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ASSESSING THE ECONOMIC BOUNDARY CONDITIONS FOR REUSING PRECAST CONCRETE ELEMENTS IN CONSTRUCTION

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ABSTRACT
Background and aim. The reuse of Precast Concrete Elements (PCEs) offers a promising method to reduce emissions in construction. However, economic feasibility remains a significant barrier to widespread implementation. While technical challenges and value creation within supply chains have been explored, limited research addresses the economic aspects.

Methods and Data. This study constructs a supply chain model to compare standard demolition, PCE reuse, and construction with virgin materials. We investigate economic factors influencing building owners' decisions to donate or sell PCEs, building buyers' choices to use reclaimed materials, and the profitability of individual actors and the overall supply chain. Using 54 data sources, we identify cost and profitability drivers and analyze key decisions through economic theory and cost management perspectives.

Findings. Building owners have strong incentives to donate or sell PCEs for reuse, while buyers' decisions are highly context-dependent. Key costs in PCE reuse include deconstruction, refurbishment, storage, and transportation, while cost reduction drivers stem from savings on landfill fees, material costs and production costs. Long-term profitability depends on economies of scale, new markets, and innovation.

Implications. Investments can already focus on the most promising opportunities, but further research on cost structures, regulatory impacts, technological innovations, and supply chain dynamics is essential to guide decisions. Economies of scale, learning curves, and technological advancements offer significant potential to improve economic feasibility.

KEYWORDS: Circular Economy, Construction costs, Economic feasibility, Finance, Investment, Precast concrete element, Sustainability.

1 INTRODUCTION

Precast Concrete Elements (PCEs) are structural components of a building that are manufactured off-site and then transported to the construction site for assembly. Common PCEs in the building stock include components such as beams, columns, wall panels, and slabs.

Reuse of PCEs involves salvaging concrete elements from buildings condemned for demolition and reassembling them in new construction projects. This process may commonly involve intermediate storage and refurbishing and reconfiguring elements to meet new design requirements.

In recent years, industry, scholarly, and policy interest in reusing PCEs in construction has been on the rise. This interest is largely driven by concrete's significant contribution to global CO_2 emissions, estimated to be approximately 5–8% (Silfwerbrand, 2020), mostly due to

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Portland cement manufacturing. Reuse is one alternative strategy for reducing these emissions in construction (Al-Najjar and Malmqvist, 2025), alongside other technologies, such as alternative cement binders (e.g., Gartner & Sui, 2018), carbon capture, and the use of alternative fuels. The reuse of PCEs should also be compared to alternative supply chains and material flows, such as the crushing and recycling of concrete elements for road construction, as well as the current practice of manufacturing conventional, carbon-intensive concrete elements. Such comparisons can promote understanding of the relative advantages of different strategies for reducing CO_2 emissions and other waste in the sector.

The implementation of alternative methods of manufacturing and building with concrete will ultimately rely on both *technical* and *economic* feasibility, which is largely determined by the pace of innovation. As with any complex production system, innovations can involve product innovation (e.g., concrete), process innovation (e.g., manufacturing and construction methods), and business model innovation (e.g., value creation and capture within supply chains).

Today, the pace of innovation is largely influenced by incentives established through legal frameworks. For reuse, the relevant legal frameworks are the European Climate Law and the EU's Fit for 55 package (European Union, n.d.), the EU Emissions Trading System (European Commission, n.d.), and various European Commission initiatives. Examples of these initiatives are the Construction Products Regulation, the Energy Performance in Buildings Directive, and the Transition Pathway for the Construction Ecosystem (Circular Economy Stakeholder Platform, n.d.), along with other legislation such as waste prevention laws. For example, a new emissions trading system, ETS2, has been introduced to cover emissions from buildings, road transport, and additional sectors (European Commission, n.d.). This system, which is set to become fully operational in 2027, complements ETS1 and other European Green Deal policies targeting these sectors. On top of this, there are also national legislation, regulation, and standards. Examples include the climate declaration act in Sweden (Regeringskansliet, 2021) and updates in the Danish building regulations (Social- og Boligministeriet, 2024).

