TOWARDS A CATALOG OF DESIGN STRATEGIES FOR VALUE RETENTIVE CIRCULAR INTERIOR PARTITION WALLS WITHIN A PRODUCT AS A SERVICE ENVIRONMENT.

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ABSTRACT

This paper explores considerations about residual value and value retentive design, that come with commercializing interior partition walls "as a Service". Due to poor construction techniques and short lifespans, interior partition walls are a major contributor to waste production. Commercialized within certain Product as a Service (PaaS) models, most of this waste could be eliminated, the product quality increased, and users, as well as companies, would benefit from it financially. Therefore, the residual value must be optimized. Within a cross industry research, Residual Value Forecasting (RVF) methods are analyzed, and decisive parameters are extracted. Based on these parameters, a Multi-Criteria Decision Analysis (MCDA) is performed on case studies, leading to a catalog of design strategies for value retentive circular interior partition walls.

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KEYWORDS: *Residual Value, Product as a Service (PaaS), Interior Partition Walls, Circularity, Waste Reduction, Durability, Remountability, Design for Disassembly (DfD), Design for Reuse (DfR), Modularity*

I. INTRODUCTION

1.1. Problem Statement

Construction and demolition waste (CDW) currently accounts for over a third of the total waste production in the EU. In 2016, there were an estimated 1,36 tons of waste per European citizen. (EEA, 2020) This number does not only illustrate the extend of environmental pollution that emanates from the construction industry, but shows the immense monetary value that is wasted. With the adoption of the EU Circular Economy Action Plans (CEAP) from 2015 and 2020, the European Commission made tackling the waste problem a binding political agenda. (EC, 2015), (EC, 2020) However, changes are only slowly taking effect. Circular economic models continue to be associated with trade-offs in profitability, while investors trust in quick profits through linear economic models. (Braakman, 2021)

With the idea of buildings as material banks, making the residual value of buildings accessible can create an economic incentive to reuse or remanufacture building components rather than to demolish them. Paired with the Product as a Service (PaaS) concept, in which users pay for the benefit they get from using products, rather than for the ownership of products, buildings become conceivable, that are more profitable for investors and more affordable for residents, while having a higher quality building substance and producing less waste than their linear counterparts. (Rau; Oberhuber, 2016)

The assumptions about the application of PaaS in the architectural context were first validated by the circular lighting project at Schiphol Airport, developed in cooperation with Turntoo and Philips in 2015. Here, light is purchased by the airport in small monthly installments, while the lamps remain in Philips' possession and can be reinstated elsewhere after the contract expires. To profit from this business model, Philips designed lamps with a modular build-up that show a 75% increase in longevity and a 50% reduction in energy consumption compared to similar linear models. (Philips Lighting Holding B.V., 2017)

This proves that customers, companies, and the environment can equally profit from this concept. Extended to further building components, design for value retention in PaaS models presents a paradigm shift that could be key in the rapid transition to a circular economy. In order to effectively use the residual value of building components as a financial trigger for investors a PaaS environment, it has to be optimized, made accessible, and calculable. Furthermore, the initial investments must be kept in balance with the residual value at the end of use. (EIT C-K B, 2020)

Based on these precepts, researchers from TNO and C2C ExpoLAB are currently investigating a Residual Value Calculator (RVC) to forecast the residual value of building components at the end of use. As of January 2022, the research team is still building up use-cases in collaboration with companies. According to TNO spokesperson Mark van Ommen, it is anticipated that the tool will be introduced for everyone to use later this year. The goal of this project is to foster circular design in the first product development stages, and to reduce financial risks. (TNO, 2019) A recent prototype of the RVC takes into account Life Cycle Costs (LCC) and critical functions such as value build-up and depreciation of specific building products to make assumptions about their end of use value. (Bouwwereld, 2020)

However, the optimization and accessibility of the residual value within these products still largely depends on their design. Therefore, architects and product developers need catalogues of concrete design strategies that guide them in making their products value retentive. The intention of this paper is to create such a catalog for the space plan, namely interior partition walls.

The space plan continues to be a central part of the waste problem. With its suspected lifespan of 5-20 years, according to the "Shearing Layers of Change" model by Duffy, it frequently undergoes transformation, compared to the total lifespan of a building. (Brand, 1994)

Today, the most commonly used interior non-loadbearing wall systems in Europe consist of a cladding from gypsum-based products and a base layer from variable materials. (Ferrandez-García et al., 2015) Due to their inferior acoustic and insulating capacity, and higher price and installation effort, base layers from hollow clay brick or concrete products are underperforming economically and technically. This explains the increased use of drywall systems. The latter are predominantly built-up from light base layers of aluminum or wood, containing insulation and installations, and gypsum plaster board cladding. Due to their low cost and high rate of wear, traditional drywall systems are hard to reuse and eventually

turn into waste. (Valencia-Barbaa et al., 2021) Once disposed in landfills, especially gypsum plaster boards present a major thread to the environment by releasing toxicity to ground and water, and causing eutrophication of water. (Green Spec, 2021)
This stresses the importance of designing out waste in future space plan systems. Circular interior partition wall solutions that can work in PaaS models, with residual value as a driving force behind their design, can potentially make a large contribution to this challenge.

1.2. Thematic Research Question

This leads to the thematic research question: "What architectural design strategies can be implemented to create circular interior partition wall systems that retain value?"
There is already a large body of knowledge on the forecasting of residual value of tangible fixed assets in leasing models. Therefore, the first sub question is: "How can the considerations from residual value forecasting models in other industries be transferred to the design of interior partition wall systems?"
The findings from this investigation are then applied to concrete case studies of contemporary circular interior partition wall systems, which leads to the second sub question: "What lessons can be learned from contemporary case studies that implement strategies to enhance durability and remountability in interior partition wall systems?".
In the final step, a catalog of design strategies is presented that intends to answer the thematic research question. (App. A)

II. METHODS

This paper proposes a sequence of methods to develop catalogs of design strategies for value retentive building products. The approach can be used in future research to expand knowledge on value retentive design to other parts of the building product palette. (App. B)
First, it must be clarified which business model is intended to be used for the commercialization of the respective products. The chosen business model has to be constructed in a manner that induces design for value retention. Here, an analysis of the business model itself, based on literature research, is followed by the outlining of how the specific products behave within the model.
The PaaS model is chosen in this paper, because it presents a derivative of leasing that, if embedded in the concept of continuous material chains as theorized by Rau and Oberhuber, has the capacity to reduce, and eventually eliminate, waste production. (App. C) By treating them as products, interior partition walls could be commercialized through PaaS, which would make considerations about designing them in a value retentive way indispensable.
Second, cross industry research is conducted. This involves analyzing the general definition of residual value for tangible fixed assets and comparing residual value forecasting (RVF) models from other industries. The emphasis in this step lies on the identification of causes for value loss and decisive parameters that can be used to verify the design of value retentive building components such as interior partition walls.
It is common knowledge that a crucial factor for value loss is the amount of time a product is used. Due to the fact that cars have a comparable life span to interior walls and that, with a leasing rate of over 60% in the Netherlands in 2020, there is a great expertise regarding residual value forecasting, RVF models from the automotive industry are used in the analysis. (VNA, 2020)
These first two steps lead to the theoretical framework that is needed to clarify the context in which the research is carried out, and to evaluate the case studies in the following.
The third step is the case study analysis. For this purpose, contemporary circular interior wall systems are analyzed based on the decisive parameters from the previous research. The intention here is to highlight aspects of the case studies that favor value retention.
In this paper, a Multi-Criteria Decision Analysis (MCDA) is used to evaluate the case studies' performance regarding value retentive design. This method is chosen, because it allows for a simultaneous assessment of different use scenarios. In the analysis, five contemporary circular interior partition wall designs are tested against the performance of a traditional drywall system. The case

studies are selected based on their Level of Circularity (LCC), and amount of information that is available about them in literature.

