Chapter 8

Blue Ocean Strategy for Business Case of Building Components Designed for Disassembly

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Abstract Sustainability requires us to show careful consideration for nature and future generations. When designing new structures, along with optimisation and cautious material selection, we should also ensure their long-term usefulness. One way to do this is to reuse whole building components, which is known from history to be practical. Life-cycle assessments prove this circular practice to be more environmentally friendly than recycling. Designing adaptable building components for disassembly and reassembly is feasible but not popular. This paper looks at the viability of such a product offering and conceptualises a business case using the Blue Ocean Strategy framework. The analysis is based on data coming from literature, case studies and interviews with practitioners. The business case of adaptable building components not only is built on the premise of subsequent uses of the products but also shows immediate benefits such as a fast assembly process. From a solely economic perspective, such products bring primary value in attracting more clients willing to pay an additional price for more sustainable buildings. Such an offering also helps to form a circular economy market of reusable products, which is desired by European incentives. The results compare and distinguish the circular business case with contemporary alternatives – monolithic and prefabricated structures. The paper provides guidelines for harnessing the value of prefabricated building elements designed with the intention of multiple applications and developing a circular economy business strategy in the built environment. Necessary preconditions, limitations and barriers are also discussed.

Keywords Circular economy · Business case · Blue Ocean Strategy · Adaptable building elements · Design for disassembly (DfD)

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8.1 Introduction

The Industrial Revolution has brought us significant advancements, allowing us to produce goods in high volume efficiently. High performance and energy-intensive manufacturing processes also have side effects – businesses optimise for short-term profits at the expense of society and the environment. Nowadays, with raising awareness of anthropogenic influence on climate change, sustainability gains attention also in construction. To minimise the greenhouse gas (GHG) emissions, designers righteously try to improve buildings' energy efficiency, but as they progress and as countries shift towards renewable energy sources, the embodied emissions of materials begin to play a very important role (Röck et al., 2020; Wiik et al., 2018).

Fivet and Brütting (2020) name three ways to address the issue of embodied GHG: (1) optimise the design to be material-efficient, (2) employ low-carbon materials, and (3) ensure long-term usefulness of elements. The first two are usually considered by the designers, but the third is overlooked, causing a mismatch between designed and actual lifespans. Speaking of time aspect, Wilkinson et al. (2014) describe three types of building lifespans: (1) the technical, driven by safety, dependent on the physical condition, that can be prolonged by maintenance; (2) functional, which ends when the building limits the use and is no longer fit for requirements and needs of the users; and (3) economic, as long as buildings generate more income than costs. Authors also list other factors that affect building usefulness – social, like fashion or demographic; legal, when a building is not compliant with regulations; and political such as zoning or heritage. When one of the lifespans ends, the building becomes obsolete or even demolished, causing underutilised materials to become waste.

Separation of the technical lifespan from the economic and functional enables the utilisation of materials' full potential. Such a breakup is a key topic of literature on circular practices. European Commission (2015) describes circular economy (CE) as an approach 'where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised'. Bocken et al. (2016) further extend the definition by providing three types of circular economy practices: (1) slowing resource loops by design of long-life goods and product life extension (repair, reuse, remanufacturing), (2) closing resource loops by using resources over and over again, avoiding taking out virgin resources (recycling), and (3) narrowing resource loops, or increasing resource efficiency, by using fewer resources per product.

The revolution in space exploration with reusing rockets, caused what is described as the 'SpaceX Effect' (Reddy, 2018). What used to be perceived as impossible became almost a standard, with international companies practicing the reuse of spaceship parts. Similarly, we have reasons to foresee such turn of events in the construction industry, which is simpler than space travel, but because the economic scale can cause even higher disruption. In fact, reuse of building components is nothing new and was practised for centuries (Fivet & Brütting, 2020). It used to be common for Norway to construct buildings with logs and stones that previously served as parts of other buildings. Prefabrication, modularity, reversible connections, and standardisation of elements are among the factors that enable the reuse of structural components (ISO, 2020) that are often already applied irrespective of future reuse.

