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Who Drives Circularity?—The Role of Construction Company Employees in Achieving High Circular Economy Efficiency

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Abstract: The circular economy in the construction industry is still in its infancy. It seems particularly difficult for companies in this sector to make strategic decisions that enable sustainable operations and ensure long-term business success. This article investigates factors such as employee involvement at the operational level that facilitate circular economy practices for companies in the construction industry. For this purpose, we conducted a company survey and analyzed it using a structural equation model. The results show that it is worthwhile for companies to empower their manufacturing employees to take actions independently in order to increase process quality and to reduce setup time, which together lead to better circular economy efficiency.

Keywords: circular economy; circular economy efficiency; employee involvement; process quality; setup time reduction; construction industry

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1. Introduction

1.1. Background

The construction and building industry, with its vast impact on society and on the environment, is one of the top priorities of the European Union (EU) for achieving a cleaner and more competitive Europe [1] The amount of construction waste generated in 2018 was 935 million tons, and it was responsible for 35.90% of the total EU waste generation. Over their entire lifecycle, the generated greenhouse gas (GHG) emissions constitute up to 40% of all such emissions in the EU [2,3]. The most promising concept for solving this major environmental problem is the transition towards a circular economy, which has the potential to reduce GHG emissions (by up to 80% due to a greater material efficiency) and to reuse the material [4,5].

The term "circular economy" is used to summarize strategies for systematic change that aim at a reduction of primary resource input, and at increasing reuse and recycling. One basic objective of the circular economy is to avoid wasting raw materials and to close material cycles [6]. This objective includes minimizing resource input, waste, and energy consumption [1,7–9].

The EU's action plan for the circular economy in the construction industry aims to address this objective and sets requirements for the durability and all forms of recyclability of construction products [1]. By fostering the use of material passports, as well as environmental product declarations, the action plan will directly affect how construction companies operate [10].

Circular economy action plans can be implemented on various aggregation levels: first, on the macro level, nations, regions, and cities can take actions. On the second level, the meso level, industrial parks or supply chains in a specific industry can implement circular strategies, and third, on a micro level, single companies can change their business practices (products, processes) in order to improve their circularity [11].

Especially at the last level—the company level—many implementation issues continue to exist, and the levels of circularity of construction products are still low, while the principle of the "linear economy" dominates [12,13]. The reasons for this are mainly the low proportion of recyclable materials used and the very costly separation of construction waste [14,15]. From the perspective of a construction company, the question arises as to what extent these circular economy practices are economically feasible. Hence, it must be ensured that the objectives of a circular economy are in line with corporate incentives and goals and that companies adopt the necessary operational competencies. Particularly when considering pathways of the transition from traditional linear practices towards more circularity, research on the circular economy's operational implementation is still scarce. For this reason, this article aims to shed light on this transition.

1.2. Literature

At a strategic level, circular business models for companies are already being increasingly discussed in both research and practice [16]. In particular, the research literature emphasizes potential complementarities between the reduction of resource consumption, due to circular economy practices, and economic profitability. Prominent examples of these circular economy practices are product service systems (PSS), where manufacturing companies no longer sell the products themselves, but instead rent out the product utilities with the objective of reducing resource consumption while still remaining profitable [17,18]. Other examples are designs for recycling, for disassembly, or for reuse, where building components still have a value after their first life [19]. All of these described approaches are potentially effective circular economy practices. However, such approaches are often lacking an explanation and fail to provide sufficient evidence for how more circular business models can be operationalized. We understand such increased operationalization as circular economy efficiency. Higher circular economy efficiency goes along with the use of fewer resources per product, an increase of the product's useful lifetime, and less material waste in all stages of production, product use, and product recycling. Circular business models that are also economically feasible have so far been the exception due to their operationalization challenges, and quantitative studies are rarely available. Other research areas have examined the interconnections between manufacturing efficiency and environmental efficiency, often referring to Hart's natural-resource-based view, where the competitiveness of a firm depends on how it manages its natural resources [20]. Even though many of these articles do not focus on a specific industry, such as the construction industry, their results are nevertheless important for increasing the construction industry's transition towards a circular economy due to its similar objective of reducing waste [21–23]. until now, the pronounced short-term focus on environmental considerations within the construction industry has mostly been set on reducing energy consumption and greenhouse gases [24]. However, efforts have recently been made to additionally focus on the overall lifecycle, including material efficiencies. This is, for example, demonstrated by the actual implementation of lifecycle assessments of buildings in the European Union's framework for sustainable buildings, which considers environmental impacts during their lifecycle, ideally from cradle to cradle [3]. More specifically, several researchers see potential for further reducing the construction industry's environmental impact when companies invest in circular economy approaches, e.g., in product design for achieving a longer durability [25–27]. For the implementation of a circular economy, the focus must be placed on efficient resource management and the associated material flows [24,28]. Recently, Dräger and Letmathe focused on this topic within the construction industry by examining how the manufacturing efficiency correlates with environmental improvements [29]. The construction industry, with its mostly project-based value creation architectures and lower standardization compared with other industries, offers a particularly good opportunity to achieve such a transformational change [30].

The extensive literature review by Benachio et al., in which the authors examined factors that can facilitate circular economy practices in the construction industry, shows that there is still a lack of research in the fields of manufacturing and operations [31]. In particular, two influencing factors are of high relevance: (1) employees and (2) processes.

In the construction industry, as in most industries, the optimal utilization of processes and people is considered to be an essential economic advantage [32].

(1) Employees: Considering employees, their empowerment is particularly relevant, i.e., increasing the degree of autonomy and self-determination of employees in production. Hence, it is remarkable that the empowerment of employees in the construction industry is particularly low, as the "Rethinking Construction" report emphasizes [33]. Managers have often been criticized in this regard for their withholding of employee empowerment because they perceive it as a form of power ceding [34]. That employees are essential for the construction performance is further shown in a study by Marin-Garcia and Bonavia, who drew their results from an empirical case of ceramic tile construction in Spain [35]. Alazzaz and Whyte have shown in their study that there is a positive linear relationship between employee involvement and productivity [36]. The same conclusion was arrived at by Price et al., who showed that empowerment strategies are a significant driver for construction performance [37]. In construction companies, empowered employees could improve circular economy practices, e.g., through reducing and sorting different types of construction waste when it occurs on site, which would save time as well as costs and would enable a better recycling cycle for these resources [38].

(2) Processes: In addition to the employee factor, the construction industry should maintain a high level of process quality, which could also lead to improvements in circular economy efficiency. This has been discussed in the literature mostly in the context of lean production, a process through which environmental efficiency, often driven by economic considerations, can be improved. Kurdve and Bellgran propose that circular economy efficiency, specifically prolonging the life of the materials, as well as reducing waste and improving the product system, can be achieved by lean improvements [39]. In their examined cases, improvement potential resulted from ensuring a high process quality, i.e., implementing an optimized change interval of tools, which resulted in less waste generation during production [40], with Six Sigma. In the construction industry, the lean concept has gained increasing importance through lean construction. Lean construction is a philosophy based on lean manufacturing concepts [41–43]. Francis and Thomas showed that on the one hand, many conceptual studies and individual case studies have been conducted to analyze the linkage between lean construction and environmental improvements [44]. On the other hand, however, a quantification and an empirical comparison between various construction companies is still needed [29,44].

Holt et al. argue that the poor performances of employees or of processes are mutually dependent and should therefore be considered in conjunction [45]. However, related to the construction industry, both factors have been insufficiently explored, as research has not adequately studied the extent to which employee empowerment and manufacturing process efficiency affect circular economy efficiency. Table 1 summarizes the results of this literature overview and shows that there is a research gap regarding the interdependencies between circular economy practices and manufacturing processes, as well as employee-orientation in the construction industry.

Table 1. Literature review of specific areas.