III. THEORETICAL FRAMEWORK

3.1. Product as a Service (PaaS)

Product as a Service (PaaS) originates from the concept of Product-Service-Systems (PSS). PSS is a business model which emerged from the cognition that selling a product within a bundle of services such as maintenance, updates, and replacement, would lead to a higher customer loyalty and greater profits than if the product were sold alone. (Sawhney et al., 2004)

Unlike in PSS, the ownership of the product always remains with the producer in PaaS models. Thus, meaning that the experience a user gets from using the product itself becomes a service. A recognizable example of the application of PaaS is the Dutch company Swapfiets that sells "the use of a working bicycle" instead of the bicycle itself. (Jansen, 2020) According to PaaS expert Rombouts, the idea connects to the concept of Servitization, and is increasingly gaining popularity among businesses in recent years. Although, providing a PaaS offering implies changes to the company's internal processes and the product design, it can create economic advantages. (Rombouts, 2020; Baines et al., 2007)

Whereas, in linear models, products are designed, built, sold, and eventually have a warranty service, PaaS models imply a shift in responsibility towards the manufacturer. This entails changes in product life cycle management. Now, products are designed, built, deployed, monitored, maintained and upgraded. This enables manufacturers to keep their products in use for longer and to pass them on to other customers, which creates sustainable revenue streams and customer relations. (Lombardo, 2019; App. D) As a consequence of this economic incentive, manufacturers create products that are more resilient and that can be reused, refurbished, or remanufactured. Therefore, PaaS presents an important "building block" in the shift towards a circular economy. (Jansen, 2020) However, products that are commercialized through PaaS are not consecrated against depreciation, and therefore not immediately circular. Although, PaaS products show an increase in lifespan, the remaining of components that depreciated beyond their usability is not defined in the concept.

In their 2016 book Material Matters, Rau and Oberhuber embed PaaS in a continuous chain of materials that describes a flow between the "first nature" and "second nature", between the earth and user. The Material as a Service (MaaS) model, or Turntoo model, relies on several actors that add to, and retain the value of materials. These actions contribute to a "value creation chain" and a "value retention chain". In the model, PaaS is seen as the last act of value creation, the relation between the manufacturer and user. Starting from there, all steps of the material towards its initial state are contractually regulated and beneficial for the respective link in the chain. By establishing an economy of continuous material chains, most of today's waste production could be eliminated in the future. (Rau; Oberhuber, 2016; App. C)

3.2. Interior Partition Walls as PaaS

Today, PaaS is predominantly implemented in consumer goods outside of building construction, such as computer hardware, washing machines, bicycles, lighting systems, or machinery. (van Stralen, 2021) The adoption of theories such as "distinguishing the infill from the support" by Habraken, the "Shearing Layers of Change" model by Duffy, and the "Circular Economy", propagated by the Ellen Macarthur Foundation, led to building practices like prefabrication and design for disassembly. These practices, in turn, lead to buildings whose components can be separated after construction without wear, which enables the use of PaaS. As a result, components can be maintained during their use and reused, refurbished, or remanufactured after. To lower maintenance costs and to increase the lifespan, designers of PaaS building components would be forced to optimize durability and remountability of the products they design.

Interior partition walls have a high potential for a PaaS integration because they are not exposed to the weather and therefore do not age as quickly. In addition, they do not have a structural function and can be maintained, moved, or removed without concern. Therefore, interior partition walls, commercialized through PaaS, would eliminate unnecessary waste during renovation work, and apartments whose space requirements change, could be flexibly redesigned at a low cost.
It would be conceivable to offer interior partition walls through a five-year subscription that does not sell the wall itself, but rather "the use of a flexible, aesthetically pleasing room layout that meets acoustic, energy, and fire requirements, and includes a guarantee for Extended Producer Responsibility (EPR)". The latter ensures that the producer returns the product to a continuous material chain after its end-of-life. (Poolen et al., 2020)
Similar to ordinary rental or leasing models, a subscription could change the distribution of cash flows and allow the user to benefit from an improved return on assets (ROA) sides the company. The difference in a PaaS subscription is that the responsibility for the product and its function according to the service agreement lies with the issuing company. Since this company retains ownership of the product, no third party such as a financial institution is involved. In this way, the customer is not expecting any hidden costs other than the subscription costs. (Ganz et al., 2020)
In order for customers to prefer the service over a one-off purchase, it must be more attractive so that they have no choice but to choose it. To determine the right price of the subscription, manufacturers therefore have to forecast the residual value of their products over a longer use period.

3.3. Residual Value Forecasting (RVF) in Car Leasing

Residual value presents a major risk factor for companies working with subscription or leasing models. An underestimated residual value can lead to losses, while an overestimated residual value means that fewer products were leased than possible due to their higher price. (Rashed et al., 2019) For this reason, companies use calculation models to predict the residual value of their products.
In a leasing context, the residual value, also referred to as salvage value, describes the value of an asset after the end of a lease term. It is defined as the original cost of an item, multiplied with the percentage of the cost that is recovered after a specified time period. (Tuovila, 2021A) Depreciation measures the amount of value an asset loses over a time period. There are several methods to describe depreciation. Whereas, the Straight-Line method describes linear depreciation, the Declining Balance (DB), Double Declining Balance (DDB), and Sum-of-the-Year's-Digits (SYD) methods describe accelerated depreciation. The periodic depreciation is an important factor in determining the amount, the lessee pays for their leasing installments. (Tuovila, 2021B) The higher the residual value of an asset is, the lower is its depreciation rate, and ultimately the price a lessee has to pay for their product. The relation between residual value and depreciation is illustrated in Appendix E.
In a changing automotive market, traditional calculation methods that take into account simple statistical parameters such as age, mileage, and maintenance, are no longer sufficient to determine the precise residual value of cars. With an expanded array of options, consumer choices are driven by personal taste, shifting fashions, but also social, macro-economic, and regulatory factors. Rear-facing cameras, anti-collision devices, and other gadgets that are considered innovative today, may be outdated within a few years. A consideration which requires forecasting models that take a higher number of decisive parameters into account. (Bentenrieder et al., 2019)
These parameters can be aesthetics, features, brand popularity, model type, model introduction year, manufacturing year, manufacturing region, fuel efficiency, and many more. (Greim, 2017) Algorithmic prediction methods from the field of statistical learning allow considering a large number of variables in the estimation of residual value, whereby increasing forecasting accuracy. (Lessmann et al., 2010) Next to static factors, such as the initial mileage set for the vehicle in the contract, engine configuration, model launch date, or list price, deep multi-task forecasting models can take into account dynamic factors such as actual mileage driven at the end of the contract, or damages occurred throughout the leasing period. These have a major impact on the residual value of a car, but are hard to predict beforehand in traditional models. (Rashed et al., 2019) A common problem with the implementation of RVF models is the lack of information car manufacturers provide about their vehicles, something that would not happen in a PaaS environment of continuous material chains because the manufacturers

themselves would be the issuing company of a lease or subscription. As such, there would be an incentive for them to collect data for RVF.
Similar to cars, PaaS interior partition walls would be offered by a brand with a certain reputation, differ in aesthetics, and have distinctive features such as different door types, openings, or cladding. Depending on their actuality, region of manufacturing and sale, geometric space efficiency, and more, it is suspected that parameters which influence the residual value of interior partition walls are in parts analogical to parameters that influence the residual value of cars. In this way, manufacturers of PaaS interior partition walls can possibly make use of state-of-the-art RVF models from the automotive industry, to increase the accuracy of residual value estimations, by using a larger number of decisive parameters than in traditional models.
The emergence of deep learning in RVF algorithms also urges car manufacturers to reconsider the importance of value retention in their products to remain competitive on the market. This is underlined by the growth of the vehicle leasing sector and car residual value rankings that form a decision support for buyers. (VNA, 2020; J.D. Power, 2021; Edmunds, 2019)
With vehicle leasing also comes a shift towards value retentive car design. The product life cycle has a major impact on a cars' grade of value retention. Value retention can be improved through a cars' resilience to social and regulatory factors, technological innovations of the industry, and deterioration behavior. In their paper, Chul Kim et al. describe the relation between these dynamic factors and parameters revolving around recycled content, material use, vehicle miles traveled (VMT), energy intensity, fuel economy, emission factors, and component reliability. (Chul Kim et al., 2003; App. F)
The research shows that the increase in residual value, or value retention, is caused by the decrease in depreciation. To achieve this, the use and maintenance costs must be reduced, the deterioration behavior improved, and the service life of a product increased. In the case of cars, the lifetime can be extended through increased resilience against overhaul by new innovations and against susceptibility to defects, namely timeless design and technology with well thought-out and durable components. Here, restrained color design and the use of high-quality materials can play just as important a role as reduced emission values in order to comply with future standards. To reduce usage and maintenance costs, low fuel consumption, and components that can be removed and reinstalled quickly and cost-effectively through modular design, can be used. This also influences the deterioration behavior, as repairs can from now on be carried out selectively in the event of a fault.
These design strategies for value retentive car design can be translated to the overarching concepts of durability and remountability, which form the basis for the evaluation criteria in the following case study analysis.

