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Circularity in Facility Management: Conceptualisation and Potential Areas for Circularity-Oriented Actions

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Abstract: Although literature discussing materials circularity in the built environment sector is well-developed, we have a limited understanding of circularity in facility services because most of the literature often generalises building operations, ignoring circularity applications via service streams. Thus, owing to the service nature of facility management, facility service providers' remit, and the building operation functions, this paper makes a first-order attempt to conceptualise circularity in the context of facility services and to identify areas corresponding to key facility functions and performance improvement criteria. Facility service is an important service stream for building operations, and it includes a range of functions ensuring better condition, quality, serviceability, and durability of building assets. Understanding the limited research undertaken to highlight circularity in facility services, this paper uses a literature review and qualitative content analysis to categorise three scopes (procurement, building use, and end of life) and the corresponding circularity-oriented action areas in facility service delivery. As key findings, subtle changes in the core facility function, such as in products' purchase approach, delivery of ongoing maintenance and refurbishment of building assets, and end-of-life management, possess the potential to enable circularity. Thus, within the buildings' operation realm, a dedicated service stream, such as the facility service, can contribute to realising circularity for facility service providers' commercial clients.

Keywords: facility management; circularity; building operations; procurement; end of life; maintenance

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1. Introduction

Environmental sustainability in the built environment sector has gained traction for its extensive natural resource consumption, greenhouse gas (GHG) emissions, and waste generation. The global construction sector, including buildings, accounts for about 20–50% of natural resources consumption and 50% of the total solid waste [1]. Many new buildings come into operation each year. However, their share in the total building stock is relatively small compared to the old ones [2]. Nonetheless, it is important to improve the sustainability performance of the whole building stock, including new ones, as their conditions tend to deteriorate over time, and to leverage emerging technologies and services that may enhance the building's sustainability performance. Another reason to consider improving the building sector's sustainability performance is that the building industry is striving continuously to deliver on global sustainability objectives, and the industry is expected to grow significantly as the global middle-class population will cross four billion by 2030 [3]. The dual challenges of minimising the resource use in existing and future building stock and improving sustainability performance throughout their lifecycle foreground the circular economy imperative.

The building sector's transition to a circular economy is critical considering the entire life cycle of the building and for fostering innovation within the built environment [4]. Circular economy is viewed as an important notion by environmental sustainability professionals for its potential to assist commercial building owners in delivering sustainable development objectives [5]. Although the initial definitions of the circular economy were related to the 4R framework (reduction, reuse, recycling, and recovering) up until 2012, most of the existing discourse and definitions use a systems perspective [6]. Thus, it is reasonable to state that the current conceptualisation of circular economy is broad enough to envision changes at the micro, meso, and macro levels with a view to retaining the value of materials throughout the assets' cycle, including the individual product's end of life [6,7].

While the general conceptualisation of circular economy and the focus of each conceptualisation, including the built environment sector, have evolved over time, the conceptual nuances pertaining to circularity in facility services are thinly explored. The conceptual nuances underscore the facility service providers' remit, service-oriented nature, and core functionality as buildings operators. This paper aims to explore the fundamental basis necessary to conceptualise circular economy in facility management practices and identify areas for circularity-oriented actions. Facility management as a service is an essential part of the building life cycle's operation stage, which is the longest stage that determines the building's life cycle sustainability performance. The International Organization for Standardization (ISO) defines facilities management as the organisational function integrating process, people, and place within the built environment [8]. The international facility management association defines facility management as a profession that integrates people, place, processes, and technology to ensure better functionality, comfort, and efficiency in the built environment [9]. It has become a crucial part of the commercial building sector and services because of the increased emphasis on building optimisation, as facility managers are involved in the monitoring and analysis of building data and the modification and upgrading of building features affecting performance [10].

Thus, understanding the boundary of facility services, this paper provides fresh insights into areas within facility management, such as procurement, building operations, and products and assets' end of life, where it may be practical to enable circular actions. The rest of the paper is structured as follows. Section 2 sheds light on facility service being a service stream and the characteristics of facility service delivery, thus elaborating on the need to separately conceptualise circularity in facility services. Thus, this section highlights the potential academic contribution of this paper. Section 3 is the methodological framework, highlighting the literature review and qualitative content analysis as fundamental research elements. Section 4 identifies the scopes for envisioning circularity in facility services and creates an analytical foundation. Section 5 identifies areas under each scope where circularity-oriented actions can be realised in facility service delivery. Section 6 provides initial insights into metrics and performance improvement criteria, and Section 7 talks about carbon dividends. Finally, Section 8 is the conclusion that also explains some limitations and areas for conducting further research.

2. Circular Economy—Understanding in the Context of Facility Service

2.1. Facility Services in Building Operations

Facility management involves important functions such as managing front-end resource inputs and back-end waste outputs whilst ensuring that buildings provide services to their owners and operators, tenants, and visitors (see Figure 1). Generally, the facility management function includes real estate management, managing occupants, delivering maintenance works, maintaining physical assets in serviceable condition, and building systems management [11]. Given the broad functions, it is reasonable to say that facility management as a service forms the crux of the decision-making regarding how physical resources are consumed and discarded after the end of life. Facility service has evolved from being a secondary service to a core functionality in decision-making whilst operating assets [12]. Thus, innovative thinking and solutions within the facility management arena are getting more traction in recent times, as there is an intention to adopt sustainable facility narratives and anticipation of changes in functionality and end-user requirements [13]. The ideas on innovative thinking for sustainable facilities are, however, driven primarily by the intelligent building discourse that foregrounds advancements in the building-sector-related smart sensors and controllers. Facility service in the building operation phase suffers from the least consideration of the optimisation of input and output flows of physical resources [14]. Nevertheless, sustainability in facility service has been a topic of discussion for about two decades as it plays a central role in determining buildings' environmental performance, although primarily for green-building-related certifications [15].