Despite vast scientific literature on circular economy, there is little visible conversion to viable businesses, and over 97% of materials consumed in Norway are not cycled back to the economy (de Wit et al., 2020). This conceptual paper aims to reflect on the viability of prefabricated building elements designed for disassembly and reusability. Since the highest embodied carbon is attributed to a building's structure (Wiik et al., 2018), the paper focuses on structural elements. We explore the hypothesis that such components are an unexploited niche with profit potential, which we investigate with help of Blue Ocean Strategy tools from Kim and Mauborgne (2015). The paper intends to contribute with business advice for new or existing enterprises by blending economics and construction engineering domains. This paper is not offering a business model, understood as the blueprint for generating profit off a product or service, strategic choices, or value creation (Jensen, 2013). Instead, it is about the business case to explain why the investment is worth doing.

8.2 Methodology

This is a conceptual paper with theory adaptation (Jaakkola, 2020). Our data is coming from existing literature, documented case studies, national statistics, as well as qualitative interviews with convenient sample of 12 industry representatives. The structure of the paper starts with an explanation of the theoretical framework, followed by the analysis of aspects influencing the business case of component reuse: feasibility, sustainability, and economic consideration. Based on the analysis, we formulate the Blue Ocean Strategy proposal. The complete picture is put together in a discussion and concluding part. Due to the limitations of a conference paper, this study will be derived from existing numerical cost estimates and conceptual logic rather than quantifying each element of the business case.

8.3 Theoretical Framework

8.3.1 Business Case

The key function of a business case (BC), according to OGC (2009b), is to justify the effort to be invested in the project. According to Gambles (2009) it is '*a recommendation to decision makers to take a particular course of action for the organisation, supported by an analysis of its benefits, costs and risks compared the realistic alternatives, with an explanation of how it can best be implemented*'. The BC defines why the work needs to be done and provides a crucial baseline for the project (OGC, 2009a). It is typically prepared at an early stage, where information is scarce, of low precision and with high levels of uncertainty.

The process of developing a BC includes understanding the needs and priorities of stakeholders, collecting relevant, correct, and updated data, modelling and processing those data, analysing the contents, quality and consequences of the data, facilitating workshops when needed, project planning, and finally preparing the information for decision-makers. Benefits and other consequences should be expressed as tangible as possible. Respecting that some effects are controversial or not possible to specify and quantify, the BC will be much more useful and likely to lead to the right decision and action if it is explicitly clear about consequences and quantifies effects.

Considering whether to invest or not, the first question is if the benefits outweigh the cost. Only if the benefits are more significant than the cost would a rational actor choose to invest. Investors normally define profit margins for estimates to meet. However, the decision is not as simple as it looks, given that different aspects of benefit weigh differently for different stakeholders. Benefits are open for interpretation by the decision-makers. The next question is if this course of action is better than the realistic alternatives. Investment funds are limited, so any rational actor needs to consider the best investment at hand. The most fundamental test is whether the investment is better than not investing. The reference alternative or 'zero-alternative' needs to be tested, as this decides whether an investment should be made or not. Then there are other investment alternatives. There is no need for a BC if there is really no alternative. Gambles (2009) points out that authors of BC often pretend there are no alternatives, but this usually is not the case. In the Norwegian public sector, the requirement is presenting minimum two real investment alternatives in addition to the reference alternative (Norwegian Ministry of Finance, 2019). This is intended to make the project proponents consider the whole space of opportunities.

The time perspective is another question. Ideally, one would look at all consequences following the investment – for all times. Practically, however, it is usual to define a limited timeframe. The BC needs to consider the short- and long-term perspectives. The limited knowledge of consequences far into the future and the fact that it is hardly possible to connect those future effects to the specific project are two reasons. Other reasons include the technical lifetime of physical assets and the requirement for nondiscrimination of alternatives. Another aspect of a long timeframe is the effect of discounting. Calculations of net present value reduce future effects by interest effect and make the real long-term effects disappear from the basis for decision-making. As demonstrated by the Norwegian Ministry of Finance (2014), one practical way to handle this is to define a standard timeframe to be used in a comparison of alternatives and an interest rate that diminishes with a longer time horizon to reduce the effect of calculating away future consequences. However, these solutions are not ideal, and discussions about how to make sustainable decisions are still ongoing.