IV. Case Studies

4.1. Evaluation Criteria

Applied to the design of value retentive interior partition walls within a PaaS environment, the concepts of durability and remountability each contain a technical and socio-economic component.
From a technical perspective, durability can refer to the use of (1a) high-quality materials, (1b) well-engineered, durable and functional components that are capable of accepting movement, (1c) the level of resistance against moisture, mold, corrosive substances, (1d) fire resistance, and (1e) a high acoustic and (1f) thermal insulating capacity. Whereas, from a socio-economic perspective, important evaluation criteria are (1g) surface qualities and patina, (1h) material texture or paint color, (1i) the acceptance of alterations such as nails, screws, custom paint, and (1j) the resistance to applied loads from shelves and other wall mounts.
Within remountability, technical evaluation criteria revolve around (2a) the independency of components, (2b) composition of components and ease of repair, (2c) ease of upgrades such as door openings, (2d) speed of assembly and disassembly, (2e) reversibility and grade of wear of connections, and (2f) accessibility and adjustability of technical systems. From a socio-economic perspective, remountability can be measured by the grade of (2g) flexibility an interior partition wall provides in case of use changes. (Guy et al., 2005; Van Vliet et al., 2019; Rajagopalan et al., 2021)

These qualitative evaluation criteria (App. G) are applied to the case studies within a Multi-Criteria Decision Analysis (MCDA) that is based on a methodology presented in a paper by Rajagopalan et al. in 2019. The researchers differentiate three interior wall types based on their turnover rate: *quickly changing interior walls, technical interior walls, and dwelling-dividing interior walls*. (Rajagopalan et al., 2021; App. H) These wall type scenarios serve as a reference for the evaluation of the case studies for different applications.
As a first step of the MCDA, the importance of the qualitative criteria for the wall type scenarios is assessed. Here, each of the criteria is assigned a weight, a relative percentage of importance. (App. I)
Second, the case studies are rated regarding their performance in the criteria. The scoring is based on a positive (1), neutral (0,5), and negative (0) evaluation. (App. J)
As a final step, each scoring is multiplied with the weight of importance from the wall type scenarios. This results in a set of matrices that provide information about what strategies are most value retentive in a specific field of application. (App. K, L, M)
The results present a simple decision support for architects and product developers to determine strategies for value retentive interior partition wall design.

4.2. Case Study Analysis

In the case study analysis, five contemporary circular interior partition wall systems are tested against the qualitative evaluation criteria that are extracted from the previous research. Case studies three to five were already analyzed by Rajagopalan et al. In their 2019 paper with a set of criteria that were in parts overlapping. As a linear reference product, a traditional drywall system is analyzed with the same criteria.

Table 1. The main characteristics of the analyzed interior partition wall systems.

Wall System	**Substructure**	**Connections**	**Finishing**
System 1: FAAY System Wall SP70	Flax Fiber Board 50mm	Floor: aluminum T-profile or wooden guide rail. Wall/ Ceiling: half wooden rails or frame panels.	Chipboard 10 mm on both sides. Eventually paint finish.
System 2: Quickpanell Circular Partition Wall	Foldable cardboard lashes and variable stiff isolation panels. Here: EverUse cellulose mats.	Either frame from aluminum or guide rail from MDF. Plug-in mechanism.	Variable materials. Here: MDF sheet material 14 mm on each side.
System 3: Wooden frame wall with gypsum fiberboard	Prefabricated wooden frame. Flax fiber board.	Screws. Wooden beams on floor and ceiling. No glue.	Gypsum fiberboard . Paint finish.
System 4: Massive wood interior wall	Solid modular wooden beams.	EPDM, L-connectors steel connector bolts. Steel spacers.	Varnish.
System 5: Steel frame wall with wooden panels	Steel frame system. Cellulose mats.	Clamps, hooks, bolts, and screws.	Plywood panels 15mm on each side. Varnish.

Reference: Metal stud drywall system with gypsum board cladding	Metal stud system. Stone wool.	Screws and plaster joining.	Plasterboard cladding 10mm on each side. Paint finish.

System 1: The FAAY System Wall SP70 is a modular wall system with which many different configurations can be made with little effort. The modules consist of a base layer from Flax Fiber Board with a thickness of 50 mm, which is enclosed by two chipboards with a thickness of 10 mm each. The modules are 600x3000 mm big, but can be individually produced in different sizes if required. The customer can choose between a floor guiding rail made of aluminum T-profiles or wood, as well as half wooden rails or frame panels on the ceiling and wall. The modules can be attached to each other and the frame panels, which are cut to size, make it easy to install openings. According to the manufacturer, the average assembly time per worker and m² is 0.2 hours. With below 20 minutes, the walls have a low fire resistance. Whereas, the weight of 32kg per m² is average, as is the sound insulation of 29dB and the thermal insulation of 0.6 m²K/W. The disadvantage is, that the panels still have to be glued to remain stable. This makes it harder to disassemble them. (FAAY, 2021; Fig. 1)

Figure 1. The FAAY System Wall SP70.

System 2: The Quickpanell circular partition wall is anticipated to especially score in remountability aspects and the quickly changing interior wall type scenario. It is modular, lightweight, made from renewable materials, suitable for reuse and refurbishment, and already available in subscription form. The user has the choice between different railing systems such as MDF and aluminum profiles. With its foldable design, and 30mm transport thickness, the modules are easy to transport and quick to set up with a reduction in adjustment work, screws and ladder use. They can be assembled and disassembled without wear and tear and weight approximately 18 kilograms per m². The element height varies between 300 and 3000 mm, whereas the element width is fixed to 600 mm. Various insulation materials can be used, depending on which the element can have good acoustic properties. Pipes can be run vertically element-wide and horizontally at regular heights. (Quickpanell, 2021; Fig. 2)

Figure 2. The Quickpanell circular partition wall.

System 3: The wooden frame wall with gypsum fiberboard cladding is insulated with flax fiber board. Mechanical connections are used within the wall, and to mount the wall to wooden beams at floor and ceiling. 80mm of insulating fiber board are cladded with gypsum fiber sheet material by the use of screws. In comparison to System 1 and 2, System 3 shows inferior acoustic and disassembly properties, whilst having a higher fire resistance due to the gypsum fiber board cladding. (Fig. 3)

Figure 3. The wooden frame wall with gypsum fiberboard cladding.

System 4: The massive wood interior wall system consists of solid modular wooden beams that are connected via steel bolts. The system shows a low complexity due to restricted material use, although EPDM rubber is used to keep the beams at distance from each other. However, this prevents damage during assembly and disassembly. It can be argued if the material could have been replaced by a more circular alternative such as cork. Undoubtedly, the sole use of wood favors an improved room climate and is aesthetically pleasing. Through the increased mass, acoustic properties are improved if mounted in a way that does not transfer mechanical vibration. (Fig. 4)

Figure 4. The massive wood interior partition wall.

System 5: The steel frame wall with 15 mm plywood panels is only using clamps, hooks, and bolts as connectors. In this way, no damage is incurred to the material during construction. This system presents a reversible solution that can be assembled and disassembled with little to no wear. Furthermore, installations are getting accessible and adjustable through this design. Its varnished surface is aesthetically pleasing and timeless. (Fig. 5)

Figure 5. The steel frame wall with plywood panels.

V. Results

The research shows that interior partition walls can be marketed as a subscription in a PaaS environment. By embedding the business model in the theory of continuous material chains, there could be a significant reduction in waste production. Furthermore, users and issuing companies would equally benefit. This makes PaaS an important building block towards a circular economy.

Unlike in linear businesses, the longer the product is used, the greater the profit in PaaS models. This gives the residual value of products a new importance.

In order to be able to make precise statements about residual value, manufacturers of interior partition walls can use the residual value forecasting models from the automotive industry as a reference. The parameters from these models, which revolve around durability and remountability, can be reformulated into a design for value retention.

According to the Multi-Criteria Decision Analysis of the case studies, circular wall systems show a higher value retention than linear wall systems. However, this value fluctuates depending on the application. For example, system 2 holds its value best as a temporary room divider, system 5 as a technical partition wall, and system 4 as a dwelling-dividing partition wall. In addition, value loss seems to depend strongly on the complexity of a system. The solid wood interior wall, for example, consistently achieved the best values, while the wood frame wall with gypsum fiber board showed a strong loss in value.