#	References	Circular Economy	Process Orientation	Employee Orientation	Construction Industry
[16]	Geissdoerfer et al. (2018)	X	-	-	X
[17]	Swift et al. (2017)	X	-	-	X
[18]	Leising et al. (2018)	X	-	-	X
[19]	Ünal et al. (2019)	X			X
[21]	Rothenberg et al. (2009)	X	X	-	-
[22]	King and Lenox (2009)	X	X	-	-
[24]	Pomponi and Moncaster (2017)	X	-	-	X
[23]	Letmathe (2002)	-	X	X	-

Table 1. *Cont.*

#	References	Circular Economy	Process Orientation	Employee Orientation	Construction Industry
[25]	Geissdoerfer et al. (2017)	X	-	-	-
[26]	Bakker et al. (2014)	X	-	-	-
[27]	Bocken et al., (2016)	X	-	-	-
[28]	Geng and Doberstein (2008)	-	X	-	X
[29]	Dräger and Letmathe (2022)	X	X	-	X
[31]	Benachio et al. (2020)	X	-	-	X
[32]	Love et al. (2000)	-	X	X	X
[33]	Egan (1998)	-	-	X	X
[34]	Denham et al. (1997)	-	-	X	X
[35]	Marin-Garcia and Bonavia (2015)	-	X	X	-
[36]	Alazzaz and Whyte (2015)	-	X	X	X
[37]	Price et al. (2004)	-	-	X	X
[38]	Wang et al. (2010)	X	-	X	X
[39]	Kurdve and Bellgran (2021)	X	X	X	-
[40]	Kurdve and Wiktorsson (2013)	X	X		
[41]	Diekmann et al. (2005)	-	X	X	X
[42]	Jørgensen and Emmitt (2008)	-	X	-	X
[43]	Koskela (1992)	-	X	-	X
[44]	Francis and Thomas (2020)	X	X	-	X
[45]	Holt et al. (2000)	-	X	X	X
[46]	Porter and Linde (1995)	-	X	-	-
[47]	Bon and Hutchinson (2000)	X	-	-	X
[48]	Cherrafi et al. (2016)	X	X	X	-

1.3. Contribution

To the best of our knowledge, there is no relevant research combining all four aspects, specifically the role of employees in operationalizing the circular economy practices through process orientation, and how this relationship influences corporate circular economy efficiency in the construction industry. Thus, the contribution of this research paper is to empirically investigate relationships between employee involvement, process improvements, and the efficiency of circular economy practices in the construction industry. In this vein, this research paper is not aiming at examining new, potentially effective circular economy practices, but rather provides empirical insights regarding how construction companies can transform their manufacturing processes in order to operationalize circular economy practices and improve their circular economy efficiency. For this purpose, the research question resulting from the previously mentioned research gap is:

How do employee empowerment and process-orientation affect the efficiency of the circular economy in the construction industry?

The remainder of this article is structured as follows: Section 2 outlines the theoretical background of our study, including the defined hypotheses and the research model. In Section 3, the methodology is presented. Section 4 outlines the results of the survey and provides a discussion of the key findings, followed by the final section, which focuses on limitations and potential avenues for further research.

2. Theory and Hypothesis Development

2.1. Lean Management Theory

The principle of lean management originated in Japan after the Second World War and gained worldwide recognition and imitation through its consistent implementation by Toyota in the 1970s until today [49]. During this period, the supply of raw materials and the buildup of inventories were critical bottlenecks that made it necessary to increase production performance [41]. These bottlenecks gave rise to various approaches in companies, such as just-in-time production, total quality management (TQM), continuous improvement, and zero inventories. Womack et al. describe the principles involved, i.e., specification of value, identification of the value stream, product flow, customer pull, and managing towards perfection, as follows [49]:

- Specify value: For the specification of value, it is at first important to focus on the customer's view. By doing this, a company should identify the needs of a customer and assess what that customer is willing to pay for a product or a service. This is particularly important for new circular business models, where PSS is being used more often. One prominent example is that of the airport in Amsterdam, to which the Philips company rents out the lighting rather than selling the airport its light bulbs. This circular business model helps the airport with its strategy to produce zero waste by 2030 and to reduce the electricity consumption by 50% by using efficient LED lamps [50]. Similar circular business models have been researched for specific construction components. In the Netherlands, for instance, an EIT Climate KIC project examined a leasing concept for facades at the university TU Delft [51]. The examined values for customers allow for consistent cash flows over time, reduce non-core processes (e.g., maintenance), and improve the flexibility of the facades with regard to design and technology [52].
- Identify the value stream: With this principle, the company must identify all those activities which create value for its customers. Any activities which do not create any additional value should be eliminated. Such activities are considered to be waste and not to contribute to the value that the customer demands. In the circular economy, waste is mainly considered to be resource waste, and thus circular economy practices in the manufacturing industry focus on avoiding waste or substituting it through continuous improvement [39]. Additionally, identifying the remaining waste and considering all relevant value streams are crucial for transitioning to a circular economy [53].
- Make the product flow: By doing so, a company makes sure that it acts and produces products in a process-oriented way and that it does not rely on slow department decisions. Furthermore, by aligning the steps of all processes, waiting times for both machines and employees are reduced, which also minimizes the value losses. This principle is also very relevant for the circular economy, where products and resources can only circulate if all process steps are known and aligned. This view might even include reverse product flow after a product's useful lifetime.
- Pull of the customer: This principle once again emphasizes the focus on the customer. However, in this case, it is not so much the defining of the value, but rather the delivering of the value at the right time, which means when the customer wants it. Therefore, principles such as just-in-time production and delivery should be applied. While these are not necessarily only relevant for circular economy practices, they should be considered in this field of research. For example, a circular economy practice—such as the take-back mechanisms for used products—requires a high level of process efficiency because the customers decide when and to where they will return the products [54]. In particular, circular economy supply chains rely on product and resource deliveries at the right time to ensure economic efficiency. Ciliberto et al. also argue that such a customer focus correlates positively with circular economy practices, and especially improves economic efficiency [55]. In particular, a customer focus can reduce the volatility of prices, because a company is able to produce exactly what the customer wants, which results in reducing waste.
- Manage toward perfection: The last principle emphasizes continuous improvement and increases the transparency of products and processes, so that waste is shown on the surface. This principle is particularly important in a circular economy where, through continuous improvement, better and more efficient ways need to be found in order to keep the resources in a loop.

For implementing these principles, the focus has often been set on reducing waste, ensuring continuous improvement, and reducing cycle times. Prior studies have shown a positive correlation between lean manufacturing and environmental performance [22,56].

Porter and Linde emphasized the similarities between environmental management (EM) and TQM [46]. Similarly to quality defects, pollution and waste are signs of poor resource efficiency. Rothenberg et al. and King and Lenox concluded that continuous improvement focused on lean plants leads to more awareness and further suggestions for reducing waste [21,22]. In the same vein, Kurdve and Bellgran examined eight different case studies, in which such continuous improvements led to circular economy contributions by avoiding waste or keeping the resources in a loop due to better recycling processes [39].