8.3.2 Blue Ocean Strategy

Since we are conceptualizing an unexploited market opportunity, we apply an analytical framework called Blue Ocean Strategy, developed by Kim and Mauborgne (2015). Blue Ocean Strategy is the desired situation with no direct competition, as opposed to a metaphorical red ocean full of competitive predators. The red ocean is characterised by high saturation of similar profile enterprises, already significantly optimised, and focused on benefit-cost trade-offs. In red oceans, businesses tend to focus on competition rather than a customer. It is usually the known market space, while blue oceans represent the undiscovered market. Blue Ocean Strategy is not focused on outperforming competitors in what they are good at but offering a quantum leap – value that is not addressed at the known market. It is not about achieving a state of monopoly but rather staying ahead of the market.

The key tool we apply from the work of Kim and Mauborgne (2015) is ‘the strategy canvas’ – a chart with aspects that a product competes in presented on a horizontal axis. The vertical axis represents the offering level that a client receives. The higher the score, the more company offers to clients with their product. The strategy canvas is about showing the relative performance in various fields of competition. To develop the chart, we implement the ‘Four Actions Framework’, where each action requires answering the related question: (1) eliminate (which of the aspects taken for granted in the industry need to be eliminated?), (2) reduce (which of the aspects should be reduced below the existing industry standard?), (3) create (what are the aspects that need to be created hitherto never offered by the industry?), and (4) raise (which of the aspects should be elevated above the current industry standard?).

8.4 Analysis

8.4.1 Feasibility of Building Product Reuse

The first question of feasibility is if the structural building products, such as columns, beams, walls, and floors, allow being taken apart and constructed into a new building. Fivet and Brütting (2020) provide examples of structures successfully built with steel and timber reclaimed components. Two interview respondents mentioned that it is easier to refurbish or reuse buildings made over half a century ago than those more modern ones. ‘We all agree that [buildings from before 70s] are easier to adapt than ones from the 80s and 90s; they are over-designed. You can put a building on top, or a roof garden. (...) Even today, we’re designing buildings that just meet requirements, because that’s more economical.’ Another interviewee adds: ‘They should not be old enough to tear down, but those are the ones we really want to tear down because they are hard to get quality in refurbishment, but when you have old buildings it is easier actually’. Lindheim (2021) in her study on buildings as ‘material banks’ concluded that some building owners already design for reusability, especially where there is frequent inventory replacement and need for flexibility so that reuse pays off quickly.

The complexity of such reuse depends on the individual product. Ceramic bricks are quite easily retrievable from walls, but that is not the case for modern porous ceramic blocks, which crush on separation. As we hear from the interviews, timber products – lumber, CLT, glulam – are usually screwed together, but whether they can be unscrewed depends on screw type and length. Both timber and steel products can be cut out and reused as shorter elements. If bolted connections are applied, elements can be reused without processing. Concrete is harder to reuse since most of the applications use monolithic connections. Reinforced concrete can be cut, but not without loss of reinforcement continuity and cover. Rather exceptional is the use of prefabricated concrete with bolted connections, easily accessible but covered with removable lime mortar (Paananen & Suur-Askola, 2018). Nonpermanent connections are more expensive but easier and faster to perform on-site. The case study of ‘KA13’ project confirms that reuse of building products is feasible and shows the practical side of reclamation (FutureBuilt et al., 2021). The building’s foundations, usually made of concrete and bound to the ground, are the hardest to prefabricate and connect reversibly. The solution for reusing foundations could be to make them reusable where they already are in situ. To enable their reuse, designers should provide connection points and specify the allowance for future loads.

ISO 20887 (ISO, 2020) provides guidance on design for disassembly (DfD) and adaptability, showing how to increase reuse suitability. Among recommendations are standardisations of elements, exposing joints for easier access, preparation of a disassembly plan, and digitalisation of all relevant information for future users. Other standards, such as the recent Hollow Core Slabs for Reuse (NS 3682, 2022), go even further and provide detailed procedures for processing, assessment, and documentation of used products.

