more frequent refurbishments increased life cycle costs for all systems, the comparative competitiveness of each wall system remained unchanged throughout the three scenarios.

SQ3: How do labour and material costs affect the total life cycle cost of different building material alternatives?

Labour costs proved to be a major determinant of life cycle cost competitiveness. The comparison between gypsum and wood finishing materials showed that labour-intensive finishing operations associated with gypsum significantly increase construction and refurbishment costs, whereas wood finishes generally require fewer interventions throughout the building life cycle.

SQ4: How can disassembly costs be estimated for demountable partition wall systems?

The proposed methodology demonstrates that disassembly costs can be estimated by applying a disassembly factor to the construction costs of each element. This factor reflects the additional effort required for disassembly by considering several characteristics of the wall system, including the type of connections, the accessibility of these connections, and other parameters affecting the ease of disassembly. As detailed in the *Disassembly Factor* section of **Appendix 4**: Complete explanation of the Excel-based LCC model, this approach provides a structured and transparent method for estimating disassembly costs based on construction costs.

Overall, this research demonstrates that demountable partition wall systems can indeed become economically competitive compared with conventional wall systems when evaluated through a Life Cycle Costing approach. However, this competitiveness is not universal and depends on several interacting factors rather than on demountability alone. The results show that the level of demountability, the compatibility of finishing materials with Design for Disassembly principles, the complexity of the wall assembly and the associated labour requirements throughout the building life cycle all play a decisive role in determining the economic performance of partition wall systems.

Beyond the quantitative findings, the interviews revealed that adopting a Life Cycle Costing approach also requires a broader shift in professional decision-making. Material selection should no longer rely solely on initial construction costs but should instead consider the long-term economic performance of building components throughout their entire life cycle. Finally, while this research demonstrates that certain demountable partition wall systems can offer clear economic advantages, their widespread adoption will ultimately depend on developments that extend beyond technical performance. The transition towards reuse also requires appropriate market conditions, regulatory support, standardisation and changes in professional practices to fully realise the potential of circular construction.

.

5 Bibliography

Ahmed, I. M., & Tsavdaridis, K. D. (2018). Life cycle assessment (LCA) and cost (LCC) studies of lightweight composite flooring systems. *Journal Of Building Engineering*, 20, 624-633. <https://doi.org/10.1016/j.jobbe.2018.09.013>

Akanbi, L. A., Oyedele, L. O., Akinade, O. O., Ajayi, A. O., Delgado, M. D., Bilal, M., & Bello, S. A. (2017). Salvaging building materials in a circular economy : A BIM-based whole-life performance estimator. *Resources Conservation And Recycling*, 129, 175-186. <https://doi.org/10.1016/j.resconrec.2017.10.026>

ASPEN. (2020). Regionale bouwkosten. Gebouwen voor bewoning [Unpublished internal document]

Association belge des Experts. (n.d.). Indice ABEX. <https://abex.be/indice-abex/>

Bertino, G., Kisser, J., Zeilinger, J., Langergraber, G., Fischer, T., & Österreicher, D. (2021). Fundamentals of Building Deconstruction as a Circular Economy Strategy for the Reuse of Construction Materials. *Applied Sciences*, 11(3), 939. <https://doi.org/10.3390/app11030939>

Biolek, V., & Hanák, T. (2019). LCC estimation model: A construction material perspective. *Buildings*, 9(8), 182. <https://doi.org/10.3390/buildings9080182>

Buildwise. (n. d.). À propos de Buildwise • Faites connaissance avec votre centre innovant. <https://www.buildwise.be/fr/a-propos-de-buildwise/>

Buildwise. (n.d.). *Dry wall & ceilings*. <https://buildwise.com.na/dry-wall-amp-ceilings/>

Buildwise. (n. d.). L'économie circulaire dans la construction. <https://www.buildwise.be/fr/themes/construction-durable/l-economie-circulaire-dans-la-construction/>

Buildwise. (n.d.). Méthodologie de référence belge pour le Circular Life Cycle Costing dans les marchés publics (PRN C-LCC). Consulté le 31 juillet 2026, sur

<https://www.buildwise.be/fr/recherche-innovation/showroom-des-projets/methodologie-de-reference-belge-pour-le-circular-life-cycle-costing-dans-les-marches-publics-prn-c-lcc/>

Buyle, M., Galle, W., Debacker, W., & Audenaert, A. (2019). Sustainability assessment of circular building alternatives : Consequential LCA and LCC for internal wall assemblies as a case study in a Belgian context. *Journal Of Cleaner Production*, 218, 141-156. <https://doi.org/10.1016/j.jclepro.2019.01.306>

Crowther, P. (2005). DESIGN FOR DISASSEMBLY – THEMES AND PRINCIPLES. *Environment Design Guide*, 1–7. <http://www.jstor.org/stable/26149108>

Dung, N. T. P., & Hong, T. H. (2021). *Circular economy policies of some Asian countries and recommendations for Vietnam*. https://www.researchgate.net/publication/356887454_Circular_Economy_Policies_of_Some_Asian_Countries_and_Recommendations_for_Vietnam

Ellen MacArthur Foundation. (2013). Towards the circular economy: Economic and business rationale for an accelerated transition (Vol. 1). Ellen MacArthur Foundation. <https://content.ellenmacarthurfoundation.org/m/27265af68f11ef30/original/Towards-the-circular-economy-Vol-1.pdf>

European Commission. (n.d.). Energy performance of buildings directive. Directorate-General for Energy. https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/energy-performance-buildings-directive_en

European Commission. (s. d.). Internal Market, Industry, Entrepreneurship And SMEs. https://single-market-economy.ec.europa.eu/industry/sustainability/buildings-and-construction_en?ettrans=fr&prefLang=fr

Galle, W. (2016). Scenario Based Life Cycle Costing, an enhanced method for evaluating the financial feasibility of transformable building. VUBIR (Vrije Universiteit Brussel). <https://doi.org/10.13140/rg.2.2.16926.02884/1>

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm ? *Journal Of Cleaner Production*, 143, 757-768. <https://doi.org/10.1016/j.jclepro.2016.12.048>

International Organization for Standardization. (2008). ISO 15686-5:2008. Buildings and constructed assets — Service-life planning — Part 5: Life-cycle costing. International Organization for Standardization. <https://www.iso.org/standard/61148.html>

Jansen, B. W., Van Stijn, A., Gruis, V., & Van Bortel, G. (2020). A circular economy life cycle costing model (CE-LCC) for building components. *Resources Conservation And Recycling*, 161, 104857. <https://doi.org/10.1016/j.resconrec.2020.104857>

JUUNOO. (2021, 9 avril). JUUNOO vs Drywall : build & dismantle [Vidéo]. YouTube. <https://www.youtube.com/watch?v=J2ZmbwiWhyQ>

JUUNOO. (n.d.). Solid Wall Partitions | JUUNOO. <https://juunoo.com/solid-walls/>