VI. CONCLUSION

5.1. Usability

It was discovered that the avoidance of complex connection details, and a more complex structure of the base layer, primarily improve value retention in interior partition walls. A light, modular design with the right subdivision of components can contribute to remountability. On the other hand, the use of high-quality materials that do not deteriorate as much, as well as robust dimensioning, can contribute to durability. Parameters from the fields of Modularity, Design for Disassembly (DfD), Design for Change (DfC), and Circular Building have been shown to positively impact residual value. Building products designed according to these principles can therefore perform better in PaaS models.

Although, these concepts are often congruent with design for value retention, it still makes sense to explore residual value of products as a design goal, as this opens up a new perspective that can help in stopping waste production. Therefore, knowledge in this field must be expanded. The presented methodology can be used by further researchers, to develop strategies for value retentive design that are tailored to other building products and business models.

Residual value is a difficult topic to approach because it touches upon many topics and therefore contains increasing levels of complexity. The parameters that influence it, thereby span from consumer behavior, over life cycle costs, to after-life-scenarios. For this reason, it must be noted that the limitations of the presented method lie within the incompleteness of, and required subjectivity to answer the presented qualitative criteria.

The proposed criteria from the MCDA, however, can provide architects and product developers with an orientation point to draw conclusions about the depreciation and residual value of the products they design. The presented research methodology, on the other hand, can be seen as a framework for researchers, that they can apply their individual case studies and considerations to.

5.2. Completeness

Due to the limited scope of this paper, it can only provide an outlook on how interior walls could be commercialized in a PaaS model. The focus lies on strategies that can help designers to optimize the residual value of interior partition walls. Therefore, it is up to future researchers, to develop PaaS models that can take advantage of these new products.

For the improved integration of products into PaaS models, Geldermans' methodology of evaluating materials and product with the Circ-Flex Assessment and Material Flow Analysis (MFA) could be used to gain new insights into the transformation of value chains. (Geldermans et al., 2019)

In order to make the evaluation of design strategies for value retention more accurate, further research can also be conducted on evaluation methods for specific sub-areas of value retentive design. In his research paper, Beem describes an evaluation method for Design for Reuse (DfR) that could also help to increase the residual value of building products. (Breem, 2019)

By using various resources and methods to approach the topics of PaaS integration of building products and value retentive design, they are a valuable addition to the body of research that is conducted in order to facilitate the transition towards a circular economy.

REFERENCES

Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., ... & Alcock, J. R. (2007). *State-of-the-art in product-service systems.* Institution of Mechanical Engineers, Part B: journal of engineering manufacture, 221(10), 1543-1552. Sage Publishers. London, UK.

Bentenrieder, M; Coccorullo, S. (2019). *A Better Approach to Residual Value. Traditional residual value business models are on their last legs; it is time to upgrade.* Automotive Manager 2019. Oliver Wyman. Munich, DE. Retrieved from: https://www.oliverwyman.de/content/dam/oliver-wyman/v2/publications/2019/jun/AutomotiveManager2019/Oliver_Wyman_Automotive_Manager_Residual_Value.pdf

Bouwwereld (2020). *Restwaarde bouwcomponenten als impuls voor circulair bouwen.* Bouwwereld. Doetinchem, NL. Retrieved from: https://www.bouwwereld.nl/bouwkennis/duurzaamheid/restwaarde-bouwcomponenten-als-impuls-voor-circulair-bouwen/

Braakman, L.; Bhochhibhoya, S.; de Graaf, R. (2021). *Exploring the relationship between the level of circularity and the life cycle costs of a one-family house.* Faculty of Engineering Technology, Department of Civil Engineering, University of Twente. Twente, NL. Retrieved from: https://ris.utwente.nl/ws/portalfiles/portal/226820504/1_s2.0_S0921344920304663_main.pdf

Brand, S. (1994). *How Buildings Learn: What Happens After They 're Built.* Viking Press. New York, USA.

Breem, A. (2019). *Research Towards and Prototyping of an Evaluation Method for Design for Reuse for Building Products in the Design Phase.* TU Delft. Delft, NL

Chul Kim, H; Keoleian, G.A.; Grande, D.E.; James, C. (2003). *Dynamic Life Cycle Inventories for Mid-Sized Cars.* Supporting Information for Environmental Science & Technology. University of Michigan. Michigan, USA. Retrieved from: https://pubs.acs.org/doi/10.1021/es0345221

Edmunds (2019). *2019 Edmunds Best Retained Value Awards.* Edmunds.com Inc. Santa Monica, USA. Retrieved from: https://www.edmunds.com/car-reviews/best-retained-value-cars.html

EEA (2020). *Construction and Demolition Waste: Challenges and Opportunities in a Circular Economy*. Retrieved from: https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-wmge-reports/construction-and-demolition-waste-challenges-and-opportunities-in-a-circular-economy

EIT Climate-Kic Benelux (2020). *Residual value - Financial trigger for stimulating circular*

construction. Retrieved from: https://benelux.climate-kic.org/news/innovation-project-residual-value-financial-trigger-for-stimulating-circular-construction/

European Commission (2015). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the Regions. Closing the loop - An EU action plan for the Circular Economy*. COM. Brussels, BE

European Commission (2020). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the Regions. A new Circular Economy Action Plan. For a cleaner and more competitive Europe.* COM. Brussels, BE

Ferrandez-García, A.; Ibánez-Forés, V.; D. Bovea, M. (2015). *Eco-efficiency analysis of the life cycle of interior partition walls: a comparison of alternative solutions*. Department of Mechanical Engineering & Construction, Universitat Jaume. Castellón, ES.

Geldermans, B.; Tenpierik, M.; Luscuere, P.G. (2019). Circular and Flexible Indoor Partitioning – A Conceptualization of Innovative Materials and Value Chains. Buildings 9(9): 194. Depertment of Architectural Engineering + Technology. TU Delft. Delft, NL. Retrieved from: https://www.researchgate.net/publication/335417729_Circular_and_Flexible_Indoor_Partitioning-A_Design_Conceptualization_of_Innovative_Materials_and_Value_Chains

Ganz, C.; West, S. (2020). *Product as a Service: Is it only rental by a different name?* 1927 Media Ltd. London, UK. Retrieved from: https://www.fieldservicenews.com/blog/product-as-a-service-is-it-only-really-rental-by-a-different-name

Green Spec (2021). *Gypsum Plasterboards – Manufacture & Addititives.* Retrieved from: https://www.greenspec.co.uk/building-design/plasterboard-drylining-partition/ (Accessed: 21.11.2021)

Greim, L. (2017). *The Impact of the Model Life Cycle on the Residual Car Value in the Leasing Industry*. University of Twente. Twente, NL. Retrieved from: https://essay.utwente.nl/72764/1/Greim_MA_BMS.pdf

Guy, B.; Ciarimboli, N. (2005). DFD – Design for Disassembly in the Built Environment: A guide to closed-loop design and building. Pennsylvania State University. Seattle, USA.

Jansen, B. (2020). *Products-as-a-Service als accelerator voor de circulaire economie.* [online] Emerce. Retrieved from: https://www.emerce.nl/achtergrond/products-as-a-service-als-accelerator-voor-de-circulaire-economie

J.D. Power (2021). *2021 U.S. ALG Residual Value Awards.* J.D. Power. Troy, USA. Retrieved from: https://www.jdpower.com/sites/default/files/file/2021-11/2021159%20U.S.%20ALG%20Residual%20Value%20Awards_1.pdf

Lessmann, S.; Listiani, M.; Voß, S. (2010) *Decision Support in Car Leasing: A Forecasting Model for Residual Value Estimation.* Retrieved from: https://www.researchgate.net/publication/221599821_Decision_Support_in_Car_Leasing_a_Forecasting_Model_for_Residual_Value_Estimation

Lombardo, T. (2019). *Research Report: The Next Product You Design Might be a Service Thanks to the IoT.* Engineering.com. Retrieved from: https://image.engineering.com/239575/articles/Jan2019/engineering.com+-+The+Next+Product+You+Design+Might+be+a+Service+Thanks+to+the+IoT+Research+Report.pdf

Poolen, D.; Ryszka, K.; Rijpert, K. (2020). *Wat is er nodig om Product as a Service (PaaS) circulair te maken?* Rabobank. Amsterdam, NL. Retrieved from: https://economie.rabobank.com/publicaties/2020/oktober/wat-is-er-nodig-om-product-as-a-service-paas-circulair-te-maken/