It is expected that these regulations, when enforced, will incentivize innovation to reduce CO_2 emissions in the construction sector. Research should aim to estimate the impact of these regulations on the industry, although the combined effect of this legislative cocktail can be challenging to predict, particularly as emerging regulations are often subject to compromise.

This creates uncertainty, especially when estimating economic feasibility. From the industry's perspective, uncertainty hampers long-term investments, such as those in new PCE reuse technologies and capacity. Nevertheless, this legislation aims to incentivize such investments in the construction industry, making the status quo of manufacturing with conventional carbon-intensive concrete elements less competitive in the market. Therefore, it is reasonable to assume that economic feasibility will increasingly favour low-carbon technologies, such as the reuse of PCEs.

Yet, little is known about the economic feasibility of reusing PCEs. Previous research has primarily addressed the technical challenges of reusing PCEs (e.g., Dervishaj et al., 2023a; Dervishaj et al., 2023b; Räsänen & Lahdensivu, 2023; Suchorzewski et al., 2023), carbon saving potential (Al-Najjar and Malmqvist, 2025), and value creation within supply chains and ecosystems (e.g., Harala et al., 2023; Riuttala et al., 2024; Sairanen et al., 2024; Aarikka-Stenroos et al., 2021), contributing both to theoretical knowledge and the implementation of reuse practices in the sector (ReCreate Project, n.d.; Återhus Project, 2023).

Consequently, there is a research gap in understanding the economic feasibility of reusing PCEs. There is also a practice-driven need within the construction industry to address the uncertainty surrounding the economic feasibility of PCEs reuse, which hampers investments and broader implementation. Therefore, *the purpose of this study is to analyze the economic boundary conditions related to the reuse of PCEs.*

2 METHODOLOGY

2.1 APPROACH TO THE ANALYSIS OF ECONOMIC BOUNDARY CONDITIONS

The discipline of economic feasibility analysis sits at the intersection of engineering studies and business studies, particularly cost management. Economic feasibility generally means that a proposed solution is financially viable and cost-effective, ensuring the benefits outweigh the costs. Cost management as a discipline focuses on cost structures related to products and services, business operations, and supply chains (Kulmala et al., 2002; Paranko, 2012).

Ideally, cost analysis should be conducted for each actor in a supply chain, as well as for the supply chain as a whole. This would highlight the contributions of different actors to the supply chain and identify opportunities for optimizing the entire system (Eriksson et al., 2019; Vigren and Eriksson, 2025). It is generally understood that every company within the supply chain must be profitable in the long term for their business operations to continue.

Firstly, such analysis would require each company in the supply chain to be aware of its own costs (Agndal and Nilsson, 2009; Suomala et al., 2010) and to provide access to this information for analysts. This is rarely the case, as cost analysis demands significant effort within individual companies, and sharing detailed cost data with external parties beyond standard external reporting practices is quite uncommon (Suomala et al., 2010).

Secondly, in nascent supply chains, such as those focused on the reuse of PCEs, cost data may not be well-collected or structured (Vigren, 2022), as initial projects are typically exploratory pilot projects with ad hoc reporting processes.

Thirdly, the reuse of PCEs is a focus of many innovations that may quickly alter the current cost structure of PCEs reuse. While construction processes involving reused PCEs remain unconventional and not business-as-usual, various process innovations — such as pre-deconstruction audit methods, inventory modeling of donor buildings, efficient and smart deconstruction methods, and optimized storage and logistics for elements (Huuhka et al., 2024) — can significantly influence cost analysis.

Fourthly, and finally, an analysis of the cost structures of emerging supply chains, if retrospective in nature, may not account for future business planning needs, as cost structures are likely to change with economies of scale, such as in production and logistics (Besanko et al., 2010). In other words, firms would operate with high unit costs in nascent supply chains, where the number of elements is limited, but significantly lower unit costs in mature businesses, where PCE sourcing, project planning, and construction are business-as-usual.

Another important reason for lower unit costs is the learning curve effect (Besanko et al., 2010), where increased experience and repetition lead to reduced costs and improved efficiency over time. Companies wishing to invest in new capabilities must anticipate future cost levels, for example, when making capital-intensive investments like production facilities and warehouses. Additionally, they need information on the future size of the market, for which no analyses are currently available: Can an investor expect the market of reused PCEs to grow, and if so, when?