Mangialardo, A., & Micelli, E. (2018). Rethinking the Construction Industry Under the Circular Economy : Principles and Case Studies. Green Energy And Technology, 333-344. https://doi.org/10.1007/978-3-319-75774-2_23

Mateus, R., Neiva, S., Bragança, L., Mendonça, P., & Macieira, M. (2013). Sustainability assessment of an innovative lightweight building technology for partition walls – Comparison with conventional technologies. Building And Environment, 67, 147-159. <https://doi.org/10.1016/j.buildenv.2013.05.012>

Minunno, R., O'Grady, T., Morrison, G. M., & Gruner, R. L. (2020). Exploring environmental benefits of reuse and recycle practices : A circular economy case study of a modular building. Resources Conservation And Recycling, 160, 104855. <https://doi.org/10.1016/j.resconrec.2020.104855>

Munaro, M. R., & Tavares, S. F. (2023). A review on barriers, drivers, and stakeholders towards the circular economy : The construction sector perspective. Cleaner And Responsible Consumption, 8, 100107. <https://doi.org/10.1016/j.clrc.2023.100107>

Nußholz, J. L., Rasmussen, F. N., & Milios, L. (2019). Circular building materials : Carbon saving potential and the role of business model innovation and public policy. Resources Conservation And Recycling, 141, 308-316. <https://doi.org/10.1016/j.resconrec.2018.10.036>

Osei-Tutu, S., Ayarkwa, J., Osei-Asibey, D., Nani, G., & Afful, A. E. (2022). Barriers impeding circular economy (CE) uptake in the construction industry. Smart And Sustainable Built Environment, 12(4), 892-918. <https://doi.org/10.1108/sasbe-03-2022-0049>

Ossio, F., Salinas, C., & Hernández, H. (2023). Circular economy in the built environment : A systematic literature review and definition of the circular construction concept. Journal Of Cleaner Production, 414, 137738. <https://doi.org/10.1016/j.jclepro.2023.137738>

OVAM. (2018). *Technische levensduur van gebouwcomponenten*. <https://ovam.vlaanderen.be/>

Poncelet. (2022). Buildwise Article 2022-06.08. Buildwise. <https://www.buildwise.be/fr/publications/articles-buildwise/2022-06.08/>

Reike, D., Vermeulen, W. J., & Witjes, S. (2017). The circular economy : New or Refurbished as CE 3.0 ? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. Resources Conservation And Recycling, 135, 246-264. <https://doi.org/10.1016/j.resconrec.2017.08.027>

Rios, F. C., Chong, W. K., & Grau, D. (2015). Design for Disassembly and Deconstruction - Challenges and Opportunities. *Procedia Engineering*, 118, 1296-1304. <https://doi.org/10.1016/j.proeng.2015.08.485>

Sakthibala, R., Vasanthi, P., Hariharasudhan, C., & Partheeban, P. (2025). A critical review on recycling and reuse of construction and demolition waste materials. *Cleaner Waste Systems*, 12, 100375. <https://doi.org/10.1016/j.clwas.2025.100375>

Salama, W. (2017). Design of concrete buildings for disassembly : An explorative review. *International Journal Of Sustainable Built Environment*, 6(2), 617-635. <https://doi.org/10.1016/j.ijsbe.2017.03.005>

Statbel. (2025). *Waste generation*. Statistics Belgium. <https://statbel.fgov.be/en/themes/environment/waste-and-pollution/waste-production>

Taburiaux, P., & Taburiaux, P. (2025). What if we thought circular economy ? For a sustainable future starting today. Foyer. <https://www.foyer.lu/en/blog/circular-economy/>

Stewart, B. (2007). Shearing Layers. In *Urban Design Reader* (pp. 302-306). Routledge.

Van Stijn, A., Eberhardt, L. M., Jansen, B. W., & Meijer, A. (2021). A Circular Economy Life Cycle Assessment (CE-LCA) model for building components. *Resources Conservation And Recycling*, 174, 105683. <https://doi.org/10.1016/j.resconrec.2021.105683>

Van Vliet, M., van Grinsven, J., & Teunizen, J. (2021). Circular Buildings: Disassembly Potential Measurement Methodology (Version 2.0). Dutch Green Building Council. https://docs.madaster.com/files/at/DGBC_Disassembly%20Potential%20Measurement%20Methodology_2022.pdf

Vertuoza. (n.d.). Coûts de main-d'œuvre sur chantier : Guide complet. <https://www.vertuoza.com/fr-be/blog/couts-de-main-doeuvre-sur-chantier-guide-complet>

Wonderwalls. (n.d.). *Wonderwalls*. <https://www.wonderwalls.systems/>

Woodward, D. G. (1997). Life cycle costing: Theory, information acquisition and application. *International Journal of Project Management*, 15(6), 335–344. [https://doi.org/10.1016/S0263-7863\(96\)00089-0](https://doi.org/10.1016/S0263-7863(96)00089-0)

6 Appendices

Table of Contents

APPENDIX 1: INTERVIEW JULIEN BERNAR	48
APPENDIX 2: GREGORY CHAUVIAUX.....	53
APPENDIX 3: VISUAL REPRESENTATION OF THE SIX WALL SETUPS	59
APPENDIX 4: COMPLETE EXPLANATION OF THE EXCEL-BASED LCC MODEL.....	63
APPENDIX 5 : HELICOPTER VIEW OF THE COMPLETE MODEL	70

Appendix 1: Interview Julien Bernar

Semi-Structured Interview Guide

Introduction

Hello,

I am currently conducting a master's thesis in collaboration with Buildwise on the economic evaluation of demountable and conventional partition wall systems using a Life Cycle Costing (LCC) model. The objective is to assess under which conditions demountable systems can constitute an economically competitive alternative to conventional solutions.

The purpose of this interview is to gather your professional opinion in order to compare the model developed with current industry practices. There are no right or wrong answers. I am primarily interested in your experience and perception to better understand the strengths and limitations of the proposed model.

The interview will take approximately 20 to 30 minutes.

Part 1 – Interviewee Profile

1.

Could you briefly introduce yourself?

- Position
- Company
- Years of experience

Hello, Julien Bernar. I've been the head of BMGT for over 15 years. We started out in garden maintenance, but our business has since expanded to include landscaping, and we also work closely with CBD, which carries out quite a few construction projects for MATEXI. At the

same time, we've also had our own homes built, and whenever we have the opportunity, we develop a few real estate projects on a private basis.

Part 2 – Current Practices

2.

When selecting a partition wall system or building material, what are the main criteria influencing your decision? Would you say that factors such as cost, quality, installation speed, maintenance requirements, durability or aesthetics are the most important?

I'd say it really comes down to value for money, but price is extremely important in our industry because every extra cent spent on materials adds up, and it's only at the end, when you look at the total cost, that you see significant price differences. So cost is extremely important.

3.

Have you ever had to choose between different partition wall systems or materials without having sufficient information to identify the most appropriate solution?

Could you describe a situation in which choosing between different partition wall systems or materials was particularly difficult? What made this decision so challenging?

As I just mentioned, it's a matter of cost; for each material, we need to compare the different offers on the market, whether it's for partitions or any other material.