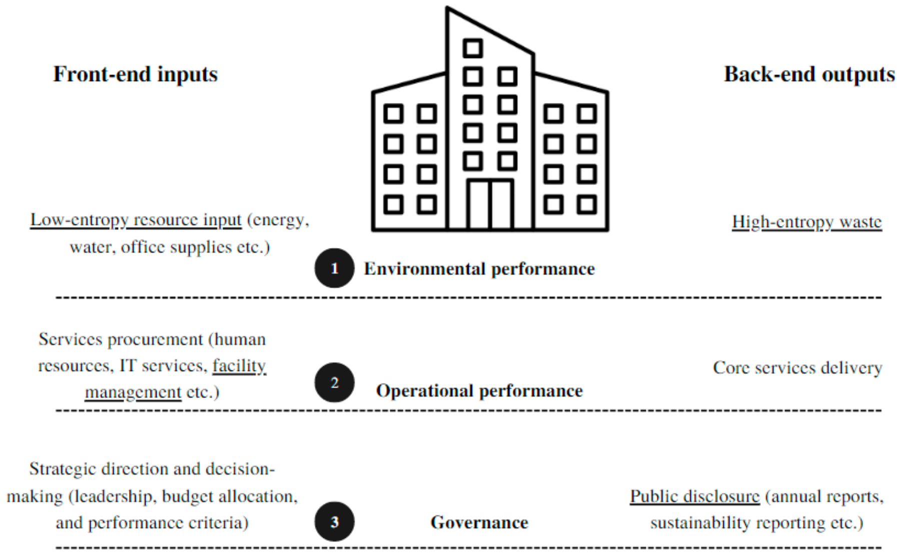

Figure 1. Front-end inputs and back-end outputs.

While the application of 'sustainability in facility services (that includes facility management function)', and 'circular economy within the broader built environment sector' are familiar narratives, the circular economy concept and its applications in facility services are rarely discussed. This is because many research scholars often disregard the fact that facility service is one of many service streams necessary for the built environment sector, and building management per se is considered a facility service. The implicit differences between facility service and building management are barely recognised to the extent necessary to clearly comprehend the underlying aspects that distinguish them. In a general sense, they appear similar as both relate to managing and maintaining building assets, ensuring the seamless functioning of the building, and satisfying user needs. The key difference, however, is the scope of work they cover. For example, building management is far more technical in the sense that the emphasis is more on the functioning of technical assets, and it relies on the use of sophisticated, intelligent technical systems (e.g., building management control systems) to manage assets.

The focus is solely on the building as a structure and a group of assets. Facility service, on the other hand, is far broader in the sense that there is a well-established ISO facility management system (41001), and it comprises people, processes, technology, and place [9]. People pertain to human resources such as facility managers, sustainability professionals, and other decision-makers who will play a key role in enabling a circular economy. Process pertains to the means by which circular economy can be enabled within the facility management practices as part of the broader facility service. For example, the identification of key areas, an implementation framework, and a performance measurement framework are in place. Technology pertains to the use of technologies that may enable a circular economy, and place refers to the facilities and buildings in general where changes need to be made. As portrayed in Figure 1, and given the service nature of facility management required to operate buildings, it may be reasonable to say that facility service providers need to develop an understanding of how circularity can be embedded in facility service delivery.

2.2. Four Perspectives Highlight the Characteristics of Facility Service Delivery and the Circularity Element

The day-to-day facility service delivery involves management and maintenance works that are aimed at improving the condition and quality of building assets, optimising their functioning, and improving the assets' life cycle performance with higher end-of-life time. All these contribute to the pursuit towards circular facility management as assets remain in the use phase for a relatively long time. Similarly, the services-oriented facility management practices and changes in the market conditions may have a profound impact on the way circular facility management is practised (Figure 2).

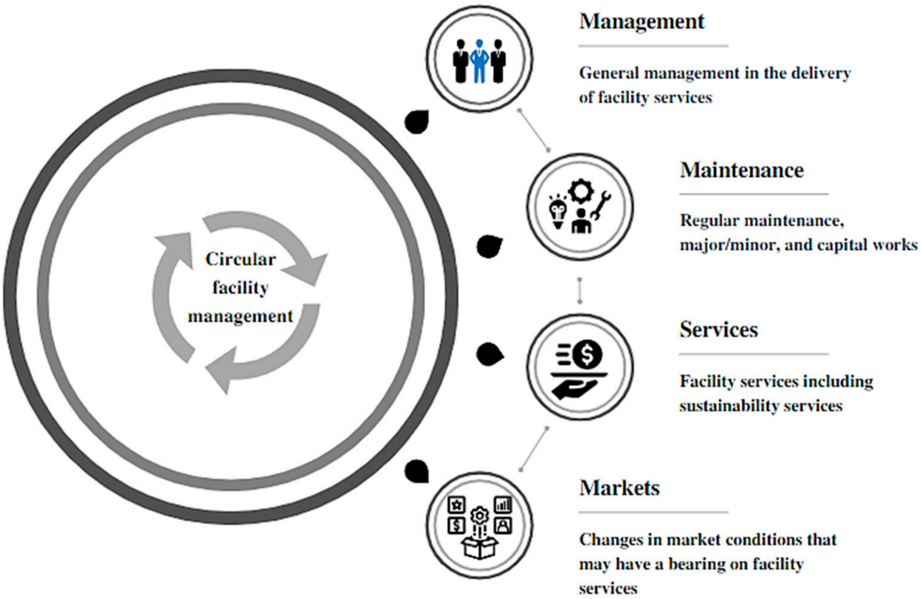

Figure 2. Perspectives on circular facility management.