Philips Lighting Holding B.V. (2017) *Case Study. Schiphol Airport opts for Circular lighting: a responsible choice.* Philips Lighting Holding B.V. Einhoven, NL. Retrieved from: https://images.philips.com/is/content/PhilipsConsumer/PDFDownloads/Global/Case-studies/CSLI20170418_001-UPD-en_AA-Case-Study-LaaS-Schiphol.pdf (Accessed: 20.12.2021)

Quickpanell (2021). MDF wall elements. Retrieved from: https://www.quickpanell.com/producten/wandelementen/mdf-wandelementen/

Rajagopalan, N.; Brancart, S.; De Regel, S.; Paduart, A.; De Temmerman, N.; Debacker, W. (2021). *Multi-Criteria Decision Analysis Using Life Cycle Assessment and Life Cycle Costing in Circular Building Design: A Case Study for Wall Partitioning Systems in the Circular Retrofit Lab.* Sustainability. 2021; 13(9):5124; Life Cycle Assessment and Environmental Footprinting. Brussels, BE. Retrieved from: https://www.researchgate.net/publication/351308369_Multi-Criteria_Decision_Analysis_Using_Life_Cycle_Assessment_and_Life_Cycle_Costing_in_Circular_Building_Design_A_Case_Study_for_Wall_Partitioning_Systems_in_the_Circular_Retrofit_Lab [accessed Jan 17 2022].

Rashed, A; Jawed, S.; Rehberg, J; Grabocka, J; Schmidt-Thieme, L; Hintsche, A. (2019). *A Deep Multi-Task Approach for Residual Value Forecasting.* Information Systems and Machine Learning Lab, University of Hildesheim. Hildesheim, DE. Retrieved from: https://ecmlpkdd2019.org/downloads/paper/410.pdf

Rau, T; Oberhuber, S. (2016). *Material Matters: Wie wir es schaffen, die Ressourcenverschwendung zu beenden, die Wirtschaft zu motivieren, bessere Produkte zu erzeugen und wie Verbraucher und die Umwelt davon profitieren.* Econ. Düsseldorf, Berlin, DE

Rombouts, S. (2020). *The reintroduction of the term Product-Service Systems (PSS).* Firmhouse. Rotterdam, NL. Retrieved from: https://www.firmhouse.com/blog/the-reintroduction-of-the-term-product-service-systems-pss

Sawhney, M.; Balasubramanian, S.; Krishnan, V (2004) *Creating Growth with Services.* MIT Sloan Management Review. Cambridge, USA. p. 34-43.

TNO (2019). *Calculation Model Stimulates the Reuse of Products.* TNO. Amsterdam, NL. Retrieved from: https://www.tno.nl/en/tno-insights/articles/calculation-model-stimulates-the-reuse-of-building-products/

Tuovila, A. (2021A). *Residual Value.* Dotdash Meredith. New York, USA. Retrieved from: https://www.investopedia.com/terms/r/residual-value.asp#:~:text=The%20Bottom%20Line-,What%20Is%20Residual%20Value%3F,pays%20in%20periodic%20lease%20payments.

Tuovila, A. (2021B). *Depreciation.* Dotdash Meredith. New York, USA. Retrieved from: https://www.investopedia.com/terms/d/depreciation.asp

Van Stralen, A. (2021) *Which products can become PaaS?* Recurring Company. Utrecht, NL. Retrieved from: https://recurringcompany.com/en/products-as-a-service/

Van Vliet, M.; Van Grinsven, J.; Teunizen, J. (2019). *Circular Buildings; Meetmethodiek Losmaakbarheid.* Alba Concepts. ‘s-Hertogenbosch, NL.

Valencia-Barbaa, Y. E.; Gómez-Soberón, J. M.; Gómez-Soberón, M. C.; Rojas-Valenciad, M. N. (2021). *Life cycle assessment of interior partition walls: Comparison between functionality requirements and best environmental performance.* Journal of Building Engineering. Volume 44. Barcelona, ES; Mexico City, MEX. Retrieved from: https://www.sciencedirect.com/science/article/pii/S2352710221008366 (Accessed: 30.12.2021)

VNA (2020). *Vehicle Leasing Market in Figures 2020.* Vereniging van Nederlandse autoleasemaatschappijen. Bunnik, NL. Retrieved from: https://www.vna-lease.nl/stream/autoleasemarkt-in-cijfers-2020-en.pdf

APPENDIX

Appendix A. The Research Framework: Thematic Research Question, Preliminary Research, and Sub Questions.

Research Framework

Thematic Research Question

» What architectural design strategies can be implemented to create circular interior partition wall systems that retain value? «

Preliminary Research

Why is it important to design for value retention?

> To create an economic incentive to reuse, refurbish, or remanufacture products.
> This could lead to a reduction in waste production.

Why are interior partition walls an important starting point for a paradigm shift in architecture?

> Due to cheap materials and poor construction techniques they produce a lot of waste today.
> Nevertheless, they bear much potential for Product as a Service (PaaS) models.

What business model can be used to commercialize value retentive interior partition walls?

> A subscription to "the use of a flexible, aesthetically pleasing room layout that meets acoustic, energy, and fire requirements, and includes a guarantee for Extended Producer Responsibility (EPR)"
> Offering products as a service requires the optimization of their residual value.

Sub Question 1

How can the considerations from Residual Value Forecasting (RVF) models in other industries be transferred to the design of interior partition wall systems?

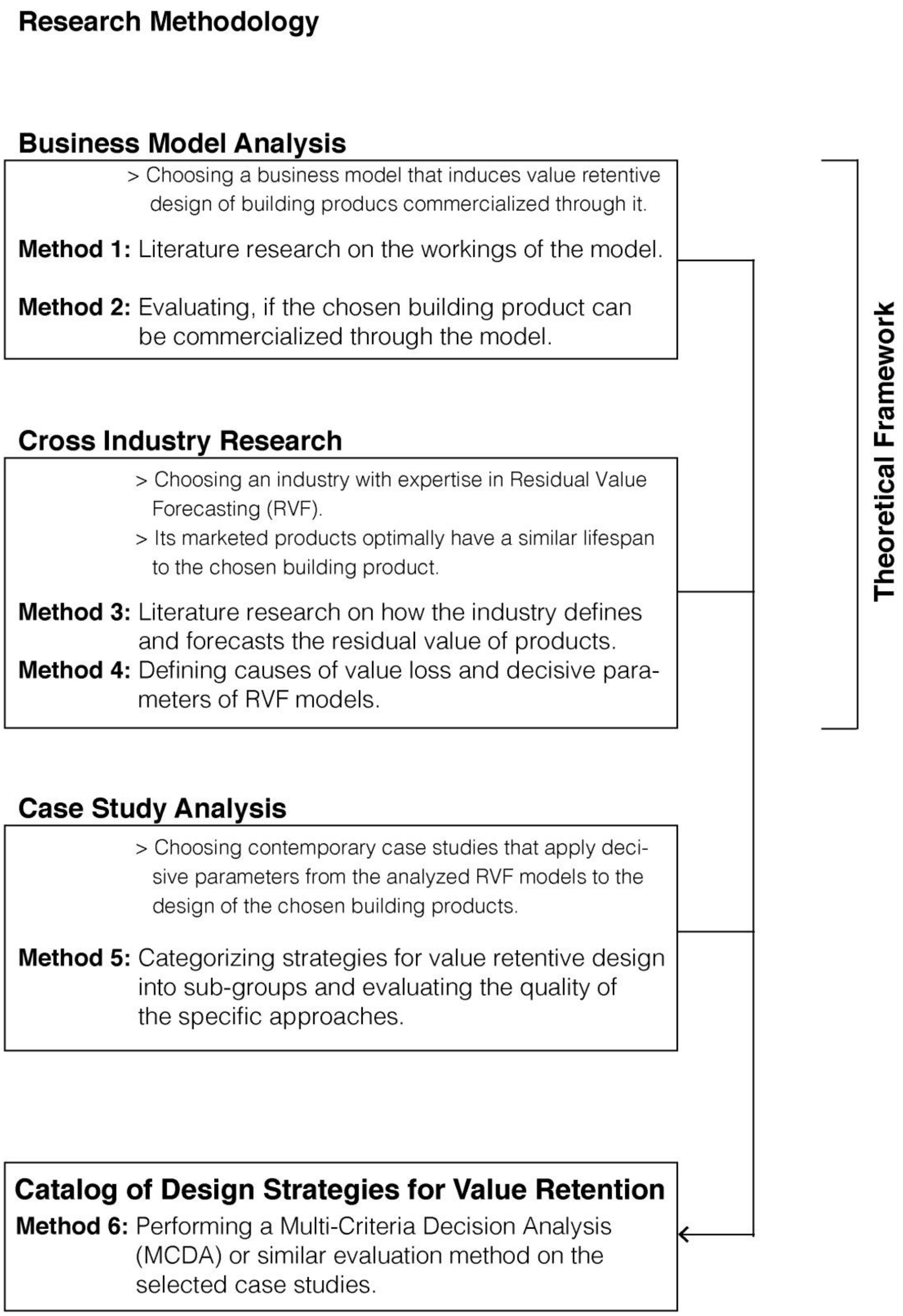
> A field of design related parameters in residual value optimization models.
> The parameters revolve around durability and remountability.