Despite these limitations, which are mostly due to the lack of data, much can still be achieved. Focused economic analysis can yield valuable insights that benefit both theory and practice. As Geroski (1997) states: "Strategy decisions often turn on 'how much?' or on 'how big?' a particular effect is, something which can be of some importance when a nifty new strategy idea gets translated into a business plan." This means that even an approximate calculation can be useful for investors and managers if the order of magnitude is correct. In such cases, the analysis can support future-oriented investment decisions.

Accordingly, we will conduct focused exploratory analyses, shifting the focus from directly analyzing the cost structure of reusing PCEs to analyzing the economic boundary conditions associated with their reuse. Economic boundary conditions are the contextual factors that define the constraints for reusing PCEs. These conditions outline the financial and resource-based limits for reusing PCEs and are not limited to a single case study.

2.2 DATA AND ANALYSIS

Figure 1 presents different supply chains related to concrete elements. The first is standard demolition, where concrete elements are deconstructed and sent to concrete recycling plants, backfilling, or landfills, representing the status quo in waste management and recycling. The second is reuse, which is currently being piloted in countries such as Sweden, Finland, Germany, and the Netherlands. The third is construction using virgin materials. Many comparisons between the supply chains could be made. Additionally, these supply chains could be divided into even more specific stages or work tasks (Crowston, 1997).

First, it's reasonable to compare standard demolition and reuse from the perspective of the building donor or seller. Economic principles suggest that, all other things being equal (ceteris paribus), the building donor or seller will choose disposal of material through standard demolition or reuse based on the costs or profits associated with these options. However, other considerations, such as interest in more sustainable alternatives, are of course relevant. Nevertheless, analysis should aim to compare these incentives, and policy should aim to adjust these incentives in favour of reuse.

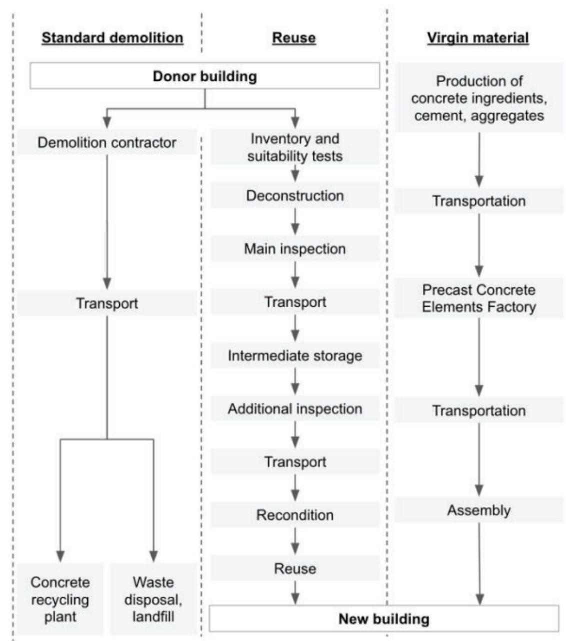

Figure 1: Supply chain of reusing PCEs.

Second, it is reasonable to compare the cost structure of the reuse and virgin material supply chains from the perspective of the buyer of a new building. Economic theory suggests that the buyer would choose the cheaper option if the quality is the same, or the higher quality option if the price is the same, assuming no other factors influence the decision. Therefore, analysis should aim to compare these alternatives, and policy should aim to adjust the incentives in favour of reuse.

Third, and finally, economic principles also suggest that all actors in the supply chain need to remain profitable in the long term in order to stay in business. This means that the analysis could focus on the profitability of each actor, and then on the supply chain as a whole.

We will consider these three cases and ask the following questions:

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1. Which economic factors influence building owners’ decisions to donate or sell PCEs for reuse?
2. Which economic factors influence building buyers’ decisions to choose reuse over virgin materials?
3. Which economic factors influence the profitability of individual actors within supply chains and the supply chain as a whole?