Management plays a crucial role in the facility services delivery as the complexity of the tasks managed range from simple to sophisticated, and the criticality of the tasks range from regular operational matters to highly strategic, essential, and confidential, in some cases [16]. In facility services, management involves support across two levels, operational and strategic [17]. The circular actions can be put under both operational and strategic matters because they can be strategic, mostly in the beginning, and more operational, as the concept is slowly integrated within the regular facility management practices. The management of environmental programs that are closely related to circular actions in facility services falls under the general management remit [16,17] puts waste disposal and environmental management in the building services and operations cluster of the facility services. It is understood that the general management in delivering facility services can be confused with the term 'facility management'. This paper distinguishes them by referring to stewardship when the paper says general management in delivering facility services. Stewardship fosters organisational change [18] and is mostly discussed in an institutional context. Stewardship in an institutional context is defined as actions aimed at changing work practices in the long-term interest of an organisation [19]. Thus, the management perspective highlights leadership.

Maintenance of built assets is often considered a cost source, although they can potentially help organisations gain long-term benefits [20,21]. Many proactive and reactive services are part of the service-oriented framework in facility management practices [22]. While capital works are quite common across the facility management space, they are often less associated with operation and maintenance related to facility management [23]. However, as the gamut of elements within broader facility services is being diversified for additional value propositions to asset owners, capital works and project management are being increasingly considered as crucial parts of the facility services. Previously, capital works were thought of as activities of external agencies, excluding facility service providers [18]. Maintenance and capital works are physical in nature, and this is where efficient management of assets (e.g., repair, repurposing, and renovations) can contribute towards a circular economy [24].

With facility services, it is said that the relationship between a facility services provider and client is based on an adversarial approach [25]. Therefore, while a collaborative approach is desired, the key areas of collaboration should be worked out between facility service providers and the clients. The collaboration areas will likely depend on the contractual arrangement between the facility services providers and the client (service buyers). Nonetheless, the following areas are common across many contractual agreements between the facility services providers and the client: (1) maintenance and asset management, (2) data management and digitalisation of FM, (3) environmental/sustainability services, (4) security services, (5) project management, (6) workplace solutions, and (7) supply chain management. From the client/property owner's point of view, maintenance (including asset management) is an important function because it may impact the financial value of the asset [26]. The market perspective emphasises the corroborative effort between the facility service providers and the market actors as market actors, such as the recycling companies and subcontractors necessary for many maintenance and refurbishment works, complement the facility service provider's capability in many cases.

3. Methodological Framework

The methodological framework is designed to answer the two main research questions. First, what does the concept of the circular economy mean in the context of delivering facility services? Second, what are the specific areas in which facility service providers can consider embedding circular strategies, and how do we monitor and measure the performance? The earlier sections have already provided insights into the conceptual nuances in the way we envision circularity in the built environment and the circularity in the delivery of facility services. Nonetheless, this research, in general, and the methodological framework underscore facility services as one of many service streams necessary for building operations, whereas the built environment is considered as a physical structure made up of various materials and products. This research builds on the aforementioned conceptual nuances to explore two different strands of the literature as part of the literature review process, as there is limited research conducted to explain the concept of circularity specifically tied to facility services. The first literature strand covers studies on circularity in the built environment and construction sectors, and the second strand covers studies on sustainability in facility services.

In the methodological framework (Figure 3) adopted by this study, the literature review and categorisation are the foundational elements. Categorisation pertains to specifying key facility service areas where this study seeks to generate useful insights into embedding circular strategies with a view to setting it apart from general considerations of sustainability matters in the facility service space. A scoping literature review and a systematic literature review are the two methods used for the literature review, and for the categorisation, this study uses qualitative content analysis. The scoping literature review is useful when there is a requirement to identify the main concepts and theories in the literature and downsize the relevant literature that may provide a comprehensive overview of topics under study and possibly seek relationships between topics [27,28]. The scoping literature review is followed by a systematic literature review, which is sometimes considered as an entailing method of the scoping literature review [29]. A meta-synthesis technique is used as part of the systematic review that interprets the findings from multiple qualitative research studies [30], as a systematic literature review method is useful if there are specific research questions, which this study has.