4.

When carrying out your projects, do you consider costs over the entire life cycle of a building, or do you mainly focus on the initial investment costs? Why?

To be honest, the first thing we look at is the immediate costs; our initial focus is on meeting the primary need specified in the project. It's harder to envision what the building might look like 50 years down the road. We rarely think about how the building might evolve over time, so I'd say that for now, we're content to meet the needs of the initial project while staying within our budget and using high-quality materials. However, for some of our construction projects, we try to use materials that won't be too difficult to maintain.

5.

Have you ever encountered difficulties when estimating life cycle costs beyond the initial construction costs? How do you currently estimate these costs?

For now, as I told you, we're mainly looking at the initial costs and trying to choose materials that are durable, high-quality, and won't require too much maintenance, since that can be expensive. And to estimate this, we rely mainly on our experience.

Part 3 – Reuse and Circular Economy

6.

What is your perception of reuse within the construction sector?

Reuse is a very good thing; I think it's a sector that's evolving. In fact, we're seeing more and more containers on construction sites for sorting and recycling different types of waste, that's already a first step, even if I don't think the rest is being implemented very thoroughly yet.

7.

In your opinion, what are currently the main barriers to the development of reuse in general? For example: costs, regulations, lack of data, established practices, liability, quality or material availability.

I know that when it comes to recycling, the government has implemented quite a few measures, including standards for certain products. But in order for reuse to become just as much a part of our practices, I think it needs to be regulated at a more comprehensive level.

And as I mentioned earlier, it's very difficult to predict how the construction industry will evolve, we don't know what our needs will be 40 or 50 years from now.

7 bis.

More specifically, what do you think are the main barriers to the reuse of partition wall systems?

I think that, generally speaking, this requires a shift in mindset. Many builders, including ourselves, prefer new materials; we don't want to take the risk of using materials that have already been used, likely out of fear that they might not be reliable. So, first of all, I'd say the industry lacks standards, certifications, and so on. Logistics also need to support reuse, which requires a whole new level of organization.

8.

Based on your experience, in which situations do demountable systems facilitate reuse, or on the contrary, make it more difficult?

We don't really work with systems that are designed to be dismantled, but actually, I think that a system designed from the start to be dismantled, so that it's easy to take apart without causing damage and while recovering the materials, is what matters most.

Part 4 – Presentation of the Model

I will now present the model developed as part of this master's thesis. After the presentation, I would like to gather your opinion on its overall functioning, the assumptions used and its potential usefulness in professional practice.

- General principle
- The six wall systems
- The scenarios
- The assumptions

9.

Overall, what do you think about the functioning of the model?

Does the overall approach seem understandable and coherent to you?

Yes, overall, the way it works seems fairly consistent and comprehensive. The model appears to be fairly well-constructed, and the logic behind the calculations is easy to understand.

10.

Do the assumptions used seem realistic to you? What do you think about the scenarios? Do they seem realistic? What is your opinion on the selected values for inflation, the discount rate and the different factors (deconstruction and direct reuse)?

As for the assumptions, I think you're on the right track; the factor estimates are fairly consistent and logical. The three different scenarios are a good way to analyze three completely different paths and possibilities. As for inflation, you're right to ask me about it, because I do think it's a bit low. I would have expected it to be around 3%.

11.

Are there any assumptions that you would modify?

Why?

Not for me, though, the rest is very realistic.

12.

Do you think any important parameters are missing?

Beyond the parameters we have already discussed, what other factors influence your decisions?

I don't think there are many parameters missing. For me, the main challenge is that some of them are very difficult to quantify precisely.

Part 5 – Usefulness of the Model

13.

Do you think a model like this could be useful in your professional practice?

Why?

Yes, eventually, I think all professionals in the industry will end up working with these kinds of tools. For now, as I told you, it's not a priority for us, because that's not what the market is demanding today either. But I think it's important for research to move forward on these topics, so that the tools will truly be ready when this technology becomes mainstream. Beyond that, it would also be interesting for research to expand to cover all building materials.

14.

At what stage of a project do you think it could be used?

- Design phase
- Material selection
- Comparison of alternatives
- Discussion with the client
- Other

I see it more as a tool for comparison when we want to analyze the economic impact of different choices.

15.

In your opinion, what would be the main advantages of such a tool?

And what would be its main limitations?

I think that's the goal, but it also helps highlight costs that we don't necessarily think about beyond construction costs.

But I see it as particularly useful for projects that are likely to evolve over their lifespan and completely change their function, as in your scenarios.

16.

What improvements would you suggest before such a model could be implemented in professional practice?

I think that if this topic gains prominence and is adopted as an official tool, it would be useful in the long run to develop an interface that is more intuitive than an Excel file; this would make it easier to use.

Conclusion

Is there anything else you would like to add or comment on?

Thank you very much for taking the time to participate in this interview.

Appendix 2: Gregory Chauviaux

Semi-Structured Interview Guide

Introduction

Hello,

I am currently conducting a master's thesis in collaboration with Buildwise on the economic evaluation of demountable and conventional partition wall systems using a Life Cycle Costing (LCC) model. The objective is to assess under which conditions demountable systems can constitute an economically competitive alternative to conventional solutions.

The purpose of this interview is to gather your professional opinion in order to compare the model developed with current industry practices. There are no right or wrong answers. I am primarily interested in your experience and perception to better understand the strengths and limitations of the proposed model.

The interview will take approximately 20 to 30 minutes.

Part 1 – Interviewee Profile

1.

Could you briefly introduce yourself?

- Position
- Company
- Years of experience

Yes, of course. My name is Gregory Chauviaux. I currently work at Deutsche Bank, where I am Head of Capital Markets & Platforms. In addition to this job, I founded a real estate company (SRL) with a business partner in 2022, which is probably why you're interviewing me today. Since founding this company, we've carried out several real estate projects, ranging from building residential buildings on vacant lots to the complete renovation of an old barn.

Part 2 – Current Practices

2.

When selecting a partition wall system or building material, what are the main criteria influencing your decision?

Would you say that factors such as cost, quality, installation speed, maintenance requirements, durability or aesthetics are the most important?

Obviously, I think cost is the factor that many people consider, because if a project is too expensive, it will reduce profitability or even eliminate it entirely. But I think that when it comes to other factors, it really depends on the project. For example, when we build housing, there are so many new environmental and quality standards to comply with that we can't just do whatever we want. We can't just go with the cheapest product.

3.

Have you ever had to choose between different partition wall systems or materials without having sufficient information to identify the most appropriate solution?

Could you describe a situation in which choosing between different partition wall systems or materials was particularly difficult? What made this decision so challenging?

Yes, I have to say it happens often, where we have solutions that offer the same features but it's hard to know which one is the most financially advantageous in the long run. We don't always know how a building will evolve or who will live there, so it's often hard to determine which solution is best. But that's also why we work with architects and tradespeople, which allows us to get multiple perspectives and minimize uncertainties.