However, because the lean management philosophy was developed within the manufacturing industry, the lean principles have also been adapted to fit the construction industry, as the two industries have different characteristics [41]. For example, the construction of a building is often project-oriented instead of flow-oriented and thus, often cannot be fully standardized. However, recent innovations, such as building information modeling (BIM) and the increased usage of off-site production, support a flow orientation. Nonetheless, buildings are still seen as immobile rather than mobile products, and thus, building construction takes place at an individual location. In a fully implemented circular economy, this assumption can be suspended, and buildings can be seen as dynamic layers of different building parts [57]. However, in the current industry structure, not all work can be undertaken in a controlled environment, such as a manufacturing plant, and on-site construction workers are still very important for maintaining high productivity levels [58]. Furthermore, many different companies have to work concurrently on a project, which often results in increased coordination efforts. In order to accommodate these special characteristics, two aspects for lean construction approaches need to be reconsidered [41]. First, even greater emphasis has been placed on involving employees, who are to receive further training at every level of the hierarchy and who are encouraged to become proactively involved [59]. By doing so, circular economy practices, such as reducing waste during production and sorting waste on construction sites, can be achieved more efficiently [38]. Second, repetitive work processes in construction companies need to be defined to ensure higher levels of standardization. This could be achieved with a high level of prefabrication, where the quality of delivery and processes is controlled and can remain constant. Errors and value losses can then be more easily detected and solved, whereby circular economy efficiency can be improved [60]. Moreover, parts and components can be constructed and standardized in a way that the materials included can be more easily separated, and the recyclability of these construction materials can be improved.

2.2. Natural-Resource-Based View

As the second part of our theoretical foundation, we draw from the natural-resource-based view of Hart [20]. His theory is an extension of the resource-based view and argues that companies depend on their entire ecosystem and that their competitive advantage depends on that environment. In addition to company-related resources, resources that are removed from the natural environment play a major role. To ensure their long-term economic competitiveness, companies must focus on three strategic objectives. First, environmental pollution should be reduced by recording and reducing emissions and waste in companies. In a narrow definition of circular economy practices, reducing waste at all stages of a product's lifecycle and keeping the product in a loop, is literally in line with objectives related to circular economy practices. Second, product responsibility should be assumed for the entire lifecycle of a product. This means that environmental sustainability factors, such as recyclability, should be taken into account as early as at the product development stage. In a circular economy, such factors can be affected through new business models, such as product service systems (PSS), which ensure responsibility over the entire product lifecycle. Finally, both of the above strategies—reducing environmental pollution and taking greater product responsibility—should be integrated into a corporate vision so that they are ensured at all levels. Company examples, such as Moringa in Germany, incorporate these views by building only cradle to cradle products [61]. Their main project in Hamburg HafenCity aims to build a sustainable residential multi-purpose building which contains a high share of recycled materials, without any pollutants. The building includes apartments, co-working spaces, restaurants, a kindergarten, and green facades. Additionally, the company works in close cooperation with researchers to ensure an incentive-based end-of-life treatment of construction products and materials through material recovery rights [62].

2.3. Hypothesis Development

Our study is designed to investigate the impact of the role of employee involvement on circular economy efficiency in the construction industry. The fact that proactive involvement of employees has a positive influence on production efficiency has often been demonstrated, especially in the operations management literature [21,22,48,63]. In this context, the principles of lean production are often used, but not with a focus on a specific industry [22,64]. Most of the literature refers to the above-mentioned principles, such as product flow and just-in-time production, which are all linked to reliable and high levels of process quality in production. Although lean production is not as widespread in the construction industry as it is, for example, in the automotive industry, a similar relationship between employee involvement and lean production can nevertheless be assumed [41,42,44]. One specific characteristic which is most prominent in the construction industry is the immobility of a product's use phase [65]. This means that a final product, such as a building, is in the end, assembled on-site, as are often, the preliminary products (e.g., walls) as well. In these on-site production processes, a high proportion of manual labor is required, and the building projects often need to meet special and unique requirements. Moreover, employees are still essential in construction projects and have a high influence on process quality. For these reasons, Hypothesis H1a is assumed:

H1a. *Employee involvement in construction companies increases the process quality of manufacturing processes.*

Another important factor discussed in the lean production literature is the reduction of non-value-adding activities [66]. Since the batch size is typically rather small in the construction industry, preparatory work, which includes non-value-adding activities, such as tool changes, machine setups, and the preparation of input materials, occur more often [67]. Alazzaz and Whyte have already showed this linkage for off-site production [36], but for on-site production, the role of employees in reducing setup times is also relevant because of less standardization and automation, and more individual orders [68]. This means that employees have to decide in many individual cases about how to configure their preparatory work in the most efficient way. In order to achieve this efficiency in construction companies, employees need to be empowered to be able decide how the preparatory work can best be accomplished. Therefore, Hypothesis H1b assumes that:

H1b. *Employee involvement in construction companies reduces setup times during manufacturing processes.*

High process quality not only reduces resource waste and ceteris paribus cost, but also general waste, because the natural environment often serves as a sink for emissions, waste water, or solid waste [21,22,64]. This aspect is particularly important when considering the circular economy, as the aim here is to achieve a high level of efficiency, especially for materials and resources. Circular economy practices which have been used with regard to manufacturing involve the reduction of waste [69,70], the usage of secondary raw materials [71], or the usage of environmentally friendly designs in the early stages of a production planning process [72]. Accordingly, if high process quality is maintained, it is possible to generate lower amounts of waste during production [39]. However, the usage of secondary raw materials can also increase due to a higher process quality, either achieved through the reuse of waste and scrap [39] or through material substitution, offering a better visibility of value losses and bottlenecks [29]. Last, but not least, a higher process quality ensured, for instance, through BIM-systems, enables construction companies to efficiently design environmentally friendly products from the beginning of the project onwards [73]. Thus, we formulate Hypothesis H2a:

H2a. *A high process quality in manufacturing processes increases circular economy efficiency.*

In addition to this, a reduction of recuperative maintenance with preventive maintenance reduces unnecessary repairing times, reworking, and waste generation, e.g., of auxiliary material as well [70]. Lastly, it can also be assumed that by reducing setup times, companies are able to use materials with a lower environmental impact in a standardized manner because they can better adapt to production changes. If lean production already enables companies to manufacture environmentally friendly products, this will have an impact on circular economy efficiency. Therefore, Hypothesis H2b is:

H2b. *A short setup time during manufacturing processes increases circular economy efficiency*.

Based on the hypotheses developed, the underlying research model can be visualized as shown in Figure 1:

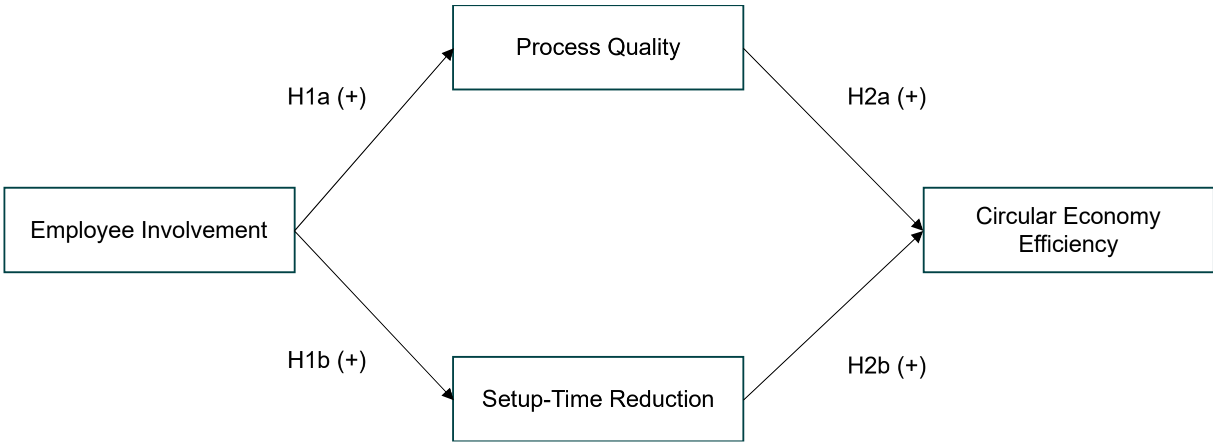

Figure 1. Research model with expected hypothesis outcomes.