Sub Question 2

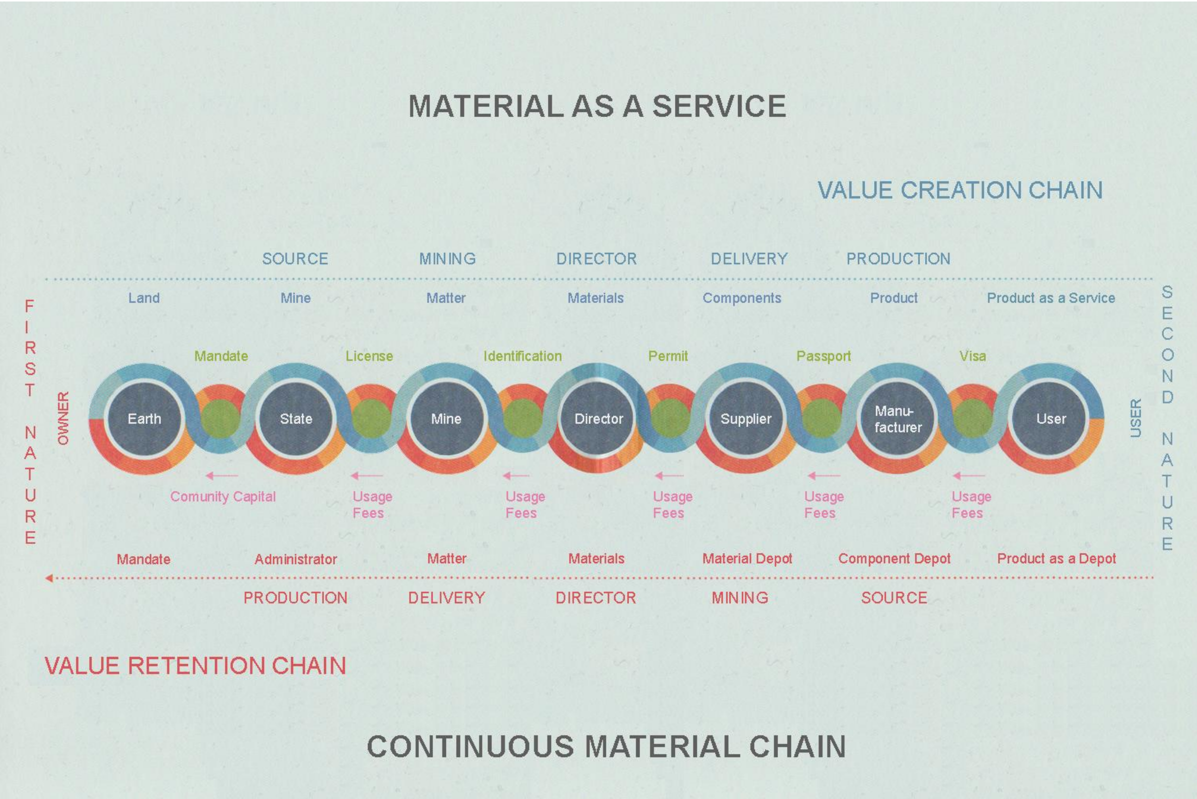
What lessons can be learned from contemporary case studies that implement strategies to enhance durability and remountability in interior partition wall systems?

> A list of design strategies that can optimize the residual value of infill components.
> The conclusion discusses possible integrations of the strategies.

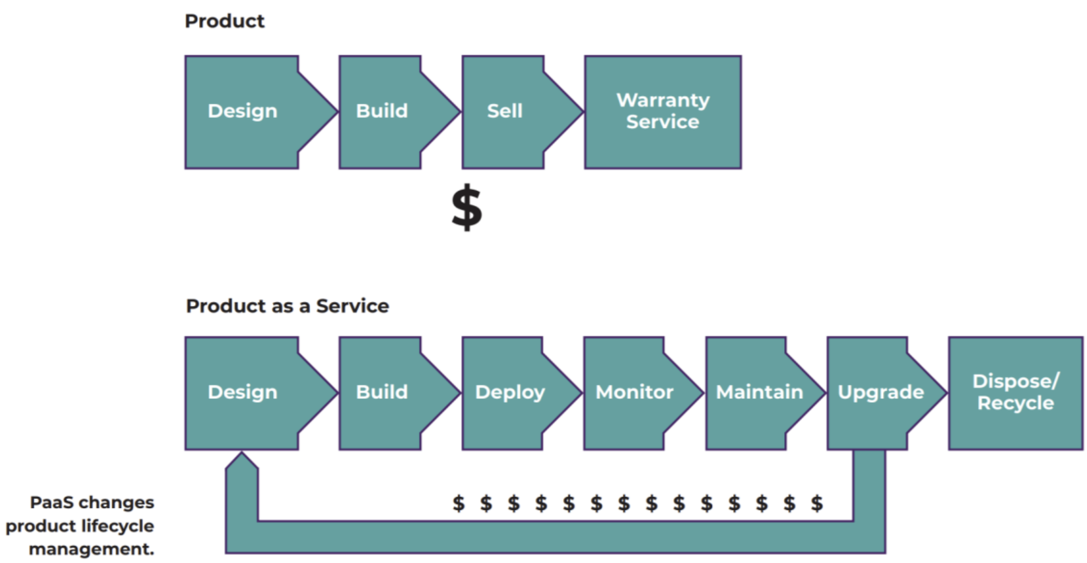
Appendix B. The proposed sequence of methods to develop catalogs of design strategies for value retentive building products. This methodology can be seen as a blueprint for future research to expand knowledge on value retentive design to other parts of the building product palette.



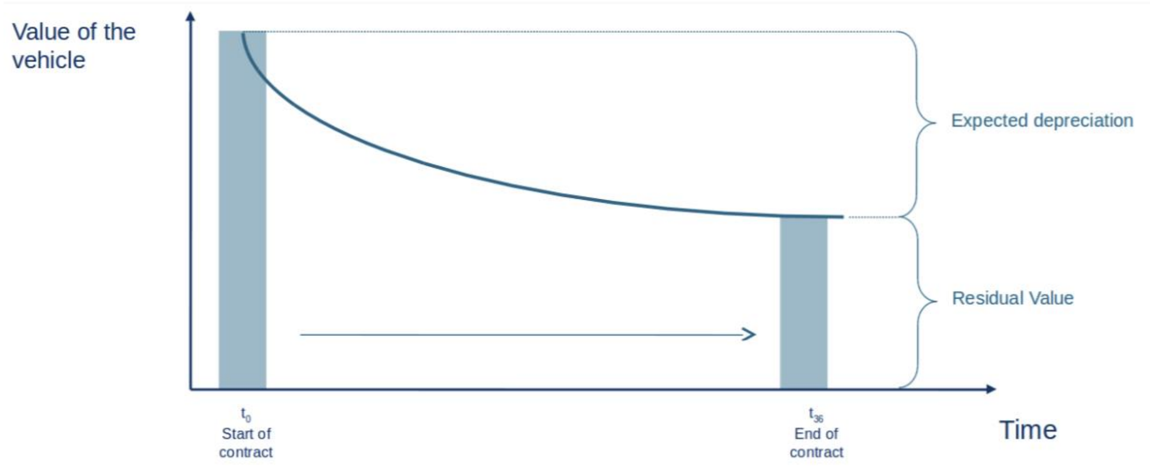
Appendix C. The concept of a continuous material chain as theorized by T. Rau and S. Oberhuber in their 2016 book: Material Matters. The graphic has been translated from German to English by the author.