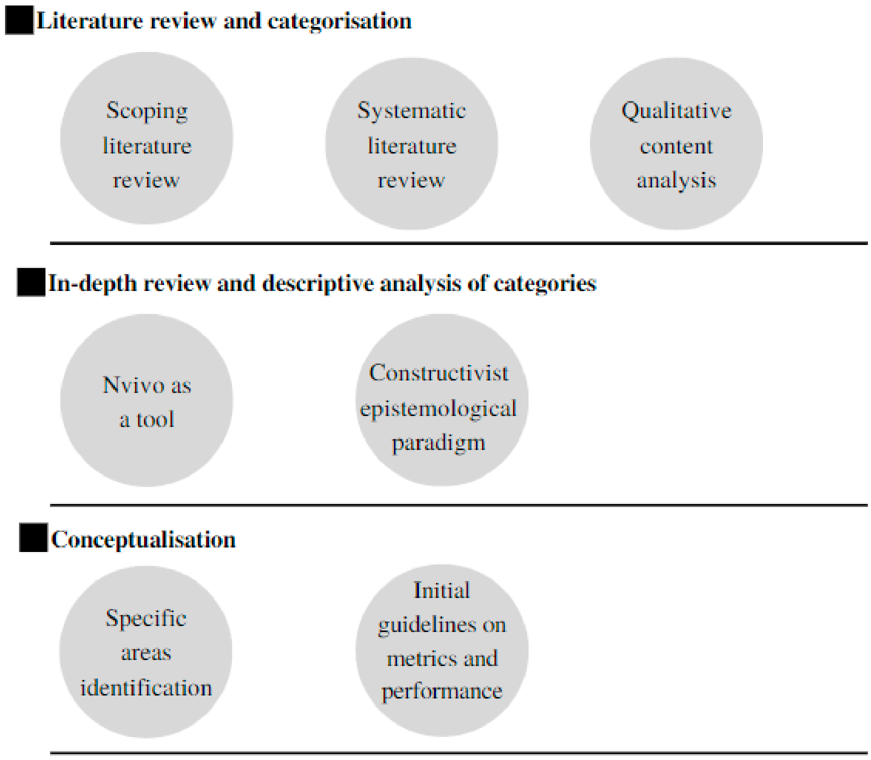

Figure 3. Methodological framework.

Qualitative content analysis is a methodological tool for conducting a structured literature review [31] and for enabling the coding of categories identified as part of the literature review. Qualitative content analysis is suitable for studies looking to analyse textual materials and unearthing the meaning of texts via coding and categorisation [32,33]. Owing to the extensive review nature of the systematic literature review process, qualitative content analysis and the categorisation, in particular, makes the review task less complicated and less time-consuming. Regarding the sources of relevant literature, this study prioritised published literature, such as academic research papers, conference proceedings, and books. White papers and other internet sources are also used but to a far less extent. Various keywords such as 'facility management', 'circular economy', 'buildings', 'built environment', 'recycling', 'sustainable procurement', 'end-of-life product', 'close loop supply chain', 'reverse logistics', etc. were used to find the relevant literature.

For an in-depth review and descriptive analysis of categories and subcategories, this study used NVivo as a tool for coding and the constructivist epistemological paradigm as an interpretative framework and the conceptualisation tool. The use of NVivo as a tool for coding categories and subcategories, allowing qualitative content analysis and in-depth review, is appropriate as NVivo has the ability to segregate qualitative data and information by sentence, paragraph, and string of texts [34]. Furthermore, NVivo enabled an understanding of interlinkage between categories. Whilst the coding and categories and the qualitative information spread across them are valuable resources to conceptualise an idea, there needs to be an interpretative framework upon which a construct on circularity in facility services is generated. Thus, this study employs a subjective interpretative process through the epistemologically constructivist lens to construct an idea of circularity in facility services. The construct (1) identifies a few areas as a starting point for facility service providers to consider circularity-oriented actions and (2) provides an evaluative framework as an initial guideline for the facility service providers to gauge the level of circularity incorporation in the delivery of facility services.

To apply the methodological framework (Figure 3), this paper uses a staged approach (refer to Figure 4). First, literature review methods are used for scoping circularity in facility services, which is the basis for categorisation and sub-categorisation. This paper has not used a systematic literature review to the extent of labelling it a review paper. The key reason is that there is very limited research conducted to elaborate on circularity in facility services, and therefore, this paper refers to other related strands of the literature (e.g., circularity in the built environment and general sustainability in facility management). Furthermore, qualitative content analysis is less compatible with a full systematic literature review.

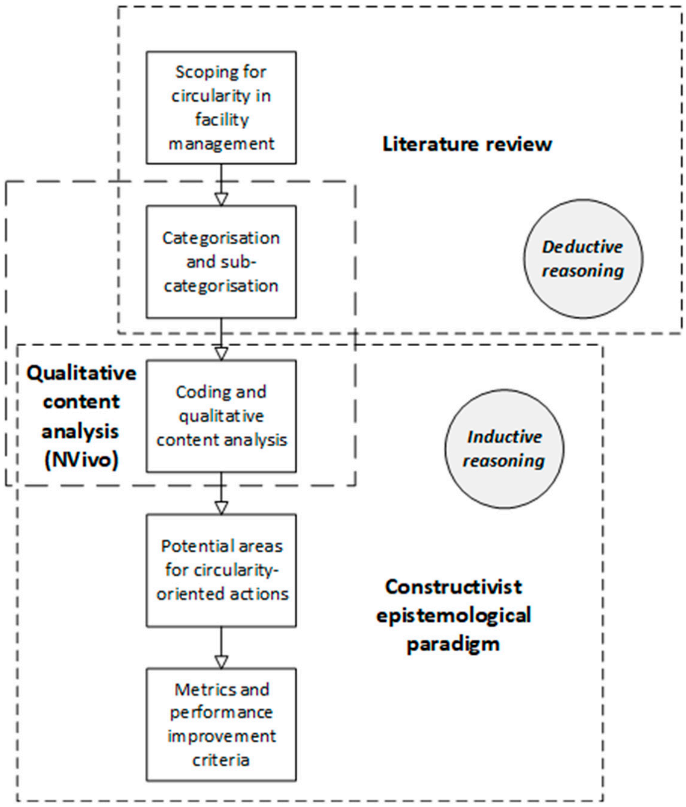

Figure 4. A staged approach to applying the methodological framework.