But to answer your question, on a daily basis we're faced with choices between different materials, different doors for example, or as you're looking into, different partition walls. Often, higher-quality products cost more, so we have to do the math to see if it's worth it.

4.

When carrying out your projects, do you consider costs over the entire life cycle of a building, or do you mainly focus on the initial investment costs? Why?

Often at the start of a project, the purchase or construction cost is the top priority, but yes, whenever possible, we try to choose materials that age well and don't require too much maintenance. I'd say it also depends on whether we're working with a client, in which case we simply stick to their budget and meet their expectations; but if you're building for yourself, of course you'll pay attention to the future costs that might be involved, etc.

5.

Have you ever encountered difficulties when estimating life cycle costs beyond the initial construction costs?

How do you currently estimate these costs?

For now, we estimate these based on experience and advice from the people around us, but we're still working with fairly standard materials, so I'd say it's pretty easy to know how long they'll last, etc. But I admit it can get complicated when you have to start managing hundreds of different materials on a construction site.

Part 3 – Reuse and Circular Economy

6.

What is your perception of reuse within the construction sector?

I think this is a very good thing. It's well known that this sector produces an enormous amount of waste, so being able to reuse it or give it a second life could be great for the environment, and it would even mean we wouldn't have to buy new raw materials, so there's clearly an economic benefit as well.

7.

In your opinion, what are currently the main barriers to the development of reuse in general? For example: costs, regulations, lack of data, established practices, liability, quality or material availability.

I imagine these practices need to remain profitable, so if it costs more to dismantle and sort the materials than to buy new ones, then this approach will never be adopted. Plus, these materials need to meet certain quality standards, and I think that could deter people, whereas when you buy new items, you know exactly what you're getting and the quality standards are clear.

7 bis.

More specifically, what do you think are the main barriers to the reuse of partition wall systems?

That's for you to tell me. No, but seriously, I imagine that, once again, it has to remain cost-effective, so it can't take too much time or be too difficult to take apart, store, and transport, and above all, we mustn't damage them during transport, since they are fragile products after all.

8.

Based on your experience, in which situations do demountable systems facilitate reuse, or on the contrary, make it more difficult?

We've reused materials like doors or tiles that were still in great condition, but to be honest, it's not something we do on a regular basis. Every project is different, and for each one, we start from scratch. But I'd say that demountable systems really have their place in settings that change a lot; in those cases, if they're easy to take apart, etc., they can be advantageous. I also imagine that the size of the project can have an impact. For example, on large projects, if you take down the demountable partitions, you'll have a large number that can be reused, whereas on a small project, the supply of potentially reusable partitions will be limited, so you'd have to call on other suppliers of demountable partitions waiting to be reused, and that can quickly become complicated.

Part 4 – Presentation of the Model

I will now present the model developed as part of this master's thesis. After the presentation, I would like to gather your opinion on its overall functioning, the assumptions used and its potential usefulness in professional practice.

- General principle
- The six wall systems
- The scenarios
- The assumptions

9.

Overall, what do you think about the functioning of the model?

Does the overall approach seem understandable and coherent to you?

Yes, at first glance and thanks to your explanations, the model is fairly easy to understand; it's easy to see where the various data inputs go, and the components of the life cycle cost are organized in a fairly logical way, so I'd say that in this regard, it's quite positive.

10.

Do the assumptions used seem realistic to you?

What do you think about the scenarios? Do they seem realistic?

What is your opinion on the selected values for inflation, the discount rate and the different factors (deconstruction and direct reuse)?

So yes, as for the scenarios, I think the context of each one seems pretty realistic. I also find it interesting to analyze three very different situations involving change; it really helps us see what happens in very distinct cases.

You're right to ask me this, because in my opinion, inflation is fairly low. I'm not sure what impact that might have on your calculations, but I'd say it should be between 2 and 4 percent. You should try to calculate an average over the last 20 years to be sure.

On the other hand, regarding the cost factors, your data and explanations about construction costs seem consistent and plausible to me.

11.

Are there any assumptions that you would modify?

Why?

As we just discussed, I think the inflation figure is debatable because 0.7% seems really low to me.

12.

Do you think any important parameters are missing?

Beyond the parameters we have already discussed, what other factors influence your decisions?

I think this is already a very good foundation; it could obviously be more comprehensive, but as a first step for the industry, it's really not bad to bring this to the table. If I really think about it, why not add the point that materials still have value after being dismantled and could be resold? That, too, would increase the profitability of materials and dismantlable solutions.

Part 5 – Usefulness of the Model

13.

Do you think a model like this could be useful in your professional practice?

Why?

Yes, absolutely. We already use tools for all sorts of things, and this one could offer a more cost-effective way to compare and truly target the most relevant solutions for each situation, even though it's limited to partitions.

14.

At what stage of a project do you think it could be used?

- Design phase
- Material selection
- Comparison of alternatives
- Discussion with the client
- Other

It really depends on the objectives, but in any case, when setting up a project and choosing materials, as you say, that's when we discuss things with the client to show them different possibilities.

15.

In your opinion, what would be the main advantages of such a tool?

And what would be its main limitations?

I think the main advantage is that it provides insight into costs beyond just construction costs, so solutions that seem cheaper at first aren't always the best.

For me, the main drawbacks are that you have to spend a little time entering the basic data on costs, lifespans, etc., yourself. Even though I suspect this is a version designed to demonstrate the economic benefits of removable partitions, eventually this type of model should offer a catalog of materials that are already pre-entered.

16.

What improvements would you suggest before such a model could be implemented in professional practice?

I think we've already answered this question in part, but why not have a pre-recorded glossary of materials? That would save quite a bit of time.

Conclusion

Is there anything else you would like to add or comment on?

No, nothing in particular. I wish you the best of luck with your defence.

Thank you very much for taking the time to participate in this interview.

Appendix 3: Visual representation of the six wall setups

The following images were created using AI for the visual understanding of the layer compositions of the different wall setups.