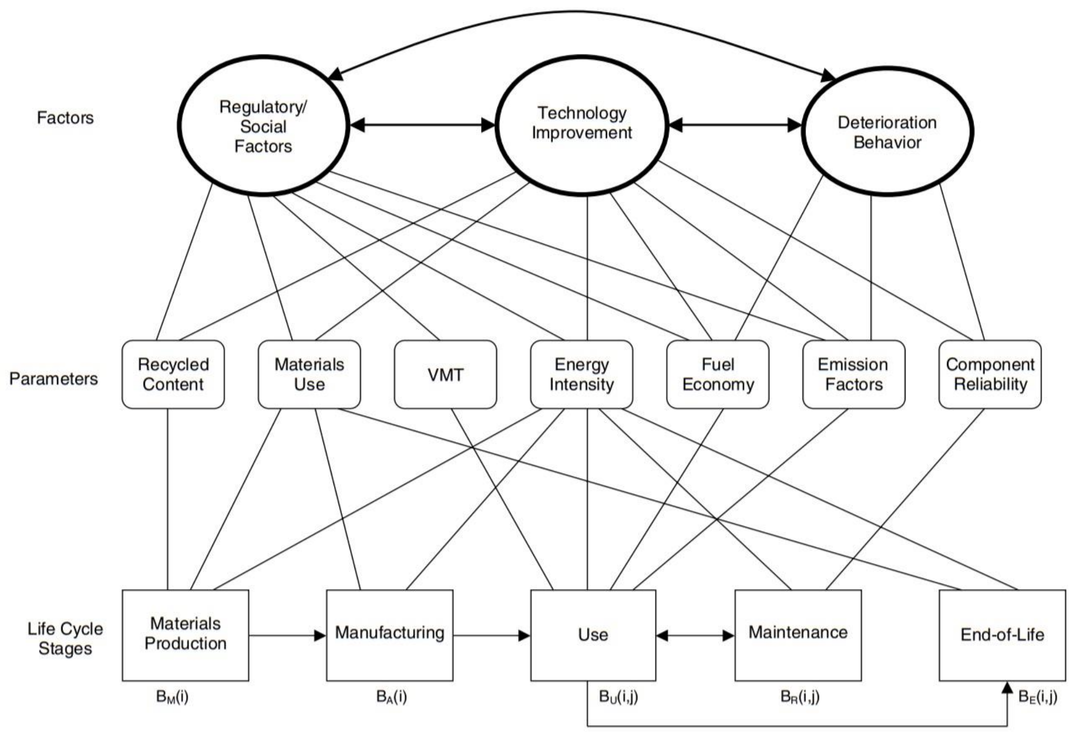
Appendix D. Comparison between Product and Product as a Service: PaaS changes product life cycle management. (Lombardo, 2019)



Appendix E. A sample timeline of depreciation and final residual value of a vehicle. (Rashed et al., 2019)



Appendix F. Structure of the dynamic Life Cycle Inventory (LCI) of a mid-sized passenger car. (Chul Kim et al., 2003)

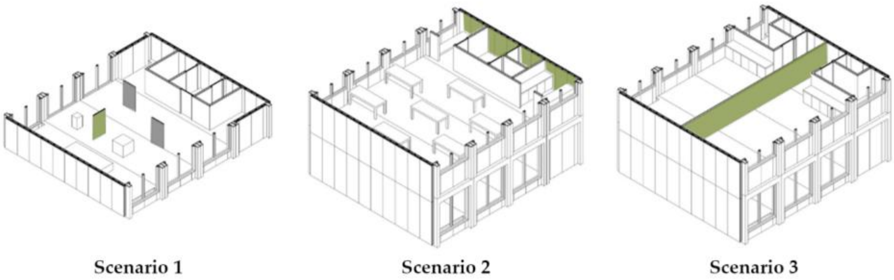


Appendix G. Qualitative criteria that decrease depreciation and increase the residual value of interior partition walls. These criteria can be regarded as indicators for value retentive design.

	Qualitative Criteria	**Positive (1)**	**Neutral (0,5)**	**Negative (0)**
1	**Durability**			
Technical				
1a	High-quality materials	Low deterioration; hard to damage	Neutral deterioration; damage possible	High deterioration; easily damaged
1b	Durable, functional components that accept movement	Robust connections and dimensioning; Well-engineered	Fair connections and dimensioning; Fair-engineered	Poor quality connections and dimensioning
1c	Resistance against moisture, mold, corrosive substances.	Mold and corrosion resistant materials, vapor-open	Does not mold	Possibly molds
1d	Fire resistance	> EI 90	< EI 60	< EI 30
1e	Acoustic insulation	High (>57 dB) acoustical performance	medium (57 dB > x > 51 dB) acoustical performance	Low (<51 dB) acoustical performance
1f	Thermal insulation	High thermal insulation	Thermal insulation present	No thermal insulation present
Socio-Economic				
1g	Surface qualities and patina	Low deterioration; beautiful patina	Normal deterioration; fair patina	High deterioration; Ages badly
1h	Material texture or paint color	Timeless aesthetic	Good aesthetic	Temporary aesthetic
1i	Acceptance of alterations	Original state can be restored	Some traces of use remain visible	Reuse is limited through alterations
1j	Resistance to applied loads	Shelves or such can be attached without wear	Some wear remains visible	Shelves or such cannot be mounted to the wall
2	**Remountability**			
Technical				
2a	Component independency	Mechanical connectors; no glue; little tools required	Reversible glues allowed; Components can be disassembled	Most components are glued or fixed in ways that prohibit easy disassembly
2b	Component composition and ease of repair	Components can easily be taken apart without wear	Components can be taken apart, however traces are left	Component disassembly leads to wear and tear
2c	Ease of upgrades	Componential logic is well organized	Partial replacement is possible	Upgrades require new components
2d	Speed of assembly and disassembly	Lightweight; mechanical connections; little tools required	More workers required; more tools required	Large complexity; Irreversible connections
2e	Connection reversibility and grade of wear and tear	Reversible and durable connections, no wear and tear	Connections are relatively durable and reversible	Irreversible connections; e.g. glue
2f	Accessibility and adjustability of technical systems	Technical systems are easily accessible and adjustable without wear and tear	Technical systems are accessible and adjustable without wear and tear	Components are damaged or must be replaced after accessing technical systems
Socio-Economic				
2g	Flexibility in case of use-changes	Components are very flexible and can be removed and moved without larger efforts	Components can be removed and moved with little damage	Components are damaged when removed or moved

Appendix H: *Three wall type scenarios distinguish between different turnover rates for different interior walls.* (Rajagopalan et al., 2021)

Wall Type Scenario	Turnover Rate (Years)	Description
Scenario 1: quickly changing interior wall	1	Walls and wall segments in the central space of the dissemination room (exhibition walls, presentation walls . . .)
Scenario 2: technical interior wall	10	False walls to cover technical systems (water, heating, electricity and ventilation)
Scenario 3: dwelling-dividing interior wall	15	Central wall or walls to split up the open space into individual housing units



Appendix I. Assessment of the importance of the qualitative criteria for the wall type scenarios. Each of the criteria is assigned a weight. The weight is expressed as a relative percentage of the criteria's importance for a specific wall type scenario.

	Qualitative Criteria	**Wall Type Scenario 1** Quickly changing interior walls	**Wall Type Scenario 2** Technical interior walls	**Wall Type Scenario 3** Dwelling-dividing interior walls
1	**Durability**			
Technical				
1a	High-quality materials	8,8%	5,9%	8,7%
1b	Durable, functional components that accept movement	9,8%	2,2%	3,8%
1c	Resistance against moisture, mold, corrosive substances.	2,9%	7,4%	5,8%
1d	Fire resistance	4,9%	5,9%	7,7%
1e	Acoustic insulation	2,9%	7,4%	8,7%
1f	Thermal insulation	0%	5,9%	6,7%
Socio-Economic				
1g	Surface qualities and patina	4,9%	6,7%	8,7%
1h	Material texture or paint color	7,8%	4,4%	6,7%
1i	Acceptance of alterations	8,8%	5,9%	7,7%
1j	Resistance to applied loads	0%	5,2%	6,7%
2	**Remountability**			
Technical				
2a	Component independency	9,8%	5,2%	5,8%
2b	Component composition and ease of repair	7,8%	5,9%	3,8%
2c	Ease of upgrades	7,8%	5,2%	4,8%
2d	Speed of assembly and disassembly	9,8%	4,4%	5,8%
2e	Connection reversibility and grade of wear	3,9%	7,4%	9,6%
2f	Accessibility and adjustability of technical systems	0%	7,4%	4,8%
Socio-Economic				
2g	Flexibility in case of use-changes	9,8%	7,4%	9,6%
		Total: 100%	Total: 100%	Total: 100%

Appendix J. A rating of the case studies regarding their performance in the criteria. The scoring is based on a positive (1), neutral (0,5), and negative (0) evaluation.