The data cited in this analysis is derived from existing academic literature, industry reports, public databases and websites, internal firm data, and other unpublished documentation (Table 1). To gather this information, we conducted an extensive search and document analysis of 54 data sources focusing on construction costs related to PCE reuse. The academic articles are published studies about PCE reuse and the industry reports and databases/websites cover published insights on PCE reuse or construction costs. Other reports and internal firm documents were obtained through the ReCreate Project (n.d.) and focus on the production cost calculations of three new residential buildings in Sweden from the building owner’s perspective, along with industry and stakeholder perspectives on costs. The documents mostly focus on projects from Nordic countries or the Netherlands.

However, the availability of structured datasets is limited, and the data is fragmented. While this supports the analysis of economic boundary conditions, it prevents more in-depth calculations related to economic feasibility.

Table 1: Data sources.

Document type	Document count
Academic article	15
Database/Website	11
Industry report	21
Other report	4
Firm internal document	3
Total	54

3 ANALYSIS OF ECONOMIC BOUNDARY CONDITIONS

This section is organized around the aforementioned questions.

3.1 WHICH ECONOMIC FACTORS INFLUENCE BUILDING OWNERS’ DECISIONS TO DONATE OR SELL PCES FOR REUSE?

PCE donors or sellers are real estate owners in the process of decommissioning buildings, and hence they must decide whether to opt for standard demolition or PCE reuse. Typically, they contract a demolition company and other experts to assess the deconstruction, demolition, and waste disposal needs and costs. The building owner is a key decision-maker; as owners, they have legal responsibilities related to decommissioning, and as clients, they control which suppliers are engaged for these tasks (Engström and Hedgren, 2012; Vigren et al., 2022). To fulfil these responsibilities, they enter into contracts with these suppliers. Furthermore, despite their important role, building owners might not necessarily have the expertise to fully understand or control what happens further down the supply chain (Vigren, 2024), especially in PCE reuse, which remain an uncommon practice in the construction sector (Engström and Hedgren, 2012).

We choose to use the term “building donors” because empirical examples from PCE reuse projects in Sweden, Finland, Germany, and the Netherlands show that real estate owners have donated PCEs for reuse (ReCreate Project, n.d.). Decisions about material disposal have considerable economic implications.

First, donating or selling PCEs can reduce waste disposal costs, as elements donated or sold for reuse reduce the amount of material sent to concrete recycling plants, backfilling, or landfills.

Second, there are expectations that the sale of salvaged PCEs could generate additional revenue for building owners and other actors in the reuse value chain (Svedmyr, 2024; Riuttala et al., 2024; Återhus Project, 2023). By establishing partnerships with organizations specializing in material reuse, building owners may monetize components that would otherwise be discarded. This would imply the creation of what could be considered a new market for reused PCEs. Entrepreneurial circularity actors, such as Blocket, CCbuild, Loopfront, and Palats, are driving the growth of digital platforms and marketplaces for recycled materials.

Third, by donating or selling PCEs, building owners can contribute to national recycling goals and achieve other sustainability or circularity targets. Achieving such targets may be a subject of many economic incentives, including tax incentives, grants, subsidies, compliance or avoidance of sanctions related to legislation, or eligibility for government-sponsored sustainability initiatives. Additionally, participation in circular economy practices may open doors to green financing opportunities, lower insurance premiums tied to sustainable operations, or enhanced market competitiveness through positive branding and alignment with corporate social responsibility goals.

These economic advantages, coupled with environmental benefits, can make the practice of donating or selling PCEs a compelling strategy for real estate owners aiming to contribute to sustainable construction and resource efficiency. Therefore, building owners are likely to already have net positive incentives to pursue reuse activities over demolition.

However, these incentives are highly dependent on the country and specific context, influenced by factors such as transportation costs, the availability of suppliers, and the demand for reused PCEs. These local conditions determine which options are available. For example, in rural areas with high transportation costs, low availability of suppliers, and low demand for new buildings, reuse might not be an option. Furthermore, deconstruction is

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more expensive than destructive demolition, and it remains uncertain who would bear these costs in a PCE reuse value chain.

We concur with Svedmyr et al. (2024) and Küpfer et al. (2023) that increased availability of data from public and private sources would enable more comprehensive analysis in the future.