- **Conventional Wall with plaster finish**

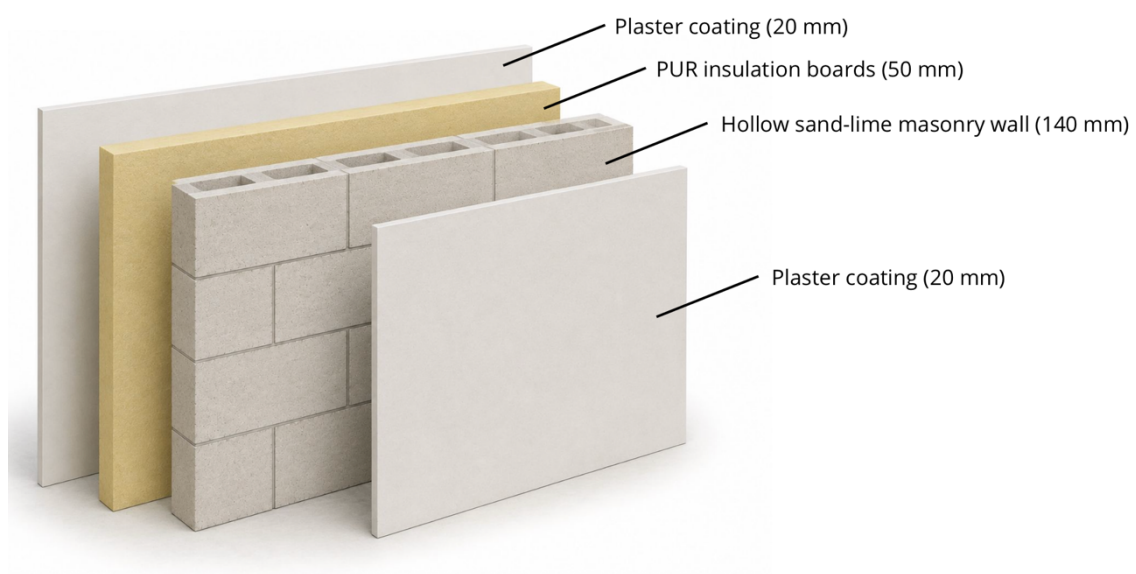


Figure 14: Layered composition of a conventional wall with plaster finish

- **Conventional Wall with wood finish**

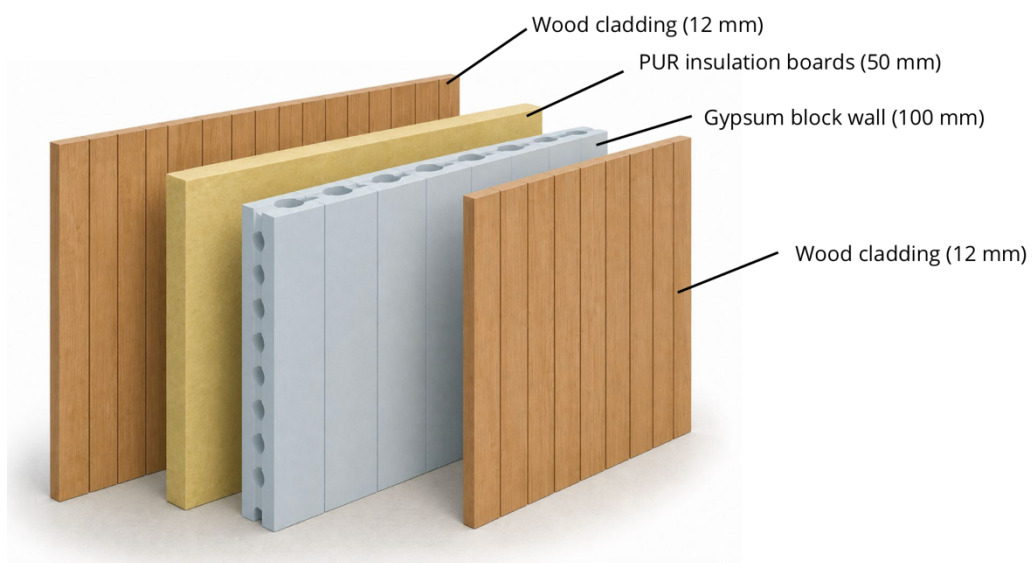


Figure 15: Layered composition of a conventional wall with wood finish

- **Hybrid Wall with plaster finish**

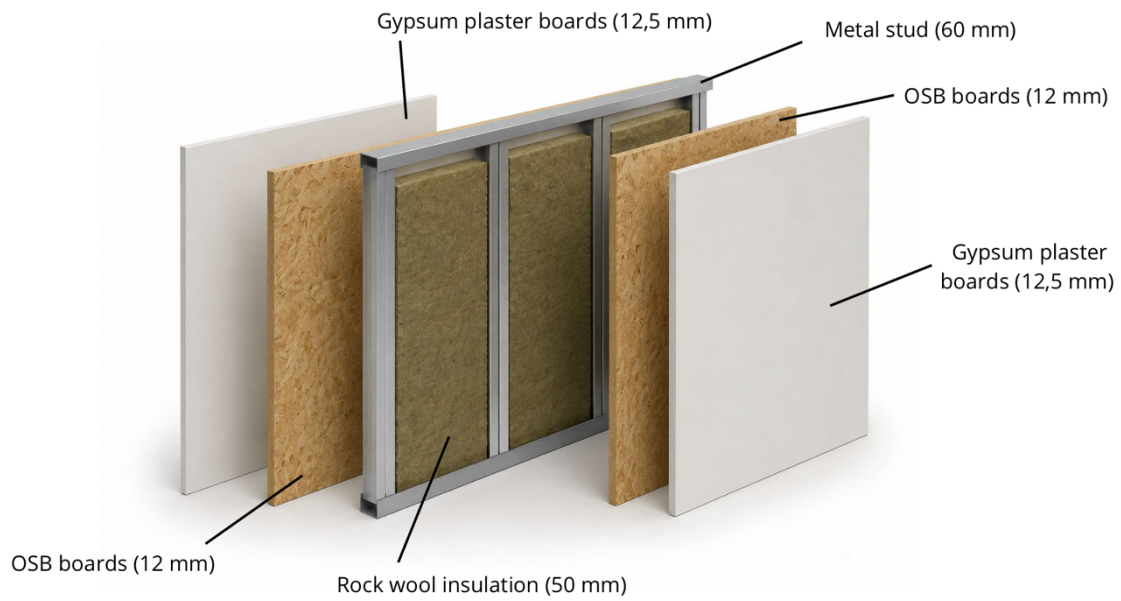


Figure 16: Layered composition of a hybrid wall with plaster finish

- **Hybrid Wall with wood finish**



Figure 17: Layered composition of a hybrid wall with wood finish

- **Demountable Wall with plaster finish**

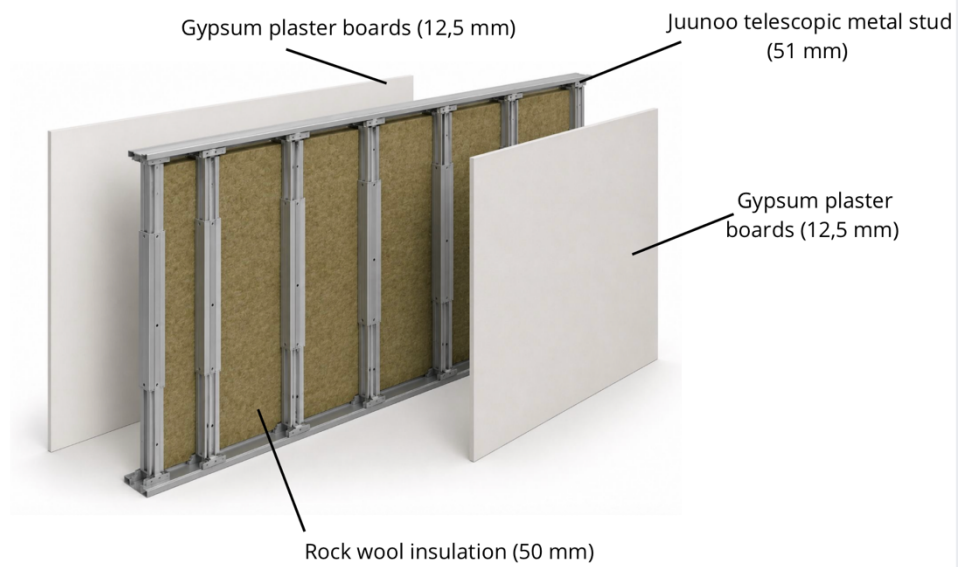


Figure 18: Layered composition of a demountable wall with plaster finish

- **Demountable Wall with wood finish**

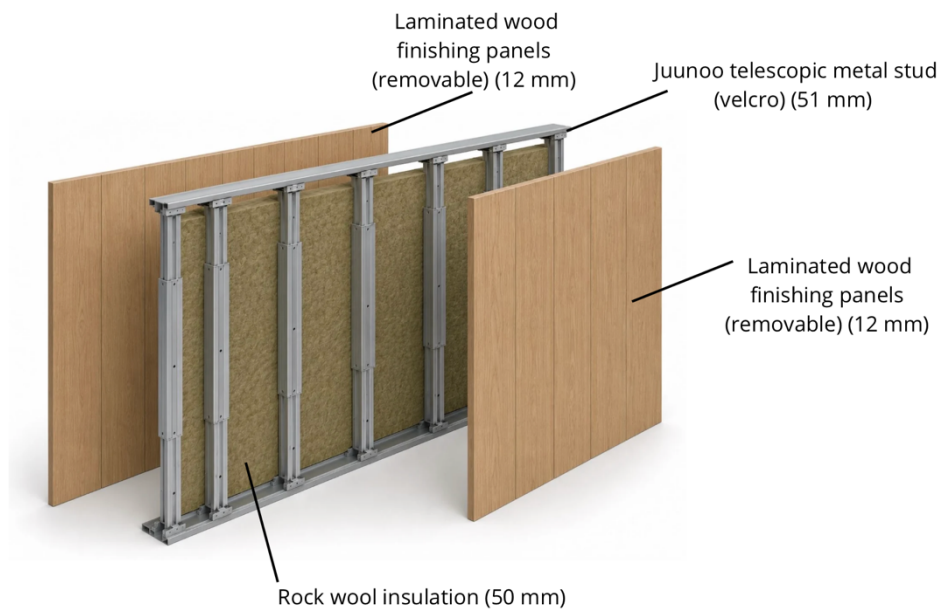


Figure 19: Layered composition of a demountable wall with wood finish

Appendix 4: Complete explanation of the Excel-based LCC model

This section describes the main components of the model which is based on an excel file designed by Buildwise and the principal assumptions adopted throughout the analysis. Its purpose is not to provide a detailed explanation of every calculation performed within the model, but rather to give the reader a clear understanding of the overall modelling approach used to obtain the results presented in this research. To facilitate the reader's understanding, screenshots illustrating the different parts of the Excel model are provided.

Before describing the model assumptions in detail, it is important to distinguish between several terms that are used throughout the cost assessment, as they refer to different intervention strategies with distinct cost implications. Demolition refers to the complete destruction of a wall system without separating the different materials, resulting in a mixed waste stream. Deconstruction refers to the selective destruction of a wall system to separate materials into individual waste streams, such as wood, metal and gypsum. Disassembly describes the careful dismantling of a wall system while preserving its components for future reuse. Renovation refers to the installation or replacement of partition wall systems in an existing building, where work is performed on existing elements rather than under new-build conditions. Finally, direct reuse refers to the reuse of components recovered through disassembly without any modification.

i) Financial assumptions