Second, the three scopes (procurement, building use/operations, and end-of-life management) are the primary nodes in the NVivo software. Section 4 provides a rationale for choosing the three scopes. Nonetheless, the three scopes result from deductive reasoning. The entailing step is further coding by using qualitative content analysis, which is a basis for creating sub-nodes and an analytical foundation. Thus, this step uses inductive reasoning with a limitation that only a few sub-areas within the core facility functions are added as sub-nodes. The inductive reasoning supports the analytical foundation. Finally, based on the textual data collected in various NVivo nodes (and sub-nodes), this paper builds a construct to conceptualise circularity in facility service. The metrics and performance improvement criteria correspond to the identified potential areas.

4. Scoping for Circularity in Facility Management and Analytical Foundation

Facility management is more relevant during building operations [35,36]. Thus, this section builds on the understanding that facility management is a crucial element of building operations—and also considers the welcome evolution of facility service from a standalone technical service to broader long-term management of buildings with additional support areas/services [37]. Additionally, considering the critical roles of procurement and end-of-life management of products and materials in building operations and their circularity linkage, this paper covers three distinct scopes where the circularity concept can be realised: (1) procurement, (2) use, and (3) end of life.

The critical role of procurement in facility management has been discussed extensively by previous researchers in the early to late 2000s [26,38–40]. In fact, procurement in facility management was considered strategic purchasing from the early 2000s [40]. Facility management functions can be embedded within the building operations phase in the building's life cycle. This paper frequently refers to the term 'Use' to refer to the building operation phase that also necessitates procurement and end-of-life products management functions, as facility services include building operation, maintenance, technical facility management, cleaning and waste management, etc. [14]. Furthermore, professional management and maintenance during building operations are core functions of facility managers, and the building operation phase is far lengthier in comparison to construction and decommission [10]. An increasing drive for embedding and improving sustainability whilst delivering facility services means that the end-of-life management of various physical products is captured under the waste management function of facility management [14,36,40]. The waste management function pertains to the end of life of various physical products and materials. Table 1 provides a description of each of the three scopes considered for envisioning circularity in the delivery of facility services.

Table 1. Description of scopes.

Scopes	Description
Procurement	relates to the supply chain and purchase of various physical products and materials necessary to operate buildings.
Use	relates to the use of various physical products and materials during building operations. This stage expends various physical products and materials and converts them from low-entropy resources to high-entropy waste.
End of life	relates to the end of life of various physical products and materials. The high-entropy waste is the target physical mass for driving circularity in delivering facility services.

Figure 5 depicts the possible material flow if we are to envision circularity in the delivery of facility services. The preventative and reactive maintenance works initiated by facility managers intend to extend the use phase of various physical products and materials. Thus, maintenance in facility management often contributes to enhancing the sustainability performance of buildings [41]. Maintenance is such a crucial aspect of facility management that moderately matured, and globally accepted computerised maintenance management systems (CMMS) were used as early as the late 1990s [42]. Computerised maintenance systems and facility managers can now leverage the power of data to optimise various facility management functions, including waste management [43]. Regardless of various maintenance-related platforms and tools at the disposal of facility managers, maintenance posits itself as a cog in the lean management framework by extending and retaining the value of various physical products and materials. Thus, maintenance alongside restoration and refurbishment of assets can be considered as acting to slow down the forward flow of materials across the building operation phase (referred to as 'Use').

Enabling the reverse logistic system can add to the effort of maintenance in slowing down the flow of materials headed towards landfills when the physical products and materials are labelled as waste at the end of their life. Reverse logistics pertains to logistics arrangements necessary to enable higher recycling and material recovery from physical products and materials at the end of their life [44]. Although the reverse logistics concept is tied strongly to supply chain management as a field of study, it has been increasingly discussed in the context of waste management, material recovery, and recycling [45]. Nonetheless, studies focusing on the interaction between supply chain management and sustainability (e.g., resource recovery and products' life extension) are prevalent [46,47].

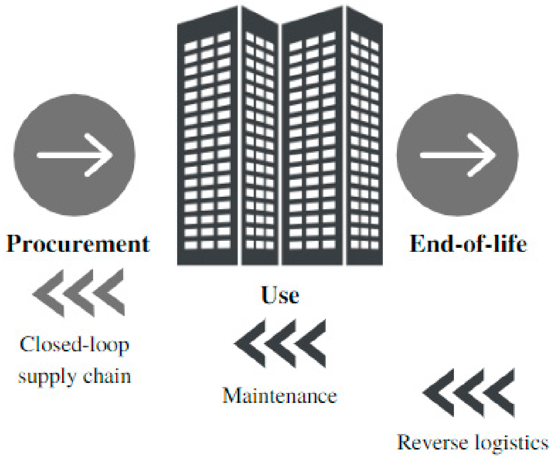

Figure 5. Forward and backward material flow across the three scopes.