	Qualitative Criteria	System 1	System 2	System 3	System 4	System 5	Reference
1	**Durability**						
Technical							
1a	High-quality materials	1	0	0,5	1	1	0,5
1b	Durable, functional components that accept movement	1	0,5	0,5	1	1	0
1c	Resistance against moisture, mold, corrosive substances.	0,5	0	1	1	0,5	1
1d	Fire resistance	0	0	1	0,5	0	1
1e	Acoustic insulation	0,5	0	0,5	0,5	0,5	0,5
1f	Thermal insulation	1	0,5	1	0,5	1	1
Socio-Economic							
1g	Surface qualities and patina	0,5	1	0	1	1	0
1h	Material texture or paint color	0,5	1	0	1	1	0
1i	Acceptance of alterations	0,5	0,5	0	0	0,5	0,5
1j	Resistance to applied loads	0,5	0	1	1	1	1
2	**Remountability**						
Technical							
2a	Component independency	0	1	1	1	1	0
2b	Component composition and ease of repair	0	1	1	1	1	0,5
2c	Ease of upgrades	1	1	0,5	1	0	0
2d	Speed of assembly and disassembly	1	1	0,5	1	1	0,5
2e	Connection reversibility and grade of wear and tear	0,5	1	0	1	1	0
2f	Accessibility and adjustability of technical systems	0	1	0,5	0,5	1	0,5
Socio-Economic							
2g	Flexibility in case of use-changes	1	1	0,5	1	0,5	0,5

Appendix K. A ranking of the systems using the weight for wall type scenario 1 – quickly changing interior walls.

	Qualitative Criteria	**System 1**	**System 2**	**System 3**	**System 4**	**System 5**	**Reference**
1	**Durability**						
Technical							
1a	High-quality materials	8,8%	0%	4,4%	8,8%	8,8%	4,4%
1b	Durable, functional components that accept movement	9,8%	4,9%	4,9%	9,8%	9,8%	0%
1c	Resistance against moisture, mold, corrosive substances.	1,5%	0%	2,9%	2,9%	1,5%	2,9%
1d	Fire resistance	0%	0%	4,9%	2,5%	0%	4,9%
1e	Acoustic insulation	1,5%	0%	1,5%	1,5%	1,5%	1,5%
1f	Thermal insulation	0%	0%	0%	0%	0%	0%
Socio-Economic							
1g	Surface qualities and patina	2,5%	4,9%	0%	4,9%	4,9%	0%
1h	Material texture or paint color	3,9%	7,8%	0%	7,8%	7,8%	0%
1i	Acceptance of alterations	4,4%	4,4%	0%	0%	4,4%	4,4%
1j	Resistance to applied loads	0%	0%	0%	0%	0%	0%
2	**Remountability**						
Technical							
2a	Component independency	0%	9,8%	9,8%	9,8%	9,8%	0%
2b	Component composition and ease of repair	0%	7,8%	7,8%	7,8%	7,8%	3,9%
2c	Ease of upgrades	7,8%	7,8%	3,9%	7,8%	0%	0%
2d	Speed of assembly and disassembly	9,8%	9,8%	4,9%	9,8%	9,8%	4,9%
2e	Connection reversibility and grade of wear and tear	2%	3,9%	2%	3,9%	3,9%	0%
2f	Accessibility and adjustability of technical systems	0%	0%	0%	0%	0%	0%
Socio-Economic							
2g	Flexibility in case of use-changes	9,8%	9,8%	4,9%	9,8%	4,9%	4,9%
	Value Retention Ranking	**61,8%**	**70,9%**	**51,9%**	**79,3%**	**74,9%**	**31,8%**

Appendix L. A ranking of the systems using the weight for wall type scenario 2 – technical interior walls.

	Qualitative Criteria	System 1	System 2	System 3	System 4	System 5	Reference
1	**Durability**						
Technical							
1a	High-quality materials	5,9%	0%	3%	5,9%	5,9%	3%
1b	Durable, functional components that accept movement	2,2%	1,1%	1,1%	2,2%	2,2%	0%
1c	Resistance against moisture, mold, corrosive substances.	3,7%	0%	7,4%	7,4%	3,7%	7,4%
1d	Fire resistance	0%	0%	5,9%	3%	0%	5,9%
1e	Acoustic insulation	3,7%	0%	3,7%	3,7%	3,7%	3,7%
1f	Thermal insulation	5,9%	3%	5,9%	3%	5,9%	5,9%
Socio-Economic							
1g	Surface qualities and patina	3,4%	6,7%	0%	3,4%	6,7%	0%
1h	Material texture or paint color	2,2%	4,4%	0%	4,4%	4,4%	0%
1i	Acceptance of alterations	3%	3%	0%	0%	3%	3%
1j	Resistance to applied loads	2,6%	0%	5,2%	5,2%	5,2%	5,2%
2	**Remountability**						
Technical							
2a	Component independency	0%	5,2%	5,2%	5,2%	5,2%	0%
2b	Component composition and ease of repair	0%	5,9%	5,9%	5,9%	5,9%	3%
2c	Ease of upgrades	5,2%	5,2%	2,6%	5,2%	0%	0%
2d	Speed of assembly and disassembly	4,4%	4,4%	2,2%	4,4%	4,4%	2,2%
2e	Connection reversibility and grade of wear and tear	3,7%	7,4%	0%	7,4%	7,4%	0%
2f	Accessibility and adjustability of technical systems	0%	7,4%	3,7%	3,7%	7,4%	3,7%
Socio-Economic							
2g	Flexibility in case of use-changes	7,4%	7,4%	3,7%	7,4%	3,7%	3,7%
	Value Retention Ranking	**53,3%**	**61,1%**	**55,5%**	**77,4%**	**74,7%**	**46,7%**

Appendix M. A ranking of the systems using the weight for wall type scenario 3 – dwelling-dividing interior walls.

	Qualitative Criteria	**System 1**	**System 2**	**System 3**	**System 4**	**System 5**	**Reference**
1	**Durability**						
Technical							
1a	High-quality materials	8,7%	0%	4,4%	8,7%	8,7%	4,4%
1b	Durable, functional components that accept movement	3,8%	1,9%	1,9%	3,8%	3,8%	0%
1c	Resistance against moisture, mold, corrosive substances.	2,9%	0%	5,8%	5,8%	2,9%	5,8%
1d	Fire resistance	0%	0%	7,7%	3,9%	0%	7,7%
1e	Acoustic insulation	4,4%	0%	4,4%	4,4%	4,4%	4,4%
1f	Thermal insulation	6,7%	3,4%	6,7%	3,4%	6,7%	6,7%
Socio-Economic							
1g	Surface qualities and patina	4,4%	8,7%	0%	8,7%	8,7%	0%
1h	Material texture or paint color	3,4%	6,7%	0%	6,7%	6,7%	0%
1i	Acceptance of alterations	3,9%	3,9%	0%	0%	3,9%	3,9%
1j	Resistance to applied loads	3,4%	0	6,7%	6,7%	6,7%	6,7%
2	**Remountability**						
Technical							
2a	Component independency	0%	5,8%	5,8%	5,8%	5,8%	0%
2b	Component composition and ease of repair	0%	3,8%	3,8%	3,8%	3,8%	1,9%
2c	Ease of upgrades	4,8%	4,8%	2,4%	4,8%	0%	0%
2d	Speed of assembly and disassembly	5,8%	5,8%	2,9%	5,8%	5,8%	2,9%
2e	Connection reversibility and grade of wear and tear	4,8%	9,6%	0%	9,6%	9,6%	0%
2f	Accessibility and adjustability of technical systems	0%	4,8%	2,4%	2,4%	4,8%	2,4%
Socio-Economic							
2g	Flexibility in case of use-changes	9,6%	9,6%	4,8%	9,6%	4,8%	4,8%
	Value Retention Ranking	**66,6%**	**68,6%**	**59,7%**	**93,9%**	**87,1%**	**51,6%**