As illustrated in *Figure 20*, the Excel model relies on several financial data. These for example include the discount rate used to calculate the Net Present Value (NPV) of each wall system, as well as assumptions related to inflation. The model also incorporates a series of cost factors, to estimate life-cycle activities for which no direct cost data were available. These factors are intended to represent how the costs of these activities compare with the initial construction or demolition costs. For example, deconstruction labour costs are assumed to be 1.1 times the demolition labour costs, reflecting the additional effort required to carefully destruct building components. Conversely, direct reuse labour costs are estimated at 0.9 times the construction labour costs, as reusable components are already manufactured to the right dimensions and only need to be reinstalled. Similarly, the material costs associated

with direct reuse are assumed to represent 10% of the initial construction material costs, reflecting the assumption that approximately 90% of the materials can be successfully recovered and reused (meaning only 10% loss due to material damage while dismantling and thus 10% of new material is needed). Finally, the direct reuse equipment costs were assumed to be 1.1 times the construction equipment costs to account for the additional equipment required for cleaning and scrubbing recovered components prior to reuse.

These assumptions were selected to represent realistic construction practices while ensuring a consistent comparison between the different partition wall systems. Although alternative assumptions could influence the numerical results, the chosen values provide a credible basis for the economic assessment.

Financial assumptions

Discount rate		
Discount rate	_rD	0,04
Inflation		
Inflation Labour	_rgL	0,03
Inflation Material	_rgM	0,03
Inflation Equipment	_rgE	0,03
Calculation Parameters		
Analysis period	_T	60
Time coefficient	_qt	2
Cost factors		
Deconstruction	_fdec	1,1
Disassembly (estimated separately for each component using the disassembly formula)	_fdis	/
Direct reuse		
	_f9	0,9 Labour
	_f10	0,1 Material
	_f11	1,1 Equipment

Figure 20: Screenshot of financial assumptions used in LCC model

ii) Construction and End-of-Life Costs

As illustrated in Figures 21 and 22, these two worksheets centralise the cost data used throughout the Life Cycle Costing model for each layer of the partition wall systems. The Construction Costs worksheet contains the technical characteristics of each wall layer, including its service life, together with the associated construction and renovation costs, which are divided into labour, material and equipment costs. The End-of-Life Costs worksheet gathers all cost data related to the end-of-life stage. It includes the costs associated with demolition or deconstruction activities, as well as the treatment costs corresponding to the different waste streams generated from deconstruction or demolition.