3. Methodology

3.1. Data Collection

The data for answering the research question were collected by a survey, which was created for German-speaking (Germany, Austria, Switzerland) companies from the construction industry. For this purpose, the questionnaire was first translated into German, then implemented in SoSci Survey (https://www.soscisurvey.de, accessed on 9 July 2020) and sent out via e-mail in August 2020. Beforehand, the questionnaire was validated by various academic and industry experts with vast experience in the construction industry; the translation was edited by native speakers, doublechecked, and back-translated to ensure the best understanding of the survey questions.

To obtain the survey participants, the Nace Rev. 2 listing was used to check whether the companies were active in one of the following areas [74]:

- 233—Manufacture of ceramic building materials;
- 235—Manufacture of cement, lime, and gypsum;
- 236—Manufacture of products from concrete, cement, and plaster;
- 237—Cutting, shaping, and finishing of stone;
- 239—Manufacture of grinding tools, abrasives products, and other products made from non-metallic minerals;
- 381—Collection of waste;
- 382—Waste treatment and repair;
- 383—Recovery;
- 41—Building construction;
- 42—Civil engineering;

- 43—Preparatory construction site work, construction installation, and other finishing trades.

All Nace Rev. 2 companies produce and transport parts or products which are directly related to the construction industry. In addition to these companies, we included companies who treat or recycle end-of-life construction products or buildings (Nace Rev. 2 codes 38.1, 38.2, and 38.3). Overall, the surveyed companies take different positions in the value chain and thus have different relevance for forming a circular economy in the construction industry, as Figure 2 shows:

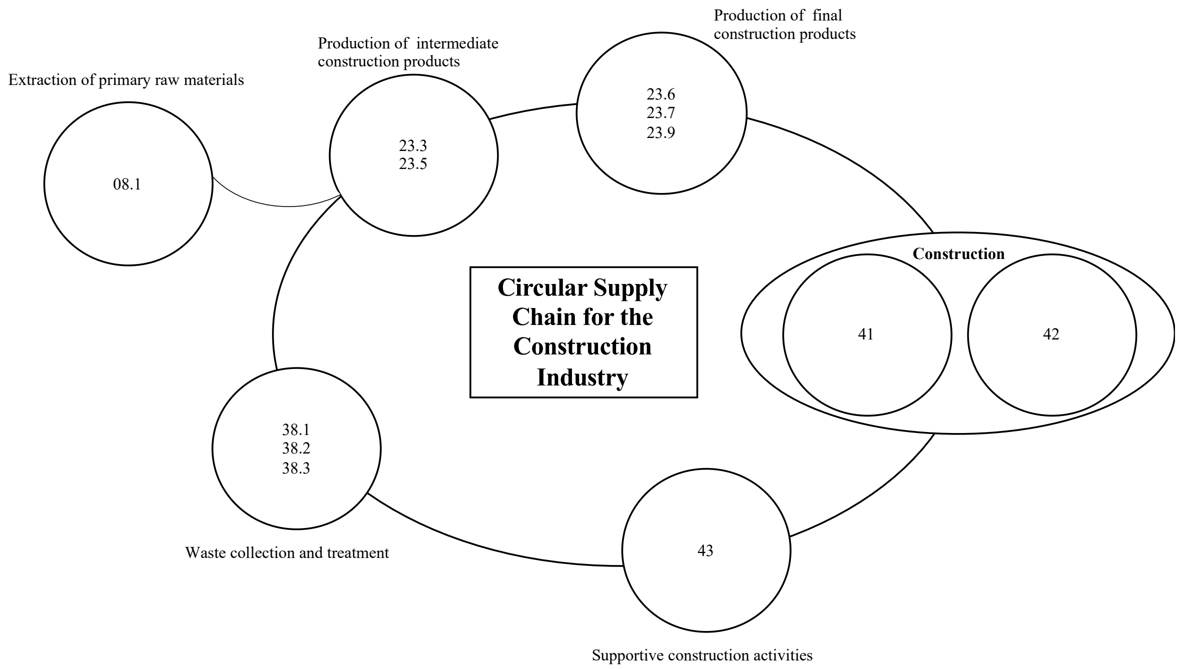

Figure 2. Circular supply chain for the construction industry, based on Nace Rev. 2.

The questionnaire was sent to the CEO's e-mail address, where available; otherwise, it was sent to the company's information e-mail address. The questions were based on 5-point Likert scales to ensure a valid analysis and a high response rate, and also to reduce the questionnaire's complexity [75].

3.2. Construct Measurement

To measure the constructs, the survey was recorded and evaluated using a 5-point Likert scale. In total, the following four constructs were surveyed: employee involvement (EI), setup time reduction (SR), process quality (PQ), and circular economy efficiency (CEE).

3.3. Employee Involvement

Employee involvement was measured by the construct of Shah and Ward due to this construct's high relevance in the lean management literature, its sound theoretical foundation, and its proven validity [76,77]. It includes four items, which target different types of active employee participation in the production process. In each case, the degree of implementation was assessed using the following:

EI1: Shop-floor employees are key to problem-solving teams.
EI2: Shop-floor employees drive suggestion programs.
EI3: Shop-floor employees lead product/process improvement efforts.
EI4 Shop-floor employees undergo cross-functional training.

3.4. Setup Time Reduction

The setup time reduction construct was also adopted from Shah and Ward for the same reasons [76,77]. It collects information about the degree of implementation of different practices:

SR1: Redesigns equipment to shorten setup time.
SR2: Uses special tools to shorten setup time.
SR3: Trains employees to reduce setup time.
SR4: Redesigns jigs or fixtures to shorten setup time.

3.5. Process Quality

For the process quality construct, items from the well-developed construct of Fullerton and Wempe were adopted [78]. We chose the non-financial performance and efficiency measurement attributes because they focused on the most relevant process quality items:

PQ1: Scrap.
PQ2: Rework.
PQ3: On-time delivery.
PQ4: Process time interruptions.

3.6. Circular Economy Efficiency

For the circular economy efficiency construct, we adapted the construct of Montabon et al. for measuring environmental efficiency [79]. Ensuring a better fit to the circular economy objectives, we focused on the areas of waste prevention [69,70], reuse of secondary materials [71], and the application of environmentally friendly designs [72]. Again, we measured the degree of implementation through 5-point Likert scales for the following items:

CEE1: Use of recycled material in the production process.
CEE2: Proactive waste reduction in terms of pollution prevention/waste elimination.
CEE3: Reprocessing of used components in relation to products, where some of the parts or components are recovered or replaced.
CEE4: Use of environmentally oriented design processes to design products eco-efficiently.
CEE5: Quantifiable environmental targets are used in product development.
CEE6: Environmentally friendly alternatives are specifically sought in product development.

3.7. Data Analysis

The hypotheses and the research model developed were tested using a covariance-based structural equation model (SEM). An SEM is particularly suitable when various relationships of latent variables, which are not directly observable, are to be empirically investigated. By applying a factor analysis and a structural path analysis, a simultaneous assessment of the measurement model and the structural model is possible [80]. Compared with other empirical analysis methods, SEMs allow for the high validity and reliability of the construct measures (outer model) and of the structural model relationships (inner model) to be achieved [81,82]. For computing the SEM, Stata version 14.1 was used.

4. Results

After cleansing, 78 companies which had answered all the questions were considered for our analysis. The questionnaire was mainly answered by the CEOs or business owners (72%), followed by financial managers (e.g., management accounting, bookkeeping) with 12%, and others, i.e., project leaders. The average company size was 47 employees, which is above the average of the construction industry. The average company age was almost 39 years, indicating a high level of experience when compared to most companies in the construction sector.