While the role of maintenance and reverse logistics is explicit in the delivery of facility services, the role of procurement is implicit. First, procurement may be dominated by the subcontracting of soft services. Second, the notable quantum and range of hard goods (physical products) that are necessary for building operations could be procured by asset owners instead of by the facility services provider. Nevertheless, facility managers may influence the procurement and delivery of hard goods [48]. If this is the case, suffice it to say that any efforts facility managers put into practicing sustainable/responsible procurement contributes to circularity in facility management. Strategic purchasing [40] by facility managers can target products that have higher recycled content and are recyclable at the end of their life. Strategic purchasing considers organisational environmental goals whilst fostering cross-functional integration across various supply chain activities [49]. Strategic purchasing has also evolved considerably by incorporating domains such as socially responsible purchasing [50], green supply chains [51], and a closed-loop supply chain [52,53]. The closed-loop supply chain is based on the principle that there exist systems in place to support both forward and reverse material flows to assist resource recovery and value creation [52,54].

While the scoping for circularity identified procurement, building use, and end of life as parent categories to create an analytical foundation, the inductive reasoning and coding information from other related literature strands identified subcategories. Together, they create an analytical foundation necessary to elaborate on potential areas for circularity-oriented actions. The subcategories across three scopes are listed as actions, and decision gateways are added to explore performance improvement criteria if decisions are to be made to integrate and deliver actions alongside the facility service delivery (Figure 6). The identified actions were recorded as they commonly occurred in the relevant literature and were processed through NVivo as part of the qualitative content analysis.

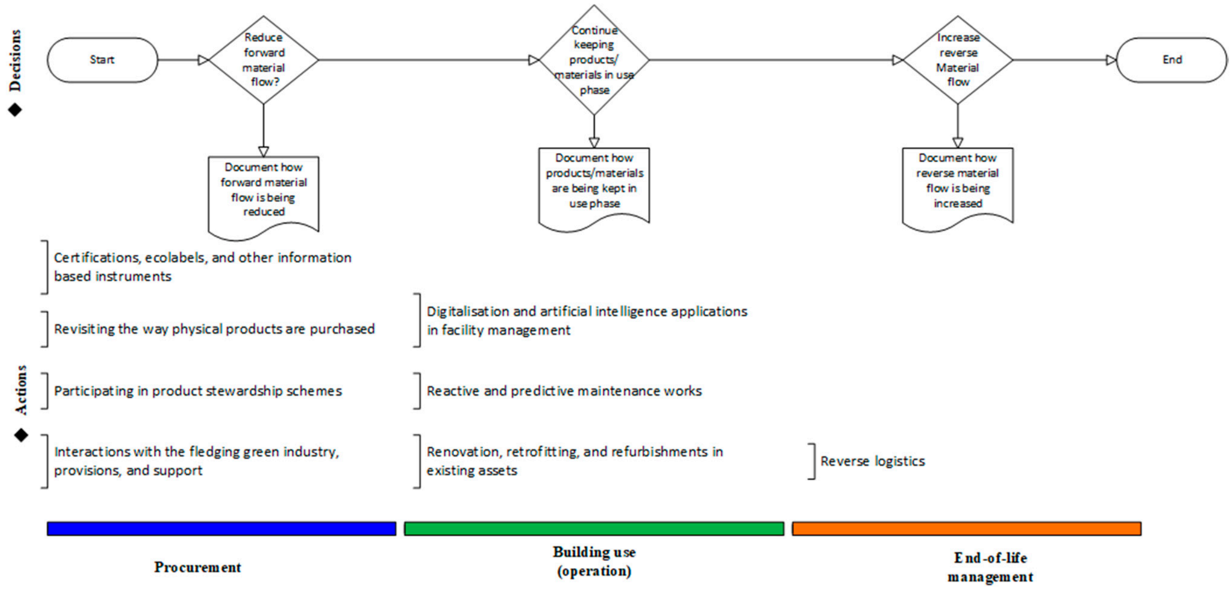

Figure 6. Actions–decisions chart creating an analytical foundation.

5. Potential Areas for Circularity-Oriented Actions—Integration with the Core Facility Functions

5.1. Procurement and Closed-Looped Supply Chain

The narratives around strategic purchasing, the sustainable/responsible supply chain, the green supply chain, and the closed-loop supply chain mean that the concept of procurement of goods and services and the supply chain, in general, are noticed through the sustainability lens. The attention can be attributed to the need to minimise externalities to help close material loops by reducing the waste quantity and reducing the cost of operations. There are two parallel concepts around the procurement of products and services—sustainable procurement and circular procurement. While both are similar in terms of their conceptual underpinning and are also used interchangeably by research scholars, circular procurement focuses more on closing energy and material loops within the supply chain, whereas sustainable procurement has an additional focus on responsible sourcing [55–58]. This paper takes both concepts into account to discuss how procurement of goods and services and the closed-loop supply chain, in particular, can enable circular facility management. Considering the nuances in the theoretical foundations in the definitions of circular procurement and sustainable procurement, a closed-loop supply chain is desired as it promotes strategic purchasing, targeting reduced forward material flow and more reverse material flow (Figure 5).

The closed-loop supply chain concept argues for the reverse material flow alongside the regular forward flow and has more players compared to the traditional supply chain [59]. This argument fits into the conceptualisation of circular facility management despite the limitation of the closed-loop supply chain concept in sufficiently addressing the value activities of fast-moving consumer goods [60]. It is normal for facility service providers to come across fast-moving consumer goods such as cleaning products, toiletries, catering, and office supplies, to name a few. However, technical products and materials (e.g., building materials, furniture, electrical, mechanical, and water-using equipment) are more relevant to this study, considering their materiality factors. Furthermore, this study presents a closed-loop supply chain as a broader concept to highlight procurement and strategic purchasing, as the concept is viewed as important to enabling a reverse flow, meaning an obvious connection to reverse logistics [61]. Thus, this study limits the closed-loop supply-chain-related discussions within the strategic purchasing and the reverse logistics linkage. Based on the available literature, this section discusses the fourfold approach to strategic purchasing and the closed-loop supply chain that facility service providers can leverage to enable circularity.