Another aspect is the lifespan of such products. In Europe, most buildings are designed for 50 years, according to the Eurocodes. However, there is a mismatch between the designed lifespan and the actual. In Denmark, residential lifespan is on average 120 years (Aagaard et al., as cited in Marsh, 2017), while in the United States, it is closer to 60 years (Aktas & Bilec, 2012), and in China and Japan, the average is even less than three decades (Wang et al., 2018; Wuyts et al., 2019). Statistical data for Norway show that buildings, on average, have a lifespan of three to six decades (Todsen, 2014). Wilkinson et al. (2014) describe three types of building lifespans: (1) the technical, driven by safety, dependent on the physical condition, that can be prolonged by maintenance; (2) functional, which ends when the building limits the use and is no longer fit for demand; and (3) economic, as long as buildings generate more income than costs. Rarely structural material degradation is the first reason for a building’s unusability. The oldest wooden church in Norway, Urnes stavkirk, which dates back to the twelfth century (UNESCO, n.d.), proves that materials can serve us much longer than we usually designed them for. When an economic or functional lifespan ends while the technical conditions are still good, it causes a mismatch, leading to the waste of valuable materials. As temporary structures prove, with appropriate design, technical lifespan can be separated from the other lifespans, preventing the waste of quality materials.

Although technically possible, there are many barriers to reuse. According to research done by Lindheim (2021), key barriers are (1) compliance with rigid rules and regulations, (2) lack of financial incentives in the market, (3) lack of a system for reuse of building materials and components to make the outcome predictable for everyone involved, and (4) knowledge gaps.

8.4.2 Environmental Sustainability

Second is the environmental impact on the natural environment by energy consumption, greenhouse gas emissions, deforestation, pollution, land occupation, etc. Reusable components are not neutral to the environment; they still affect it negatively, but they prevent waste production, and it can be argued that also the production of a new component that would double the environmental impact.

The benefits of reuse should be reflected in the Life-Cycle Assessment (LCA) – the process of measuring a building's environmental performance. How to account for the benefits of reuse in the LCA is not straightforward. In some studies, reuse and recycling are incorporated at phase D of the LCA, called 'benefits and loads beyond the system boundary'. Robert Crawford (2011) writes that the initial use of such elements should not be credited because no guarantee can be made that they will actually be reused. His approach is more realistic than the first one but also means that an element that will be used twice (or more) will have multiple times higher LCA values on first use than on the following ones. On the other hand, people might take advantage of this assumption and sell components that were in use for a short time as low embodied carbon products, arguing that product production stages (A1–A3 of LCA) were already addressed in the first use cycle. The difference is significant since the product stage is responsible for most of the GHG emissions of building materials – for prefabricated steel and concrete even exceeds 95% (Norwegian EPD Foundation, 2021).

The case study project 'KA13' compares GHG emissions of used products with newly produced and achieves 97% reduction for steel, 89% for hollow core slabs, and 92% for windows (FutureBuilt et al., 2021, after Walter & Høydahl, 2020). In research by Brütting et al. (2020), more conservative assumptions are taken, with more energy demanding disassembly and post-processing, and reuse is compared to new steel of much lower embodied carbon. Still, the result shows reduction of over half of GHG emissions when elements are reused.

8.4.3 *Economic Consideration*

The report by 3XN, supported by the Danish Environmental Agency, shows a case study of a representative office building in Denmark with a new built value of DKK 860 million (Sommer et al., 2016). The study compares traditional demolition with the circular approach. The added costs of investing in reversible elements compliant with CE model are estimated to be only 0.35% of the total value of the building. If such a building needed to be demolished, it would cost additional DKK 16 million (1.9%), but if the disassembly was possible, DKK 35 million (−4.1%) could be claimed from the resale of the superstructure components, 8% on entire buildings, and even 16% in 50 years considering projected material prices.

Previously mentioned 'KA13' study which achieved significant GHG reduction shows that while reuse of some products is cheaper (e.g. windows ~60% cheaper), steel building products are 49% more expensive than buying new material (FutureBuilt et al., 2021, after Walter & Høydahl, 2020). Several interviewees blame this on low price of virgin materials: 'It's much too cheap to tear down the building, and we're not paying enough for landfill' – says one of them – 'I can't understand how virgin steel from China can outcompete steal from local steel providers in Norway, made with renewable energy and fully from recycled steel'.

In a short-time perspective, the proposed products are more expensive than alternatives. However, when the total cost of ownership is considered, adaptable components gain an advantage because apart from the product price, this measure incorporates the product's quality, delivery (including assembly), and maintenance costs. For a higher price, they provide better quality, durability, and reduce uncertainty by allowing for inexpensive building adjustments.