The dimensionality of the constructs for the outer model was evaluated by factor analysis (FA). Therefore, all factor loadings were measured, and factor loadings below 0.70 were removed. This was the case for CEE1, CEE2, CEE3, PQ1, PQ4, and EI4. The reliability of the remaining constructs was measured with Cronbach's alpha. Here, all constructs exceeded the recommended value of 0.70 [82–84]. The results of the FA are provided in Appendix A. Additionally, the correlations between the different constructs were measured. They exhibit significant correlations between all constructs, especially between the hypothesized constructs. Considering these aspects, we conclude that the measurement model has a good overall fit.

The results of the main SEM model are shown in Figure 3. The χ^2 statistic was not significant, which indicates a first good fit. Other indices were the root mean square of approximation (RMSEA) of 0.000, the standardized root mean square residual (SRMR) of 0.029 (cut-off value 0.08), the comparative fit index (CFI) of 1.000, as well as the Tucker–Lewis index (TLI) of 1.044. Following the goodness of fit, no re-specification of the model was necessary, because the CFI and TLI were above the recommended value of 0.90 [85].

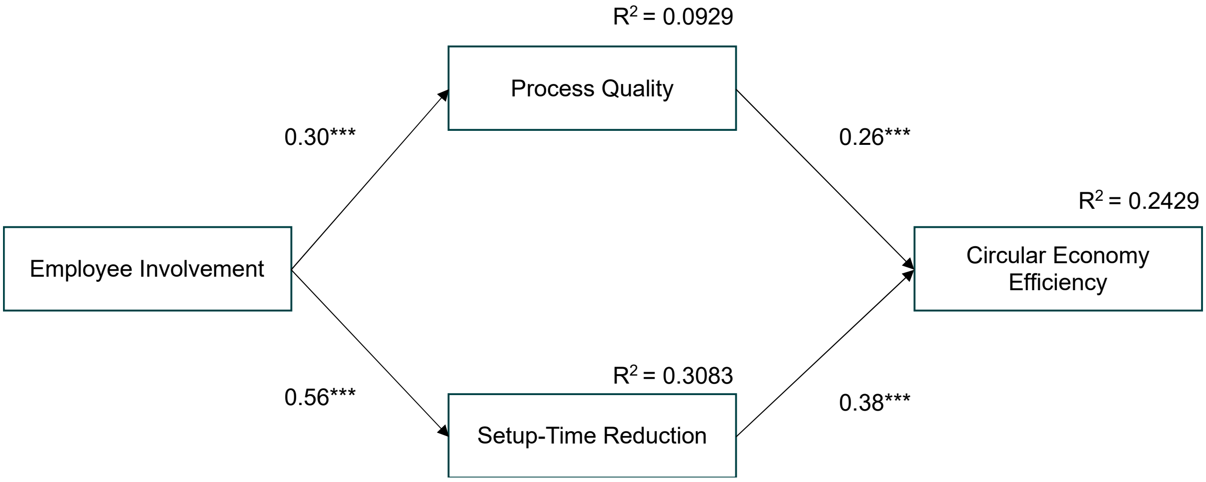

Figure 3. The structural equation modeling (SEM) parameter estimates (standardized solution). *** coefficient statistically significant at $p < 0.01$ (two-tailed).

Hypothesis H1a is highly significant, with a coefficient of 0.30 ($p < 0.01$), which means that employee involvement positively influences the process quality in construction companies. Additionally, the correlation between employee involvement and setup time reduction is highly significant, with a coefficient of 0.56 ($p < 0.01$) Thus, Hypothesis H1b, which states a positive relationship between those two factors, is supported as well. Hypothesis H2a, suggesting a positive relationship between process quality and circular economy efficiency, is also supported, with a coefficient of 0.26 ($p < 0.01$). Lastly, Hypothesis H2b is also significant, with a coefficient of 0.38 ($p < 0.01$). The overall explained variance of the model is relatively high, with $R^2 = 0.35305$; the lowest value is related to process quality ($R^2 = 0.0929$), followed by circular economy efficiency ($R^2 = 0.2429$), and setup time reduction ($R^2 = 0.3083$).

For the robustness of the proposed model shown in Figure 3 (model 1), we additionally tested two scenarios (model 2 and model 3), which are presented in Table 2:

Table 2. Different tested models.

	Model 1	**Model 2**	**Model 3**
PQ → CEE	0.2595437 ***	0.355743 ***	0.2624001 **
SR → CEE	0.3773866	0.3648605 ***	0.3859567 ***
EI → CEE			−0.0165585
EI → PQ	0.3048599 ***	0.5350242 ***	0.3048599 ***
EI → SR	0.5552202 ***	0.6408256 ***	0.5552202 ***

** coefficient statistically significant at $p < 0.05$ (two-tailed); *** coefficient statistically significant at $p < 0.01$ (two-tailed).

First, model 2 was tested with all variables included from the measurement model (see Table 2). This model still showed significant results, although the goodness of fit indicators showed lower values (RMSEA = 0.103; SRMR = 0.092; CFI = 0.852; TFI = 0.827). Additionally, we evaluated one model (model 3) with an additional direct connection between employee involvement and circular economy efficiency. Interestingly, this relationship was not statistically significant and provides a hint that employee involvement only indirectly contributes to circular economy efficiency. One explanation could be that circular economy efficiency needs to be operationalized in production through more specific tools and procedures that simultaneously improve setup times and process quality, as well as circular economy efficiency.

5. Conclusions

In this article, we have investigated the question of whether strong employee involvement has an impact on an improved circular economy efficiency in construction companies. For this purpose, a questionnaire was sent to construction companies in Germany, Austria, and Switzerland. The 78 completely answered questionnaires were tested using a structural equation model.

First, the results indicate that in the construction industry, employee involvement has a strong impact on process quality, which supports Hypothesis H1a. This finding shows that especially in areas where automation is not on the same level as in other industries, employees play an important role in maintaining high standards. Second, Hypothesis H1b is supported by the fact that preparatory activities, such as setup times, which account for a large proportion of non-value-added activities in the construction industry, can be significantly reduced if employees are given more responsibilities.

These two factors, high process quality and low setup time, are essential for influencing circular economy efficiency, which leads to our third contribution, supported by the results of Hypothesis H2a and H2b. This is supported under the assumption that the circular economy efficiency in the construction industry depends in particular on avoiding waste in production, as well as reusing or recycling process waste. The major implication of the article is, that especially in the construction industry, one success factor for operationalizing circular economy strategies is when manufacturing employees are provided with the freedom to implement related practices of their own accord, since they are the people who can detect unnecessary waste in production processes. This act of detection can then lead to a direct reuse of the resources and thus improve the circular economy efficiency. Additionally, employees can positively influence setup time reduction in production, which helps to more rapidly adapt the production processes for transitioning to circular economy-efficient products. On the one hand, efficient setup times reduce waste, i.e., inefficient energy usage or wrongly used tools. On the other hand, these efficiency gains can only be detected by employees who are encouraged to think “outside the box”. This is particularly important for circular economy-efficient products, because they require an innovative mindset in the design phase, as well as in the production phase. This contribution also underlines the theoretical foundation of lean construction, which implies that special attention must be paid to an employee-centered approach in order to transfer the lean philosophy to the construction industry [41].

This suggests that a transformation to a circular economy will work if employees are involved and empowered. Hence, companies should implement practices that involve their employees as promotors of improving the environmental efficiency and circular economy efficiency of their employers. The operational implementation of these strategies, measurable in terms of efficiency, mainly materializes in the form of an increased resource efficiency, which can, however, include several factors.

Material savings in product design, but also less waste in the form of scrap, can increase this form of resource efficiency. In both scenarios, people are still the driving factors influencing resource efficiency, even though digital performance measurement systems are increasingly present in the construction industry [73,86]. However, resource efficiency leading to better capacity utilization and lower costs still plays a crucial role. With regard to capacity utilization, efforts should be made to reduce those time portions that do not add value, i.e., waiting times (idle times) and setup times. These value-added losses can include substantial cost efficiency losses in construction companies, as previously shown by Dräger and Letmathe [29]. However, cost efficiency can be misunderstood, as it can suffer due to new process chains and ramp-up costs in the beginning, but it can also perform better than conventional processes in the long run. All three factors should be designed to be as efficient as possible, since they are mutually dependent and consequently, influence overall efficiency.