3.2 WHICH ECONOMIC FACTORS INFLUENCE BUILDING BUYERS' DECISIONS TO CHOOSE REUSE OVER VIRGIN MATERIALS?

Building buyers are real estate owners considering the construction of a new building or a major renovation of an existing one. From their perspective, many factors related to the new development may have economic consequences. Buildings need to be usable, buildable, operable, and sustainable, and the choice of building materials may have several implications for all these qualities (Fischer, 2017). Furthermore, as with donating or selling PCEs, economic benefits such as tax incentives, grants, subsidies, green financing opportunities, compliance, or branding may become important economic drivers for PCEs (e.g., Riuttala et al., 2024).

Nevertheless, the cost of acquiring a building is, of course, a central concern for buyers. Therefore, it is relevant to compare the cost structures of new buildings based on reused PCEs and virgin materials. The cost of the building's structural frame essentially represents the total "budget" or room for economic flexibility with regard to PCE innovations, such as reuse. To illustrate this, we analyzed the total cost of apartment buildings using data obtained from a Swedish real estate owner.

Let us assume an apartment building costs €15,000,000, and the structural frame and roof system account for 20% of the total costs — €3,000,000. This estimate was considered reasonable by a representative from a precast concrete building systems provider. Now, if we assume a 25% price increase (€750,000) in the cost of the structural frame and roof system, the total cost of this system will be €3,750,000. The total project cost would then be €15,750,000, representing a 5% increase over the original price.

This analysis demonstrates how sensitive the total cost of acquiring a building is to fluctuations in specific cost increases or decreases. Table 2 presents additional scenarios based on the same calculation logic. Notably, this table is general to any cost changes and could therefore be applicable to cost increases related to virgin materials, the cost impact of new legislation, or any other costs associated with an increase in project costs.

Table 2: Scenarios of how cost increases or decreases impact the total costs of an apartment building.

Project cost	Structural frame cost change	New project cost	Project cost change-%
€15,000,000	-25%	€14,250,000	-5%
€15,000,000	+25%	€15,750,000	+5%
€15,000,000	+50%	€16,500,000	+10%
€15,000,000	+75%	€17,250,000	+15%

Are these scenarios reliable and meaningful? First, the reviewed literature shows that construction costs vary significantly based on factors such as location, building type, materials used, project scale, labor costs, and regulatory requirements. Therefore, the estimates are mainly indicative.

Eklund et al. (2003) report on a Swedish case of new student accommodation constructed in 2001 in Linköping using reused elements. The project was 10%–15% more expensive than similar buildings constructed using conventional methods. Nevertheless, the contractors were confident that, through learning and larger-scale projects, the costs could be reduced to the level of conventional methods. This statement demonstrates the importance of economies of scale and the learning curve effect (Besanko et al., 2010) in driving down costs over time, thereby contributing to the increased adoption of PCE reuse. Furthermore, in this case, the Swedish government covered the costs with grants for developing new environmentally responsible construction methods (Eklund et al., 2003).

Some other projects reported in the literature indicate a variance in construction costs between approximately -80% – +60% when compared to alternative methods (Küpfer et al., 2023). However, as Küpfer et al. (2023, p. 23) state, these comparisons should be made with caution, as "computing methods, system boundaries, and hypotheses are heterogeneous." In the Swedish Återhus pilot project (2023), the costs have been comparable to or slightly higher than conventional methods, with the expectation of becoming directly economically beneficial once reuse is implemented with more standardized methods. For more information on cost levels, see also Salama (2017) and Huuhka et al. (2015).

The variance in reported costs for projects with PCE reuse demonstrates that costs can vary significantly depending on the type of project and its organization. On the other hand, annual construction cost fluctuations at the range of -10% – +10% are quite normal in the construction industry. Therefore, price changes reported in the literature and Table 2 may be considered moderate.

Given that most of these examples are dated, technological developments over the past 10–15 years have likely contributed to reducing the cost difference, bringing project costs closer to price parity with the use of virgin materials. Emerging technological developments could offer the potential for reduced costs in PCE reuse practices over time. For example, the efficiency and

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quality of deconstruction and design operations could be enhanced with artificial intelligence, sawing and drilling operations could be automated using robotics, and material tracking could be managed through digital technologies and workflows (Brozovsky et al., 2024; Dervishaj et al., 2023a; Dervishaj et al., 2023b; Dervishaj & Gudmundsson, 2024). On the other hand, there is uncertainty regarding the maturity of these technologies and their cost impacts.