5.1.1. Certifications, Eco-Labels, and Other Information-Based Instruments

Although studies [62,63] provide a comprehensive literature review on the role of eco-labels in a circular economy, this study specifically focuses on the discussion around facility management. Eco-labelling, one of various product labelling schemes, is an information-based tool supporting sustainable consumption and production by providing guidance on the environmental impact associated with the use of the product [64]. Although initially criticised for information overloading and editing the choice of consumers by the government, manufacturers, and retailers, it is now widely applied across various product sectors, including office buildings and consumer electronics [63]. Its contribution towards enabling the circular economy has been studied [62,65] to find the following important features: (1) they contribute to extending the products' use duration (i.e., extending the service time); (2) they can contribute to enhancing the environmental performance of products as the use of hazardous substances in products is limited, thus improving the recyclability; (3) eco-label criteria such as products' durability, repairability, and upgradability are applicable to many eligible products; and (4) they are considered as easily made changes in the production practices, although the environmental improvements may also be small.

Many building certification schemes and green public procurement policies encourage the use of environmental product declarations (EPDs) [66–68]. The consideration of the life-cycle impacts of building materials and products is an important feature of EPDs that can also inform the embodied carbon and material contents. Although the EPDs are voluntary, the extensive quantitative and verified information forms the basis for decision-making regarding the environmental performance of building materials and products. While it does assist in making better material and product choices considering the environmental performance across the procurement, use, and end-of-life stages, it opens up opportunities for instruments like material passports and digital product passports to enable a circular economy [69,70]. Material passports and digital product passports are relatively less prevalent in comparison to EPDs.

5.1.2. Revisiting the Way Physical Products Are Purchased

Some closed-loop supply-chain-related literature has pointed out the need to shift focus from ownership to access and change in purchase models such as product-service systems [60,71]. From the products' suppliers' perspective, product service systems (PSS) focus on selling services and performance instead of physical products and are identified as one of many circular economy enablers [72,73]. In fact, one of the key features of enabling circularity is the servitisation of an economy through long-lasting maintenance, repairs, and recycling [74]. The broader maintenance element of facility service incorporates different types of maintenance (e.g., reactive and preventative), repairs, and recycling, too, as a part of managing maintenance-related waste.

From the facility service provider's perspective, if the goal is to reduce the forward flow of materials, then PSS can not only achieve this goal but also significantly reduce the maintenance responsibility and end-of-life management of waste products. The downside, however, is the financial risk to the facility service providers as they generate a certain fraction of the total revenue from maintenance and end-of-life management. The downside is both visible and perceivable if there is an individual organisation perspective. If we are to use a broader perspective, considering the entire industrial ecosystem and a novel network of product and service providers, the downside may not be too daunting to facility service providers who rely on generating revenue from self-delivery of maintenance and product end-of-life management works [75,76]. For example, many large-facility service providers subcontract critical facility activities like cleaning, catering, and refurbishments. It is an opportune environment to create novel and collaborative business models with subcontractors to manage them on the client's behalf and with pay based on their services instead of the products they deliver. It may be reasonable to say that it is already standard practice for many facility service providers, especially for cleaning and catering subcontracting. Likewise, on the maintenance front, facility service providers can prefer preventive maintenance service purchasing instead of reactive maintenance service purchasing from subcontractors on the client's behalf. In fact, preventive maintenance is identified not only as a PSS enabler of resource reduction but also as alleviating the challenges of PSS provision [73,74,77]. Additionally, facility service providers have choices to leverage result-oriented PSS instead of product-oriented. Result-oriented PSS, such as activity management, per-day service unit, and functional result, are known to generate value in the service content [74].

5.1.3. Participating in Product Stewardship Schemes as a Large-Scale Consumer

Product stewardship schemes enable various consumer goods manufacturers to extend their responsibilities beyond just manufacturing to broaden the focus on other benefits in addition to economic benefits, such as environmental and social benefits [78]. Unlike extended producer responsibility, product stewardship schemes involve non-manufacturers and, more importantly, consumers as among the many key participants. Facility services providers can be considered large-scale consumers because of the range and extent of consumer goods they buy and use on the asset owner's behalf. Thus, by default, the onus is on the facility services provider to effectively manage various consumer goods when they are labelled as end-of-life physical products. In addition, considering that product stewardship has evolved from having an early focus on hazardous management to a much broader focus on resource conservation and recycling [79], participation in product stewardship schemes will assist facility service providers in kickstarting any circular initiatives. For example, in Australia, there is a product stewardship scheme called 'FluoroCycle' that intends to recover mercury and other materials such as glass and aluminium as many building owners transition from legacy luminaires (e.g., fluoro tubes and globes) to energy-efficient luminaries (e.g., LED lights). The lighting upgrades can be a part of the regular maintenance work that facility service providers come across. Thus, facility service providers managing multiple assets and buildings have an option as large-scale consumers of lighting products if they are to participate in product stewardship schemes such as FluoroCycle.