6. Discussion

In summary, our results show that employee involvement can be an important facilitator of establishing circular economy practices in the construction industry. However, in the context of this work, the focus was mainly on circular economy efficiency, without consideration of the cost and revenue perspective. Further research should therefore look more closely at the extent to which circular economy efficiency has a financial impact on companies. For example, to what extent investments in employees—but also modern facilities—impact circular economy efficiency could be investigated. Investments in employees should include training sessions that build an awareness for the fact that actions in production processes affect circular economy efficiency, e.g., waste reduction of tools. It can be expected that the results could even be strengthened if training sessions went beyond established lean practices and focused more on specific characteristics of circularity. This can either include the handling of new or alternative raw materials, or the more frequent reuse of tools. While this is not adding an additional layer in an effective circular economy, it shows that known circular concepts need to be implemented more efficiently. Kurdve and Bellgran previously showed that in such cases, an overuse of tools could be reduced by up to 50%, and a recycling rate of 75% was possible [39]. Additionally, further automation and digitization investments in the production process will affect circular economy efficiency. BIM, as a flexible digital solution for storing and managing construction data, enables companies to evaluate their products' environmental footprints through lifecycle assessments (LCA) and can enable companies to evaluate circular products at a detailed level [73]. Furthermore, it would be interesting to see how circular economy strategies are operationally implemented in manufacturing. The financial competitiveness, with the consideration of market mechanisms under which such strategies emerge, would also be of interest. Especially in the construction industry, any procurement that is aimed at purchasing primary materials at the lowest possible cost can obstruct the reusing of secondary materials. Hence, circular economy strategies should be implemented with a long-term view in mind. Another point that should be investigated in more detail in this context is whether the results differ when other areas of the construction value chain, e.g., recycling and processing companies, are included in the evaluation. This could lead to holistic strategies that are applicable for an entire and more sustainable value chain architecture and not just for individual companies. While this study only depicts specific parts of an effective circular economy, future research could investigate whether employee involvement and lean practices also support further circular economy strategies. Additionally, future research should evaluate in more detail, if a 'one size fits all approach' holds true for different types of construction companies, e.g., through multiple case studies. Ultimately, a circular way of thinking and operating can only be implemented in the construction industry if the chosen approach takes all actors (including the customers) into account.

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Abbreviations

BIM	building information modeling
CEE	circular economy efficiency
CFI	comparative fit index
EI	employee involvement
EU	European Union
e.g.	exempli gratia—"for example"
FA	factor analysis
GHG	greenhouse gas emissions
i.e.	id est—"that is"
LCA	life cycle assessment
PSS	product service system
RMSEA	root mean square of approximation
SEM	structural equation model
SR	setup time reduction
SRMR	standardized root mean square residual
TLI	Tucker–Lewis index
TQM	total quality management

Appendix A

Table A1. Constructs and Indicators.

Variable	Factor Loadings
Circular Economy Efficiency	Cronbach's Alpha: 0.8836
CEE1	0.5294
CEE2	0.5452
CEE3	0.5091
CEE4	0.7519
CEE5	0.8419
CEE6	0.8978
Process Quality	Cronbach's Alpha: 0.7591
PQ1	0.5408
PQ2	0.7045
PQ3	0.5872
PQ4	0.7045
Setup Time Reduction	Cronbach's Alpha: 0.8949

Table A1. *Cont.*

Variable	Factor Loadings
ST1	0.7126
ST2	0.8052
ST3	0.9178
ST4	0.8410
Employee Involvement	Cronbach's Alpha: 0.8687
EI1	0.8291
EI2	0.7964
EI3	0.7958
EI4	0.5954

Variables < 0.7 were excluded and are not contributing to Cronbach' Alpha.

Table A2. Correlation matrix.

	CEE	PQ	ST	EI
CEE	1			
PQ	0.3363 ***	1		
ST	0.4543 ***	0.2842 ***	1	
EI	0.2637 **	0.3142 ***	0.5544 ***	1

** coefficient statistically significant at $p < 0.05$ (two-tailed); *** coefficient statistically significant at $p < 0.01$ (two-tailed).

References

1. European Commission. *Circular Economy Action Plan for a Cleaner and More Competitive Europe*; European Commission: Brussels, Belgium, 2020.
2. Eurostat. *Generation of Waste by Waste Category, Hazardousness and NACE Rev. 2 Activity [WWW Document]*; Eurostat: Luxembourg, 2018.
3. European Union. Level(s): Taking Action on the TOTAL Impact of the Construction Sector En. 2019. Available online: https://op.europa.eu/en/web/general-publications/doi (accessed on 14 July 2022).
4. Hertwich, E.; Lifset, R.; Pauliuk, S.; Heeren, N.; Ali, S.; Tu, Q.; Ardente, F.; Berrill, P.; Fishman, T.; Kanaoka, K.; et al. *Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future*; International Resource Panel (IRP): Paris, France, 2019. [CrossRef]
5. Gallego-Schmid, A.; Chen, H.-M.; Sharmina, M.; Mendoza, J.M.F. Links between circular economy and climate change mitigation in the built environment. *J. Clean. Prod.* **2020**, *260*, 121115. [CrossRef]
6. Kirchherr, J.; Reike, D.; Hekkert, M. Conceptualizing the circular economy: An analysis of 114 definitions. *Resour. Conserv. Recycl.* **2017**, *127*, 221–232. [CrossRef]
7. Keijer, T.; Bakker, V.; Slootweg, J.C. Circular chemistry to enable a circular economy. *Nat. Chem.* **2019**, *11*, 190–195. [CrossRef]
8. Webster, K. *The Circular Economy: A Wealth of Flows*; The Ellen Macarthur Foundation: The Isle of Wight, UK, 2015.
9. Evans, S.; Gregory, M.; Ryan, C.; Bergendahl, M.N.; Tan, A. *Towards a Sustainable Industrial System: With Recommendations for Education, Research, Industry and Policy*; University of Cambridge, Institute for Manufacturing: Cambridge, UK, 2009.
10. European Commission. *Circular Economy-Principles for Buildings Design*; European Commission: Brussels, Belgium, 2020.
11. Elia, V.; Gnoni, M.G.; Tornese, F. Measuring circular economy strategies through index methods: A critical analysis. *J. Clean. Prod.* **2017**, *142*, 2741–2751. [CrossRef]
12. Heisel, F.; Schlesier, K.; Hebel, D.E. Prototypology for a circular building industry: The potential of re-used and recycled building materials. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *323*, 012023. [CrossRef]
13. Dräger, P.; Letmathe, P.; Reinhart, L.; Robineck, F. Measuring circularity: Evaluation of the circularity of construction products using the ÖKOBAUDAT database. *Environ. Sci. Eur.* **2022**, *34*, 13. [CrossRef]
14. Eisele, J.; Harzdorf, A.; Hüttig, L.; Otto, J.; Stroetmann, R.; Trautmann, B.; Weller, C. *Multifunktionale Büro Und Geschäftshäuser*; Springer: Berlin/Heidelberg, Germany, 2020. [CrossRef]
15. Katerusha, D. Attitude towards sustainability, study contents and the use of recycled concrete in building construction-case study Germany and Switzerland. *J. Clean. Prod.* **2021**, *289*, 125688. [CrossRef]
16. Geissdoerfer, M.; Morioka, S.N.; de Carvalho, M.M.; Evans, S. Business models and supply chains for the circular economy. *J. Clean. Prod.* **2018**, *190*, 712–721. [CrossRef]
17. Swift, J.; Ness, D.; Kim, K.; Gelder, J.; Jenkins, A.; Xing, K. Towards adaptable and reusable building elements: Harnessing the versatility of the construction database through RFID and BIM. In Proceedings of the UIA 2017 Seoul World Architects Congress, Seoul, Republic of Korea, 3–10 September 2017; pp. 1–7.