However, the accumulation of the learning curve effect and economies of scale (Besanko et al., 2010) is unlikely, as current projects are isolated pilot initiatives. Economies of scale — cost advantages that lead to a decrease in the average cost of production — would require repetition across multiple similar projects. The path toward economies of scale could begin with governmental support and investment, structured efforts within the innovation system, and legislative changes that prioritize PCE reuse over the use of virgin materials.

Furthermore, decision-making exhibit inertia (Engström and Hedgren, 2012), meaning that decision-makers are likely to choose options familiar to them. This is problematic from the PCE perspective and requires a change in attitudes, as well as efforts in research, education, and deliberate attempts to promote these new ideas and solutions to decision-makers. Pulkka and Junnila (2015) discuss a "gravitational slingshot analogy," suggesting that innovation systems can leverage change-driven momentum to shift trajectories toward desired system states. Furthermore, a shift in trajectories toward the larger adoption of PCE reuse practices would require improved legitimacy for these practices within the sector (Thomas and Ritala, 2022).

The learning curve effect, in turn, would require either repetition by the same actors to accumulate expertise or effective knowledge transfer between actors. On the other hand, many current projects are regional, and it is likely that future value chains will remain local due to high transportation costs and varying local norms and regulations (Svedmyr, 2024; Ghisellini et al., 2018). From the perspective of building buyers, this was particularly challenging in the observed pilot projects, as regional buyers rarely engage in the construction of new buildings. The knowledge fragmentation, a common challenge in the construction sector (Dubois & Gadde, 2002), generally hinders learning, innovation, and the scalability of new ideas.

Nevertheless, current projects, research and development, and education in circularity practices foster the learning curve effect and knowledge transfer within the sector. The development of theoretical frameworks and practical guidelines for PCE reuse is particularly important because building owners and other actors need novel frameworks for business development and to guide their sustainability initiatives (Nyoni et al., 2023). With further analysis, these frameworks could also be tailored for investors.

3.3 WHICH ECONOMIC FACTORS INFLUENCE THE PROFITABILITY OF INDIVIDUAL ACTORS WITHIN SUPPLY CHAINS AND THE SUPPLY CHAIN AS A WHOLE?

The third relevant question related to PCE reuse concerns profitability. Economic theory suggests that, over the long term, firms must remain profitable to avoid bankruptcy. Without consistent profitability, firms cannot cover operating costs, repay debts, or invest in necessary resources, ultimately leading to financial distress and potential insolvency. Profitability is a key driver of sustainability and circularity, as firms require profits to invest in new, sustainable technologies and methods. Additionally, these new technologies and methods must be more profitable than alternative options for firms to have the incentives to make the costly investments required for their adoption.

It follows that each actor in the supply chain, as well as the supply chain as a whole, must remain profitable over the long term. This has two implications for the unit of analysis. First, each firm must have incentives to invest in alternative methods, meaning the analysis should focus on firm-level incentives. Therefore, a firm reluctant to invest in new capabilities may slow down the development for others. Second, the way value is created and captured within the supply chain or broader business ecosystem sets the analytical focus at the system level (e.g., Harala et al., 2023; Riuttala et al., 2024; Sairanen et al., 2024; Vigren, 2024). Here, while value is created through the interdependent supply relations across the supply chain.

In the PCE reuse supply chain, the individual actors include building donors and sellers; architectural and engineering firms that make inventories of existing PCEs in buildings and conduct suitability tests and inspections; deconstruction firms; storage operators; transport firms; design firms; reconditioning facilities; and contractors and clients of the new building. Additionally, actors in the standard demolition supply chain include demolition firms, waste management and recycling facilities, while actors in the virgin material value chain include concrete suppliers, concrete manufacturers, and PCE factories. Furthermore, all supply chains rely on consultants, such as environmental consultants, have relationships with government agencies, and are indirectly connected to other supply chains, such as those involving other materials supplied for construction sites.

These operations may be organized by individual firms or vertically integrated firms that operate across multiple phases within the supply chain (Besanko et al., 2010). Nevertheless, effective operations present a major coordination challenge between people and workflows (Eriksson et al., 2019).