The cost ratio between reuse and new is also foreseen to drop with improved circular processes, especially access to information, establishment of circular market, and experience. The trends on Fig. 8.1 show that in case of Norway, each year more and more demolition waste is being produced. With raising raw material prices due to their scarcity (sand, cement, iron ore, asphalt) and emission trading systems,

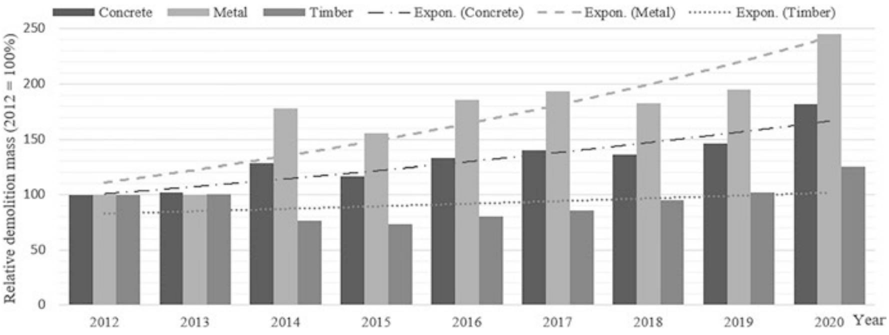

Fig. 8.1 Relative mass demolition for Norway. (Source: SSB, 2021)

as well as raising prices for waste disposal, reuse of building components is expected to become cheaper alternative in near future.

The business case of adaptable building components is built on reduced embodied carbon emissions. Having optimised building stock with extended material flows before they are discarded have a less destructive impact on the environment. From a solely economical perspective, this brings value in attracting more clients who are willing to pay an additional price for more sustainable buildings. Certification systems like BREEAM and DGNB also assign points for reuse practices, which are translated to higher real estate value. Larry Fink, Chief Executive Officer at BlackRock company managing the largest assets globally, writes in his annual letter 'We focus on sustainability not because we're environmentalists, but because we are capitalists and fiduciaries to our clients. (...) Every company and every industry will be transformed by the transition to a net zero world. The question is, will you lead, or will you be led?' (Fink, 2022).

In economics, the term 'Betongold' describes the supposed security of real estate ('concrete') from falling in value, especially in times of crisis. Real estate value is usually linked to the usable floor area and the building's location. While traditional building components are single-use, adaptable components preserve value independently of the building's lifetime and location. For that reason, they can be considered separate financial instruments that gain value with the rise of the circular economy market and provide secure material stock, independent of uncertain raw material prices. Some even conceptualise the idea of 'Building Components as a Service' (Wainwright, 2020), where elements are rented in a take-back system, and the manufacturer or retailer remains the sole owner.

Another economic aspect of adaptable building components is that financial institutions are willing to offer better conditions to sustainable investments, which is already a case for refurbishments loans or mortgages on timber buildings. This use of economic incentives to drive sustainable investments will be even stronger in the future. In June 2020, the EU commission published the EU taxonomy (European Commission, 2019), a classification system for investments. The purpose is to move capital to sustainable investments, which is expected to have considerable effect on the building and construction industry. According to the 'Circular Economy – Principles for Building Design' (EU, 2020), enhancing durability will decrease the financial risk and suggest that finance/insurance companies could specify in requirements standards for due diligence when assessing the circularity of the project. Authors also advice looking at investments from the life-cycle costing (LCC) perspective to grasp the increased revenue streams and capitalise future risks of difficulty to deconstruct buildings and cost of waste management.

The 'triple bottom line' has, for decades, defined sustainability. The first, economic, and, second, environmental, have already been described. The third bottom line is the social impact. Adaptable components address that aspect by opening a new market for disassembly, diagnostics, storage, transportation, and assembly, providing job and development opportunities. Among other social benefits is better adaptation to temporary needs, leading to less obsolete buildings, better land utilisation, and easier recovery after destruction due to natural or anthropocentric causes.