18. Leising, E.; Quist, J.; Bocken, N. Circular Economy in the building sector: Three cases and a collaboration tool. *J. Clean. Prod.* **2018**, *176*, 976–989. [CrossRef]
19. Ünal, E.; Urbinati, A.; Chiaroni, D.; Manzini, R. Value Creation in Circular Business Models: The case of a US small medium enterprise in the building sector. *Resour. Conserv. Recycl.* **2019**, *146*, 291–307. [CrossRef]
20. Hart, S. A natural-resource-based view of the firm. *Acad. Manag. Rev.* **1995**, *20*, 986–1014. [CrossRef]
21. Rothenberg, S.; Pil, F.K.; Maxwell, J. Lean, Green, and the Quest for Superior Environmental Performance. *Prod. Oper. Manag.* **2009**, *10*, 228–243. [CrossRef]
22. King, A.A.; Lenox, M.J. Lean and green? An empirical examination of the relationship between lean production and environmental performance. *Prod. Oper. Manag.* **2009**, *10*, 244–256. [CrossRef]
23. Letmathe, P. *Flexbile Standardisierung: Ein Dezentrales Produktionsmanagement Für Kleine Und Mittlere Unternehmen*; Deutscher Universitäts-Verlag GmbH: Wiesbaden, Germany, 2002.
24. Pomponi, F.; Moncaster, A. Circular economy for the built environment: A research framework. *J. Clean. Prod.* **2017**, *143*, 710–718. [CrossRef]
25. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, E.J. The circular economy—A new sustainability paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [CrossRef]
26. Bakker, C.; Wang, F.; Huisman, J.; den Hollander, M. Products that go round: Exploring product life extension through design. *J. Clean. Prod.* **2014**, *69*, 10–16. [CrossRef]
27. Bocken, N.M.P.; de Pauw, I.; Bakker, C.; van der Grinten, B. Product design and business model strategies for a circular economy. *J. Ind. Prod. Eng.* **2016**, *33*, 308–320. [CrossRef]
28. Geng, Y.; Doberstein, B. Developing the circular economy in China: Challenges and opportunities for achieving 'leapfrog development'. *Int. J. Sustain. Dev. World Ecol.* **2008**, *15*, 231–239. [CrossRef]
29. Dräger, P.; Letmathe, P. Value losses and environmental impacts in the construction industry—Tradeoffs or correlates? *J. Clean. Prod.* **2022**, *336*, 130435. [CrossRef]
30. Chui, M.; Mischke, J. Global Infrastructure Initiative the Impact and Opportunities of Automation in Construction. McKinsey 2019. Available online: https://www.mckinsey.com/~/media/McKinsey/Industries/Capital%20Projects%20and%20Infrastructure/Our%20Insights/The%20impact%20and%20opportunities%20of%20automation%20in%20construction/The-impact-and-opportunities-of-automation-in-construction.pdf (accessed on 25 July 2022).
31. Benachio, G.L.F.; Freitas, M.D.C.D.; Tavares, S.F. Circular economy in the construction industry: A systematic literature review. *J. Clean. Prod.* **2020**, *260*, 121046. [CrossRef]
32. Love, P.E.D.; Heng, L.I.; Irani, Z.; Faniran, O. Total quality management and the learning organization: A dialogue for change in construction. *Constr. Manag. Econ.* **2000**, *18*, 321–331. [CrossRef]
33. Egan, S.J. Rethinking Construction: Report of the Construction Task Force, Construction Task Force. *Dep. Environ.* **1998**. Available online: http://constructingexcellence.org.uk/wp-content/uploads/2014/10/rethinking_construction_report.pdf (accessed on 19 May 2021).
34. Denham, N.; Ackers, P.; Travers, C. Doing yourself out of a job? *Empl. Relat. Int. J.* **1997**, *19*, 147–159. [CrossRef]
35. Marin-Garcia, J.A.; Bonavia, T. Relationship between employee involvement and lean manufacturing and its effect on performance in a rigid continuous process industry. *Int. J. Prod. Res.* **2015**, *53*, 3260–3275. [CrossRef]
36. Alazzaz, F.; Whyte, A. Linking employee empowerment with productivity in off-site construction. *Eng. Constr. Arch. Manag.* **2015**, *22*, 21–37. [CrossRef]
37. Price, A.D.F.; Bryman, A.; Dainty, A.R.J. Empowerment as a Strategy for Improving Construction Performance. *Leadersh. Manag. Eng.* **2004**, *4*, 27–37. [CrossRef]
38. Wang, J.; Yuan, H.; Kang, X.; Lu, W. Critical success factors for on-site sorting of construction waste: A china study. *Resour. Conserv. Recycl.* **2010**, *54*, 931–936. [CrossRef]
39. Kurdve, M.; Bellgran, M. Green lean operationalisation of the circular economy concept on production shop floor level. *J. Clean. Prod.* **2021**, *278*, 123223. [CrossRef]
40. Kurdve, M.; Wiktorsson, M. Green performance map: Visualizing environmental KPI's. In Proceedings of the International EurOMA Conference, Dublin, Ireland, 7–12 June 2013.
41. Diekmann, J.E.; Krewedi, M.; Joshua, B.; Stewart, T.; Won, S. *Application of Lean Manufacturing Principles to Construction*; University of Colorado: Denver, CO, USA, 2005.
42. Jørgensen, B.; Emmitt, S. Lost in transition: The transfer of lean manufacturing to construction. *Eng. Constr. Arch. Manag.* **2008**, *15*, 383–398. [CrossRef]
43. Koskela, L. *Application of the New Production Philosophy to Construction*; Stanford University: Stanford, CA, USA, 1992; Volume 72.
44. Francis, A.; Thomas, A. Exploring the relationship between lean construction and environmental sustainability: A review of existing literature to decipher broader dimensions. *J. Clean. Prod.* **2020**, *252*, 119913. [CrossRef]
45. Holt, G.D.; Love, P.E.d.; Jawahar Nesan, L. Employee empowerment in construction: An implementation model for process improvement. *Team Perform. Manag. Int. J.* **2000**, *6*, 47–51. [CrossRef]
46. Porter, M.E.; van der Linde, C. Toward a New Conception of the Environment-Competitiveness Relationship. *J. Econ. Perspect.* **1995**, *9*, 97–118. [CrossRef]
47. Bon, R.; Hutchinson, K. Sustainable construction: Some economic challenges. *Build. Res. Inf.* **2000**, *28*, 310–314. [CrossRef]