CONSTRUCTIE KOSTEN (niveau materiaal laag)			Technical (Bspan)				Construction prices			Refurbishment prices				
ARTIKEL	Unit	Dikte d	Minimum Pmin	Expected Pexp	Maximum Pmax	Random Pmd	Labour C1	Material C2	Equipment C3	Labour C8	Material C9	Equipment C10	C8/C1	Mean C8/C1 1,092011
BB/SB code Omschrijving	m²	m	-	-	-	-	-	-	-	-	-	-	-	-
22. Kalkzandsteen helle metselblokken (290/90/140) - vuilverk	m²	0,14	-	75	-	-	€ 44,24	€ 17,60	€ 0,00	€ 48,17	€ 17,60	€ 0,00	€ 1,09	
22. Gypsum block/ plaster block wall (100mm)	m²	0,1	-	40	-	-	€ 29,02	€ 23,55	€ 0,00	€ 31,69	€ 23,55	€ 0,00		
22. Plasterboard panels on metal support structure	m²	0,0125	-	44	-	-	€ 16,45	€ 3,95	€ 0,00	€ 17,91	€ 3,94	€ 0,00	1,088754	
22. Plasterboard panels on wooden support structure	m²	0,0125	-	44	-	-	€ 16,45	€ 3,95	€ 0,00	€ 17,91	€ 3,94	€ 0,00	1,088754	
41. Isolatie - rockwool platen (50mm)	m²	0,05	-	75	-	-	€ 5,11	€ 5,50	€ 0,00	€ 5,56	€ 5,50	€ 0,00	1,088063	
42. *Bepaling op baksteen of betonblokken (20mm) - manueel + geschilderd	m²	0,02	-	50	-	-	€ 45,29	€ 12,22	€ 0,00	€ 49,31	€ 12,22	€ 0,00	1,088761	
42. Structuur in metaal METALSTUD	m²	0,06	-	53	-	-	€ 9,38	€ 6,87	€ 0,00	€ 10,21	€ 6,87	€ 0,00	1,088486	
42. *Enkele gipskartonplaat geschroefd (12,5mm) - breedte 600 afgewerkt en geschilderd	m²	0,0125	-	44	-	-	€ 55,24	€ 12,04	€ 0,21	€ 62,49	€ 12,71	€ 0,21	1,131245	
42. Lathwerk in hout (20/50)	m²	0,0022	-	50	-	-	€ 7,50	€ 6,40	€ 0,00	€ 8,17	€ 6,40	€ 0,00	1,089333	
42. OSB beplating (12mm)	m²	0,012	-	50	-	-	€ 15,58	€ 5,39	€ 0,00	€ 16,96	€ 5,39	€ 0,00	1,088575	
42. Plastering on plasterboard panels	m²	0,015	-	50	-	-	€ 22,41	€ 7,25	€ 0,00	€ 24,40	€ 7,25	€ 0,00	1,0888	
42. Plasterboard panels	m²	0,0125	-	44	-	-	€ 16,45	€ 3,95	€ 0,21	€ 17,91	€ 3,94	€ 0,21	1,088754	
42. Wooden battens framework	m²	0,0022	-	71	-	-	€ 7,50	€ 6,40	€ 0,00	€ 8,17	€ 6,40	€ 0,00	1,089333	
42. Painting works on walls - Latex paints	m²	0,001	-	4	-	-	€ 12,21	€ 3,83	€ 0,00	€ 13,29	€ 3,83	€ 0,00	1,088452	
Finishing plates - Laminated wood panel	m²	0,012	-	50	-	-	€ 2,14	€ 24,03	€ 0,00	€ 2,34	€ 24,03	€ 0,00		
JIUNDO telescopic metal stud system (with velcro or screws)	m²	0,051	-	100	-	-	€ 2,14	€ 24,03	€ 0,00	€ 2,34	€ 24,03	€ 0,00		
Gypsum block finish coating	m²	0,001	-	50	-	-	€ 16,00	€ 1,62	€ 0,00	€ 17,47	€ 1,62	€ 0,00		
41. Spouwplaten in PUR (50mm)	m²	0,05	-	75	-	-	€ 9,00	€ 12,15	€ 0,00	€ 7,72	€ 12,15	€ 0,00		
Wood cladding	m²	0,012	-	50	-	-	€ 15,58	€ 24,03	€ 0,00	€ 16,96	€ 24,03	€ 0,00		

Figure 21 : Screenshot of construction costs worksheet used in model

END-OF-LIFE ACTIES		Demolition prices			Waste streams			
Actie		Labour	Material	Equipment	Type of waste stream	Processing cost mixed	Processing cost sorted	
		C1	C2	C3		C12 (€/m³)	C14 (€/m³)	
	WAND							
	Bekleding in gipskartonplaten - afbraak draagstructuur metaal	21,72	0	0	Metal	0	0	
	Bekleding in gipskartonplaten - afbraak draagstructuur hout	21,55	0	0	Flat glass	0	0	
	Bekleding in gipskartonplaten - afbraak gipskartonplaat geschroefd	15,58	0	0	Wood	25	3	
	Bekleding in gipskartonplaten - afbraak gipskartonplaat genageld	11,4	0	0	Reinforced concrete	25	19	
	Afbraak bekleding in OSB platen geschroefd	6,08	0	0	Stony materials / masonry	25	30	
	Afbraak bekleding in OSB platen genageld	5,59	0	0	Mineral wool	43	5	
	Slopen van binnenwanden in betonblokken (m3)	342,08	0	19,52	Synthetic foams	43	8	
	Machinaal verwijderen van gipsbepleistering	14,96	0	0,65	Plastic	43	16	
					Gypsum	43	24	
					Asphalt	43	24	
					Cellular concrete	43	85	
					Bitumen		211	
					Asbestos		79	
FR								
	Plasterboard cladding — demolition of metal support structure	€ 21,72	€ 0,00	€ 0,00				
	Plasterboard cladding — demolition of wooden support structure	€ 21,55	€ 0,00	€ 0,00				
	Plasterboard cladding — demolition of screwed plasterboard panel	€ 15,58	€ 0,00	€ 0,00				
	Plasterboard cladding — demolition of nailed plasterboard panel	€ 11,40	€ 0,00	€ 0,00				
	Demolition of screwed OSB board cladding	€ 6,08	€ 0,00	€ 0,00				
	Demolition of nailed OSB board cladding	€ 5,59	€ 0,00	€ 0,00				
	Demolition of interior walls in concrete blocks (m2)	€ 47,89	€ 0,00	€ 2,73				
	Mechanical removal of gypsum plastering	€ 14,96	€ 0,00	€ 0,65				
	Removing plasterboard plastering	€ 14,96	€ 0,00	€ 0,65				
	Removal of rockwool insulation boards	€ 2,00	€ 0,00	€ 0,00				
	Breaking off multiplexboard cladding (screw)	€ 31,16	€ 0,00	€ 0,00				
	Demolition of interior walls in masonry (m2)	€ 47,51	€ 0,00	€ 2,71				

Figure 22: Screenshot of demolition activities used in model

iii) Life Cycle Costing Calculations

The core of the Excel model consists of the calculations required to determine the Net Present Value (NPV) of each partition wall system over its entire life cycle.

As illustrated in Figure 23, the **construction costs** are calculated by summing the labour, material and equipment costs of each individual layer composing the partition wall system. The total construction cost per square metre is then obtained by adding the costs of all wall layers.