As urbanisation progresses, so does increase the need for change in our physical built environment. Example of shopping malls becoming obsolete after customers switch to online shopping shows how building stock does not reflect changes in people's lifestyles fast enough. Adaptable building components are a means to improve a building's flexibility. Another example is building according to the actual demand, not predictions. Instead of building a school with a constant capacity for decades, the space could be extended or reduced according to the actual demographics. Considering social benefits, second-hand components should be cheaper than brand new, making it more affordable for young and low-earning social group. Ability to modify the building for a reasonable price would allow customers to build houses they can afford without much mortgage and extend it later. It would also work in the other direction; they could reduce the size of property if no longer needed by selling its parts. Altogether it provides better conditions for the future generations.

Sustainability (the triple bottom line) also needs to be supported by a fourth leg – governance – the structures and rules by which society and organisations uphold and develop its existence. Governance includes developing strategies, making decisions, and managing resources on a society or organisational level. The business case is a part of the governance theme and must be informed by all aspects of the triple bottom line. This is the only way strategic decisions on investments can lead to sustainable outcomes in the short, medium, and long range.

8.4.4 Blue Ocean Strategy for Reusable Building Products

The first question from the 'Four Actions Framework' asks what could be eliminated from the existing, competitive market. In the case of adaptive buildings, highly optimised, tailored components limit flexibility, so design optimation is not desirable. Instead, universal design and standardisation are recommended by industry experts and standards (ISO, 2020). Spending less time at this step of design reduces engineering costs. Standardisation also helps to automate the manufacturing and storage of products. Reusability prevents waste generation, so waste-related costs and issues are eliminated. The strategy canvas presenting the described aspects is shown in Fig. 8.2, on the example of three reinforced concrete products: (1) monolithic, (2) prefabricated, and (3) designed for disassembly.

The second action from the framework is to reduce factors predominant in the industry which are not much needed. One of them is the required amount of skilled in situ workforce. In countries such as Norway, labour costs drive the prices of construction. DfD elements with simple, reversible connections can be assembled by a small group of visiting workers and lifting equipment. Tasks requiring specialists, such as fixing reinforcement, formwork, welding, and carpentry, are all done at the prefabrication plant. The product's initial price and carbon footprint might be higher than non-DfD products, thus having a lower offering level. The initial uncompetitiveness in market price comes in exchange for long-term investment in much lower

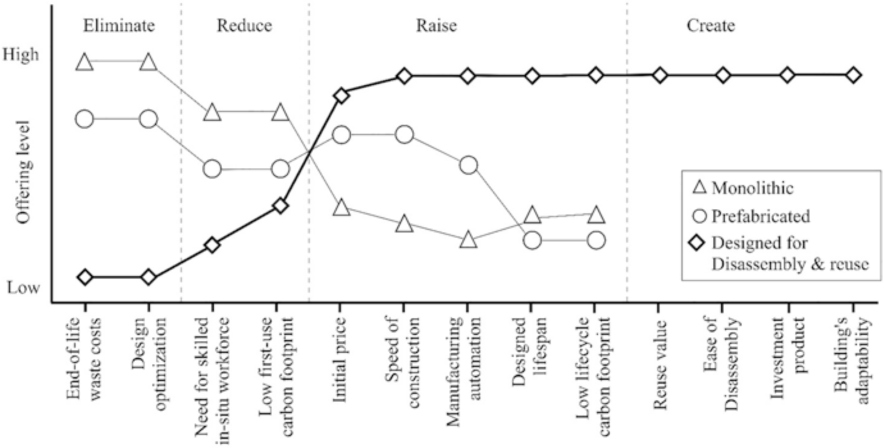

Fig. 8.2 Strategy canvas implementation for structural building elements for reuse – reinforced concrete case. (Source: own graphic)

whole-life carbon footprint products with high reuse value, not susceptible to raw material price and availability.

Another aspect, already mentioned in previous chapters, is the designed lifespan of 50–60 years. This assumption does not match the material's capacity and thus could be favourably restated into shorter predictions of individual use cycles and much longer product lifespan. The already mentioned separation of the technical lifespan of an element from the functional and economic lifespan of a building is necessary to achieve it.

Finally, there are questions that help create entirely new demands and make strategic price shifts: what factors should be elevated or created that are not addressed by existing business models? The adaptable components rely on the quality of reversible connections. Making all designs reversible makes the distinction between temporary and permanent obsolete. Other needs are designing for disassembly, developing proper end-of-life scenario plans, and establishing the reuse market. Remaining factors have already been covered while analysing the sustainability considerations.