48. Cherrafi, A.; Elfezazi, S.; Chiarini, A.; Mokhlis, A.; Benhida, K. The integration of lean manufacturing, Six Sigma and sustainability: A literature review and future research directions for developing a specific model. *J. Clean. Prod.* **2016**, *139*, 828–846. [CrossRef]
49. Womack, J.; Jones, D.; Roos, D. *The Machine That Changed the World: The Story of Lean Production, Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry*; Free Press: New York, NY, USA, 1990.
50. Circular Economy Institute (CEI). Renting lighting: Schiphol Airport [WWW Document]. 2015. Available online: https://www.circulareconomyclub.com/solutions/renting-lighting-schiphol-airport/#post_profile (accessed on 14 July 2022).
51. ClimateKIC; Azcarate-Aguerre, J.F. Project: Façade Leasing. 2015. Available online: https://www.climate-kic.org/projects/facade-leasing/ (accessed on 7 December 2022).
52. Azcarate-Aguerre, J.F.; Klein, T.; Vrijhoef, R. Façade Leasing: Drivers and Barriers to the Delivery of Integrated Façades-as-a-Service Creating the Network of Knowledge Labs for Sustainable and Resilient Environments-KLABS View Project Juritecture View Project. 2018. Available online: https://www.researchgate.net/publication/329034829 (accessed on 7 December 2022).
53. Perey, R.; Benn, S.; Agarwal, R.; Edwards, M. The place of waste: Changing business value for the circular economy. *Bus. Strat. Environ.* **2018**, *27*, 631–642. [CrossRef]
54. Hazen, B.T.; Mollenkopf, D.A.; Wang, Y. Remanufacturing for the Circular Economy: An Examination of Consumer Switching Behavior. *Bus. Strat. Environ.* **2017**, *26*, 451–464. [CrossRef]
55. Ciliberto, C.; Szopik-Depczyńska, K.; Tarczyńska-Łuniewska, M.; Ruggieri, A.; Ioppolo, G. Enabling the Circular Economy transition: A sustainable lean manufacturing recipe for Industry 4.0. *Bus. Strat. Environ.* **2021**, *30*, 3255–3272. [CrossRef]
56. Yang, M.G.; Hong, P.; Modi, S.B. Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. *Int. J. Prod. Econ.* **2011**, *129*, 251–261. [CrossRef]
57. Durmiševic, E. Reversible building design. In *Designing for the Circular Economy*; Charter, M., Ed.; Routledge: New York, NY, USA, 2018; pp. 344–359. [CrossRef]
58. Dixit, S.; Mandal, S.N.; Sawhney, A.; Singh, S. Relationship between skill development and productivity in construction sector: A literature review. *Int. J. Civ. Eng. Technol.* **2017**, *8*, 649–665.
59. Lapré, M.A.; Mukherjee, A.S.; Van Wassenhove, L.N. Behind the Learning Curve: Linking Learning Activities to Waste Reduction. *Manag. Sci.* **2000**, *46*, 597–611. [CrossRef]
60. Minunno, R.; O'Grady, T.; Morrison, G.M.; Gruner, R.L.; Colling, M. Strategies for Applying the Circular Economy to Prefabricated Buildings. *Buildings* **2018**, *8*, 125. [CrossRef]
61. Moringa, n.d. Moringa [WWW Document]. 2022. Available online: www.moringa.eco (accessed on 7 December 2022).
62. ZukunftBau. *Material Recovery Right*; Forschungsförderung; ZukunftBau: Aachen, Germany, 2022; Available online: https://www.zukunftbau.de/projekte/forschungsfoerderung/1008187-2247#projektbeteiligte (accessed on 7 December 2022).
63. Dhingra, R.; Kress, R.; Upreti, G. Does lean mean green? *J. Clean. Prod.* **2014**, *85*, 1–7. [CrossRef]
64. Yang, C.-L.; Lin, S.-P.; Chan, Y.-H.; Sheu, C. Mediated effect of environmental management on manufacturing competitiveness: An empirical study. *Int. J. Prod. Econ.* **2010**, *123*, 210–220. [CrossRef]
65. Nam, C.H.; Tatum, C.B. Major characteristics of constructed products and resulting limitations of construction technology. *Constr. Manag. Econ.* **1988**, *6*, 133–147. [CrossRef]
66. Han, S.; Lee, S.; Fard, M.G.; Pena-Mora, F. Modeling and representation of non-value adding activities due to errors and changes in design and construction projects. In Proceedings of the 2007 Winter Simulation Conference, Washington, DC, USA, 9–12 December 2007; pp. 2082–2089. [CrossRef]
67. Wu, P.; Low, S.P.; Jin, X. Identification of non-value adding (NVA) activities in precast concrete installation sites to achieve low-carbon installation. *Resour. Conserv. Recycl.* **2013**, *81*, 60–70. [CrossRef]
68. Melenbrink, N.; Werfel, J.; Menges, A. On-site autonomous construction robots: Towards unsupervised building. *Autom. Constr.* **2020**, *119*, 103312. [CrossRef]
69. Esa, M.R.; Halog, A.; Rigamonti, L. Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. *J. Mater. Cycles Waste Manag.* **2017**, *19*, 1144–1154. [CrossRef]
70. Adams, K.T.; Osmani, M.; Thorpe, T.; Thornback, J. Circular economy in construction: Current awareness, challenges and enablers. *Proc. Inst. Civ. Eng. Waste Resour. Manag.* **2017**, *170*, 15–24. [CrossRef]
71. Nußholz, J.L.K.; Nygaard Rasmussen, F.N.; Milios, L. Circular building materials: Carbon saving potential and the role of business model innovation and public policy. *Resour. Conserv. Recycl.* **2019**, *141*, 308–316. [CrossRef]
72. Akanbi, L.; Oyedele, L.; Delgado, J.M.D.; Bilal, M.; Akinade, O.; Ajayi, A.; Mohammed-Yakub, N. Reusability analytics tool for end-of-life assessment of building materials in a circular economy. *World J. Sci. Technol. Sustain. Dev.* **2019**, *16*, 40–55. [CrossRef]
73. Xue, K.; Hossain, U.; Liu, M.; Ma, M.; Zhang, Y.; Hu, M.; Chen, X.; Cao, G. BIM Integrated LCA for Promoting Circular Economy towards Sustainable Construction: An Analytical Review. *Sustainability* **2021**, *13*, 1310. [CrossRef]
74. Eurostat. *NACE Rev. 2–Statistical Classification of Economic Activities in the European Community, Office for Official Publications of the European Communities*; Eurostat: Luxembourg, 2008.
75. Babakus, E.; Mangold, W.G. Adapting the SERVQUAL scale to hospital services: An empirical investigation. *Health Serv. Res.* **1992**, *26*, 767–786.
76. Shah, R.; Ward, P.T. Defining and developing measures of lean production. *J. Oper. Manag.* **2007**, *25*, 785–805. [CrossRef]
77. Marodin, G.; Frank, A.G.; Tortorella, G.L.; Netland, T. Lean product development and lean manufacturing: Testing moderation effects. *Int. J. Prod. Econ.* **2018**, *203*, 301–310. [CrossRef]

78. Fullerton, R.R.; Wempe, W.F. Lean manufacturing, non-financial performance measures, and financial performance. *Int. J. Oper. Prod. Manag.* **2009**, *29*, 214–240. [CrossRef]
79. Montabon, F.; Sroufe, R.; Narasimhan, R. An examination of corporate reporting, environmental management practices and firm performance. *J. Oper. Manag.* **2007**, *25*, 998–1014. [CrossRef]
80. Lee, L.; Petter, S.; Fayard, D.; Robinson, S. On the use of partial least squares path modeling in accounting research. *Int. J. Account. Inf. Syst.* **2011**, *12*, 305–328. [CrossRef]
81. Bollen, K.A. *Structural Equations with Latent Variables*; Wiley: New York, NY, USA, 1989.
82. Hair, J.F. *Multivariate Data Analysis*; Kennesaw State University: Kennesaw, GA, USA, 2009.
83. Fornell, C.; Larcker, D.F. Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *J. Mark. Res.* **1981**, *18*, 39–50. [CrossRef]
84. Hair, J.F., Jr.; Matthews, L.M.; Matthews, R.L.; Sarstedt, M. PLS-SEM or CB-SEM: Updated guidelines on which method to use. *Int. J. Multivar. Data Anal.* **2017**, *1*, 107. [CrossRef]
85. Hu, L.T.; Bentler, P.M. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct. Equ. Model.* **1999**, *6*, 1–55. [CrossRef]
86. Jang, S.; Lee, G. Process, productivity, and economic analyses of BIM–based multi-trade prefabrication—A case study. *Autom. Constr.* **2018**, *89*, 86–98. [CrossRef]