A3-4 Construction cost				
C1	C2	C3	Cost element	Total cost
Labour	Material	Equipment	(€/m ²)	(€)
			BUILDING	48241,13145
				(*50)
€ 35,96	€ 13,55	€ 0,00	€ 198,01	€ 9.900,50
€ 45,29	€ 12,22	€ 0,00		
€ 9,00	€ 12,15	€ 0,00		
€ 44,24	€ 17,60	€ 0,00		
€ 45,29	€ 12,22	€ 0,00		

Figure 23: Screenshot of construction costs calculations

The **replacement costs** are determined according to the technical service life assigned to each material within the database. Two types of replacement are distinguished: *technical replacement*, which occurs when a material reaches the end of its functional service life, and *esthetic replacement*, where a material is replaced for visual reasons despite remaining technically functional. In the case of technical replacement, the material is replaced directly as soon as its technical service life is reached. In contrast, esthetic replacement may be postponed if it is foreseen just before the wall system is scheduled to be demolished or deconstructed, thereby avoiding the replacement of a component shortly before its removal. For example, if a gypsum board has a technical service life of 44 years and the wall system is scheduled to be demolished or deconstructed in year 46, a technical replacement would be carried out in year 44, whereas an esthetic replacement would be postponed until year 46. Within the wall systems analysed, only the exterior finishing layer may undergo esthetic replacement, whereas the remaining inner layers are only subject to technical replacement. Based on the service life of each material, the selected replacement criterion and the refurbishment frequency, the model automatically determines the years in which replacement operations occur. Depending on whether the wall system is conventional or demountable, the model then applies the appropriate intervention strategy, namely demolition or deconstruction followed by renovation.

B4 Replacement															
E/T	t _i	P _{repl} L	P ⁱ _{repl} L	C ₁₁	C ₁₂	C ₁₃	C ₁₁ f _{dec}	C ₁₄	C ₁₃	C ₈	C ₉	C ₁₀	NPV _{laag}	NPV element	Total NPV
Esthetic/Technical				labour	material	equip.	labour	material	equip.	labour	material	equip.	(€/m²)	(€/m²)	(€)
				demolition			deconstruction			renovatie					
														BUILDING	10078,52
														0,00	0,00
E		50	50	€ 14,96	€ 0,86	€ 0,65	€ 16,46	€ 0,48	€ 0,65	€ 49,31	€ 12,22	€ 0,00		0	
T		75	60	€ 2,00	€ 2,15	€ 0,00	€ 2,20	€ 0,25	€ 0,00	€ 7,72	€ 12,15	€ 0,00		0	
T		75	60	€ 47,89	€ 3,50	€ 2,73	€ 52,68	€ 4,20	€ 2,73	€ 48,17	€ 17,60	€ 0,00		0	
E		50	50	€ 14,96	€ 0,86	€ 0,65	€ 16,46	€ 0,48	€ 0,65	€ 49,31	€ 12,22	€ 0,00		0	

Figure 24: Screenshot of replacement costs calculations

The **refurbishment costs** constitute one of the key components of the Life Cycle Costing model. Rather than assuming a static building throughout its life cycle, the model simulates the successive refurbishment operations that may occur over time. Three refurbishment scenarios, presented above, represent different frequencies of interior modifications. For each wall system, the model distinguishes between the inner layer, corresponding to the central structural component of the partition wall, and the outer layers, which include all remaining wall layers. To avoid unnecessary refurbishment interventions, the model allows refurbishment activities of the outer layers to be aligned with those of the inner layer. This is controlled by the decision settings necessary and favourable (when an outer layer is set to necessary, it is refurbished at its scheduled interval. When it is set to favourable, its refurbishment may be postponed so that it coincides with the refurbishment of the inner layer, thereby reducing the number of interventions. For example, if the inner layer is scheduled for refurbishment in year 24 and an outer layer in year 21, the refurbishment of the outer layer can be postponed to year 24 when it is set to favourable). In the present model, all wall layers were assigned the necessary setting, meaning that no postponement of refurbishment activities was applied, this is because in this model, refurbishment events are fixed in time based on the defined scenarios. Depending on the type of wall setup, the refurbishment operation is then carried out using different intervention strategies. Conventional wall systems are refurbished through demolition followed by renovation, whereas demountable systems follow a strategy based on disassembly and direct reuse whenever applicable.

Figure 25: Screenshot of refurbishment costs calculations

independency and product edge geometry. As these scoring tables are extensively documented by Van Vliet et al. (2021), they are not reproduced here, and readers interested in the complete methodology are referred to the original publication.

The four criteria are combined using the following equation:

$$DP = \frac{4}{\frac{1}{CT} + \frac{1}{CA} + \frac{1}{ID} + \frac{1}{GPE}}$$

The resulting score represents the theoretical disassembly potential of each wall layer which is then converted into a disassembly factor. This disassembly factor is then multiplied with the construction labour costs. Although this approach is based on theoretical assumptions rather than measured disassembly times, it provides a structured and consistent method for estimating the additional labour effort required for disassembly and therefore contributes to a more realistic calculation of refurbishment costs.

WALL SETUPS		COMPONENT SCORE				LI CALCULATION	CORRECTION FACTOR Fdis
		CT — Connection Type	CA — Connection Accessibility	ID — Independency	GPE — Geometry of Product Edge		
CONVENTIONELE ELEMENTEN							
Conventional wall Type 1							Fdis
0							
1	Plaster coating	0,1	0,1	0,1	0,1	0,10	No reuse / not applicable
1	PUR insulation boards	0,1	0,4	0,4	1	0,25	No reuse / not applicable
1	Hollow sand-lime masonry wall	0,1	0,1	0,1	0,1	0,10	No reuse / not applicable
1	Plaster coating	0,1	0,1	0,1	0,1	0,10	No reuse / not applicable
0							

Figure 27: Screenshot of disassembly factor calculation

v) Geometric discounting

The replacement and refurbishment decisions described in the previous subsections are coordinated through a geometric discounting decision mechanism. This concept, developed in the doctoral thesis of Waldo Galle (2016), is integrated into the Excel model to determine the most economically appropriate timing of interventions throughout the building's life cycle. As the methodology underlying the geometric discounting mechanism is extensively described by Galle (2016), only its application within the Excel model is presented in this research.

In practice, replacement and refurbishment activities are often carried out simultaneously to minimise disruption and reduce overall intervention costs. Rather than treating replacement and refurbishment as independent activities, the model addresses the following question: *"Is it economically more advantageous to refurbish this component now, or to wait until the next replacement?"* This decision depends on several parameters, including the technical service life of the material, its replacement criterion (technical or esthetic), the refurbishment frequency, and also the decision settings *necessary* and *favourable*. When a refurbishment intervention is set to *necessary*, it always occurs at its scheduled interval. When it is set to *favourable*, the model evaluates whether postponing the refurbishment intervention to coincide with another scheduled replacement activity is economically preferable.

For example, consider a wall component requiring technical replacement every 30 years, while the selected refurbishment scenario schedules refurbishment every 6 years. If the refurbishment setting is *favourable*, the refurbishment initially scheduled in year 24 may be postponed until year 30 so that both interventions are carried out simultaneously. Conversely, if refurbishment is set to *necessary*, the refurbishment still takes place in year 24 and is therefore performed separately from the replacement.

Consequently, the intervention strategy adopted by the model does not depend on a single criterion, but on the combination of all relevant parameters. By coordinating replacement and refurbishment schedules, the geometric discounting mechanism provides a more realistic representation of intervention planning while avoiding an overestimation of life cycle intervention costs.

Appendix 5 : Helicopter view of the complete model