8.5 Discussion

The first consideration should always be if the building needs to be deconstructed. As long as there are plenty of underperforming or even obsolete buildings not worthy of refurbishment, the reuse is next best solution. Reuse only extends the lifespan of objects, not neutralising their influence on the environment. At some point, adaptable components will also need to be discarded. That is not the ultimate solution to the environmental threat of construction, but as long as we rely on nonregenerative materials, it is a sustainable step towards it. If possible, the ideally circular, regenerative approach should be pursued (also called ‘cradle-to-cradle’), in which nonharmful materials flow in closed loops with minimum loss.

Generalisations of design cause individual elements to be not fully optimised. This stems from the fact that universal elements need higher capacity by applying higher safety and uncertainty factors. Oversized elements have higher volume, thus embodied emissions, which is the opposite of intended results. Similarly to the presented economic aspects, the analysed case requires an upfront investment of resources and greenhouse gas emissions now to be able to save more resources and emissions later.

The business case of adaptable building components is not only built on the premise of subsequent uses of the products but also shows immediate benefits such as a fast assembly process. At the moment, the reuse of structural building components takes place mainly on pilot projects and requires additional investment compared to alternatives. High uncertainty about products history, lack of experience, and established procedures all raise the costs.

The presented business case could be more favourable if encouraged by regulations and subsidies for reusable components (Lindheim, 2021). This is already beginning to take place with regulation of prices of materials causing high emissions, such as cement, for example, in the European Emission Trading System. The EU Taxonomy mentioned above is another example of strong incentives that will force investors in a more sustainable direction. However, it does not necessarily make them go for DfD components. Sustainably produced timber also performs well with regard to GHG emissions.

Key barrier to enabling the reuse workflow is to close the circularity loop, but since the market with used products is not established, the demand for such products is low. Even if the stock of reclaimed products would be available, it requires a functioning information system where designers could search for suitable products.

8.6 Conclusions

The paper presents how reusable building components can be a viable business case. Usually, the value of structural components is wasted when the building ends its life, or only a part of the value is recovered by downcycling. The basis of this business case is to separate the technical lifespan of a component from the functional and economic lifespan of a building, by applying existing industry practices like prefabrication and design for disassembly. This way, one can harness the full value of elements.

The price of adaptable components is higher than of other products on the market, but there are immediate benefits that discount for it. One of them is the speed of construction with bolted connections. Another advantage is the relatively lower values of GHG emissions considering whole life cycle of a component. This translates to more sustainable profile of such products, which can be documented with sustainability certificates, that leads to more sustainable investments.

Full return on investment is realised at moment of building teardown or partial reconstruction: firstly, because the disassembly is cheaper than demolition of monolithic structures, and, secondly, because the salvaged elements are of much higher value if they are ready to be reused without much post-processing. Their value could even exceed that of virgin products, as their environmental analysis no longer includes the production phase.

This paper also displays the indirect benefits of the proposed model, such as increased value of buildings designed for disassembly due to its adaptability. Such structures can be extended, reduced, or modified to fit the given demand, preventing inefficiency. They could also be built temporarily and displaced after in places that would not be profitable otherwise.

The research reported here is only conceptual at this stage. The potential for reusable building components is illustrated, and the necessary conditions to make it possible are identified. In addition, barriers and real-life problems that need to be overcome are described. More thorough analysis is needed to be able to specify a business case that holds as a basis for decisions to choose this path.

The work primarily addresses the 12th Sustainable Development Goal about responsible consumption and production. It shows a path forward for the industry that contributes about 11% of global emissions to the atmosphere just from the use of materials (IEA & UNEP, 2018). This is not the ultimate solution to environmental threat of construction, but as long as humanity relies on virgin resources, it is a sustainable step towards it. Presented approach to building design could be encouraged by regulations and subsidies favouring reusable components. The paper also touches Sustainable Development Goals 8, 9, and 11, by opening a circular economy market with reusable components and makes our built environment more resilient. The scientific contribution of the paper comes from spanning the often-siloed fields of construction and economics, with the help of tools previously not applied in this context.

The blue ocean approach confirms that there is a business case for DfD building components, in particular for those making the first move.

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