For most, time efficiency is a major profitability driver, as labor costs represent a large share of their operations. In this sense, learning new construction methodologies represents a challenge because it requires an investment of time, which may decrease the overall efficiency and profitability over an uncertain period. As a result, innovation is not generally incentivized in the sector. Additionally, the construction sector is generally a low-margin industry, making it difficult to allocate resources for learning and innovation.

However, with PCE, there is limited knowledge about the cost structure within the value chain. First, the literature generally indicates that deconstruction costs are significantly higher with PCE reuse compared to standard demolition. An estimate from a representative of a precast concrete building systems provider suggests that dismantling a building for PCE reuse is 1.5 to 2 times more expensive, although there are significant differences between building types, such as office and residential buildings. On the other hand, demolition can be performed in various ways (Ghisellini et al., 2018), and salvaging other building materials on-site is becoming more common. This suggests potential synergies between deconstruction efforts aimed at salvaging PCEs.

Second, substantial cost savings arise from avoiding landfill fees and other expenses associated with standard demolition.

Third, additional savings are achieved through reduced material costs compared to using virgin materials. Some estimates suggest that salvaged panels can cost as little as one-third of the price of new ones (Huuhka et al., 2019; see also Küpfer et al., 2023).

Fourth, the storage costs of PCE reuse are significantly higher compared to standard demolitions, as reuse often requires both on-site and intermediate storage. These costs are closely related to the distance between the deconstructed building and the new building. Close proximity may reduce the required transportation and intermediate storage. Additionally, as Addis (2012) points out, inventory turnover is another important metric. Stored inventory accrues costs over time, as money, time, and other resources, such as space, are tied up in the PCEs. Therefore, the contractor owning the PCEs would only salvage items with a high likelihood of being quickly demanded for new construction, thus keeping storage costs to a minimum (Addis, 2012). Furthermore, the type of storage will impact the costs, such as the amount of protection needed from the weather.

Fifth, transportation costs are a major cost driver, and distance may also impact the environmental benefits of PCE reuse. With longer distances, transportation costs and environmental impact increase. Therefore, authors such as Ghisellini et al. (2018) and Svedmyr (2024), highlight that the circular economy in the construction and demolition sector is primarily a territorial activity.

Sixth, and finally, the increased availability of PCEs in the construction sector could lead to the creation of what might be considered an entirely new market, which is currently in its infancy. The development of new markets can have significant economic implications. First, markets serve as forms of coordination that promote efficiency and facilitate information exchange. Second, markets generate signals for investors, with growing markets being particularly attractive to them. Third, increased economic activity could stimulate further innovation, economies of scale, and learning curve effects, all of which may have substantial impacts for all actors in the supply chains in the future (Besanko et al., 2010).

4 TOWARDS AN AGENDA FOR RESEARCH AND INVESTMENT DECISION-MAKING

Current literature and analyzed sources highlight that PCE reuse has a long history and is supported by extensive contemporary studies (Table 1). However, surprisingly little attention has been given to economic analysis. This is notable, as the economic feasibility of any innovation is a major factor in its adoption.

Further economic analysis would make important contributions to research and would also be valuable for investors. In this context, investors broadly refer to those managers who decide to invest in human resources, such as new skills and capabilities, or in capital investments, including buildings, logistics capacity, storage capacity, production capacity, and machinery. These capital investments require long-term planning and financing. Currently, the PCE reuse market is in its infancy and faces significant uncertainty due to legal and economic factors. To alleviate these uncertainties, further analysis of economic feasibility and legal impacts is needed.

Based on economic theory (Besanko et al., 2010) and cost management perspectives (Kulmala et al., 2002; Paranko, 2012), this article has made an attempt to address these needs by outlining the economic principles for assessing the boundary conditions of the economic feasibility of PCE reuse. The use of economic theoretical concepts to identify key issues and interdependencies constitutes the article's contribution (cf. Tarafdar and Davison, 2018) and represents the first step in economic feasibility analyses. Our model (Figure 1) establishes the theoretical boundary for further analysis and comparison of different alternatives of demolition, reuse, and construction from virgin materials. Specifically, we contribute by analysing the key decision-making moments. This contribution may also be relevant to the wider circular economy and sustainability literature.

These economic principles hold regardless of context, but significant research opportunities exist in exploring specific cost items, such as the cost of PCE components across supply chains, or conducting case studies focused on particular phases within these supply chains. Further studies could also target the economic feasibility of individual buildings and projects. Additionally, research could examine the impact of regulatory changes on PCE reuse costs, investigate how supply chain dynamics influence economic feasibility, and explore the role of technological innovations in reducing costs across the value chain. Exploring the cost implications of different PCE reuse methods also offers valuable avenues for future research.

However, studies focusing on the economic feasibility of reusing structural steel (Yeung et al., 2017) show that the analysis is highly sensitive to context-specific factors,

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such as labor costs, (de)construction methods, and the value of steel components. This challenge was also recognized in Swedish pilot project (Återhus Project, 2023), as it was difficult to have a comprehensive view of the economics of projects related to reuse, as well as how the value of reuse is communicated throughout the value chain. Stakeholders assess reuse in different ways, and the benefits and costs arising from reuse are allocated to different actors. Additionally, costs vary significantly between regions and countries (Svedmyr, 2024).

These variances serve as a caution against generalizing findings from case studies. Another caution pertains to generalizing findings from pilot projects, which often involve high exploration costs and high unit costs. Nevertheless, specific studies can be highly informative, especially if they demonstrate profitability and investment opportunities despite these uncertainties and higher costs. Furthermore, we encourage, along with others (Svedmyr et al., 2024; Küpfer et al., 2013; Kulmala et al., 2002), that data from public and private sources be made available to researchers and analysts for further research and more comprehensive analysis of cost structures. This also serves as a recommendation for industry analysts to monitor these developments closely. Systematic data on actors, costs, prices, and markets are prerequisites for informed investment decision-making.

This article also sets aside other important areas of economic research for future investigation. Küpfer et al. (2023) aptly point out that reuse has the potential to create new jobs and business models, and promote local sourcing of materials, thereby contributing to local job markets and economic activity — important topics for future research.

This article also does not focus on other societal perspectives, such as externalities of construction, which are an important area of future research (see also Återhus Project, 2023). Other relevant questions include: What new roles or actors may arise? How can the mediation or matching between deconstructed buildings and new constructions be facilitated?

Additionally, we have not addressed other possible mechanisms related to the value chains, including more specific categorization of tasks and processes (Crowston, 1997) involved in standard demolition, reuse, and the use of virgin materials in construction, as well as their combinations. For example, in reality, not all PCEs fulfill the criteria for reuse, and a certain percentage of materials used in new constructions would still need to be produced from virgin materials. For example, a precast concrete building systems provider stated that the largest economic potential lies in the reuse of floors rather than walls.

Finally, further research could investigate incentive structures related to tax incentives, grants, subsidies, compliance or avoidance of sanctions related to legislation, eligibility for government-sponsored sustainability initiatives, green financing opportunities, lower insurance premiums tied to sustainable operations, and enhanced market competitiveness through positive branding and alignment with corporate social responsibility goals.

5 CONCLUSION

In sum, the analysis concludes that:

Economic factors such as reduced waste disposal costs, potential revenue from salvaged components, contributions to sustainability goals, and possible associated economic incentives (e.g., tax incentives, grants, or green financing) provide building owners with compelling incentives to donate or sell PCEs for reuse. However, these incentives are highly context-dependent and require further data for comprehensive analysis.

Building buyers' decisions to choose reused PCEs over virgin materials are influenced by cost considerations. Costs have varied significantly in previous reuse projects, showing both cost savings and additional expenses compared to other methods. Therefore, economic feasibility is highly contextual. Future investments can already be directed toward the most promising opportunities. However, further data on costs and prices are needed. Expectations of economies of scale, learning curve effects, and technological advancements present opportunities to improve economic feasibility.

For the supply chain, the main cost categories in PCE reuse include higher deconstruction, storage, and transportation costs, while cost reduction drivers come from savings on landfill fees and material costs. Profitability depends on these costs, as well as the potential for new markets, economies of scale, and innovation, which can enhance economic feasibility in the long term.

Further economic feasibility research on the cost structures, regulatory impacts, technological innovations, and supply chain dynamics is necessary to inform better investment decisions in this emerging market.

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