Product stewardship grew as a dominant business model for recycling if we are to consider a broader waste-management industry [80]. Thus, it may be reasonable to say that product stewardship schemes have created a bridge for physical flows of materials between consumer goods' production and consumption spaces. The anticipated physical flow is in the backward direction from consumption space to production space as the product stewardship goal is to minimise materials ending up in the external environment [81]. An Australian example is the Paintback scheme, which is an industry-led product stewardship scheme that takes unwanted paint and packaging and disposes of it responsibly. While the facility service providers are responsible for the waste and end-of-life management of various physical products, most of them may be subcontracting because of the extent of the purchase and the waste and end-of-life products buildings/facility generate. For example, lighting upgrades (LED lights) and painting services are sourced via third-party service providers. In these circumstances, facility service providers are better off stipulating the product stewardship requirement right at the onset during the service purchase so that facility service providers participate in schemes via subcontractors.

5.1.4. Interactions with the Fledging Green Industry, Provisions, and Support

The United Nations Environment Program (UNEP) states that green industries develop and sell products, solutions, and technologies that reduce carbon emissions and pollution and improve energy and overall resource efficiency [82]. Thus, the green industry has been defined in the context of envisioning the shift from unsustainable production and consumption towards sustainable and resource-efficient production–consumption systems. While there have been significant debates and discussions about identifying the best possible pathways for green industry development [83], it would be reasonable to point out the evolutionary nature of the green industry. The concurrent sustainability challenges and fast-paced innovations driven by various market actors make the green industry dynamic, and it is characterised by incremental to radical changes on a regular basis. The end-users' requirements for green facility management [84] put facility service providers in a situation where they are constantly seeking solutions and innovations that the green industry is driving. Another driver for seeking interaction with the green industry is the creation of a high return on value for owners and other stakeholders [85]. Improving corporate image and the organisational ethos are also areas of motivation for facility managers to seek participation in the green movement [86]. Amidst various motivation areas and drivers, consideration of sustainability in building operations can still be a secondary priority for facility service providers, meaning they will have relatively less time and resources compared to delivering core facility services. This creates an appropriate environment for facility managers to explore provisions in the market with fledging green industry actors.

The interaction is bi-directional from the facility service providers' point of view. First, facility service providers leverage the green industry provisions to deliver sustainability services, including circular initiatives. Second, they support the circular-economy-focused green industry by creating various business opportunities for them. In both types of relationships, strategic purchasing has a key role. For example, the performance-based and service-oriented procurement and criteria concerning the reuse and recycling attributes of physical goods promote a circular economy [87]. The performance-based and service-oriented businesses are part of the fledging green industry, although the PSS and integrated product service offering concepts have some history. Shared value is another key advantage of promoting a circular-economy-focused green industry [88]. On the one hand, facility service providers are better off leveraging the innovation and solutions the green industry keeps generating. On the other hand, the innovative business models many green industry participants come up with receive support from facility service providers. However, there is a caveat in the interaction with green industry participants. For example, although the green industry may offer innovative business models and solutions, facility service providers may end up in a situation that does not reduce the forward flow of materials and decrease the backward flow of physical materials. The reason is that many fledging green industry business models and innovative solutions may still look to generate revenue by selling physical products. Thus, it is up to the facility service providers to gauge the value proposition in a way that emphasises circularity.

5.2. Building Use and Maintenance

While there has been significant research conducted to understand the circular economy application in buildings and their operations [89,90], there has been limited focus on the circular-economy–maintenance nexus. Initially, the circular economy research in the built environment focused on macro-scale (e.g., eco-parks) and micro-scale, such as the individual products and materials used in building operations [91]. Furthermore, the construction aspect of the built environment is a preferred area for researchers focusing on circular economy in the built environment. Building maintenance received attention for its focus on ensuring the best condition of assets for as long as possible [92], which is one of the essential conditions for achieving a circular economy. Building maintenance is a deeply ingrained element in facility service-related narratives and business value propositions. Thus, this subsection elucidates the role of maintenance and refurbishments in enabling circularity in the delivery of facility service. First, this paper highlights the digital applications in facility management as various digital techniques are increasingly used in envisioning smart facility management [93], especially focusing on the better performance of maintenance works. Second, this paper talks about reactive and preventative maintenance works, as some studies [4,94,95] have pointed out their importance and the comparative share of two maintenance techniques in enabling circularity in building operations. Third, the subsection highlights the refurbishment and restoration of existing buildings and assets as an area with circularity potential in building operations, as these are often labelled as additional elements to regular maintenance works, although put in different service categories [96].

5.2.1. Digitalisation and Artificial Intelligence Applications in Facility Management

Digital applications in facility management are increasingly considered as revolutionising the facility management industry in countries such as Australia and the UK. However, the facility management industry has the fewest implementation examples, specifically in the retrofitting and refurbishment areas of facility management [97]. Digital applications are focused more on the design and construction stages largely because of the advancements in building information modelling (BIM), reality capture technologies such as 3D scanning, the internet of things (IoT), and the geographical information system [98]. Nonetheless, one of the most preferred digital technologies in facility management, BIM, has offered benefits in retrofit planning for existing assets [99] and developing preventative maintenance plans [100]. Likewise, IoT technologies (e.g., RFID) have also enabled the capture of critical building maintenance information and building performance monitoring [101]. These emerging digital trends targeting extending the assets' use cycle length can be a circular economy value diver.

Mechanical, electrical, and plumbing (MEP) engineering applications are regular in facility service delivery. The MEP subsystems and the underlying complexities in handling MEP components' maintenance works make it challenging for facility technicians [102]. Ref. [103] conducted research to identify if artificial intelligence and its sub-fields can be used to assist facility service providers in overcoming the challenges in relation to coming up with an effective and rapid means to maintain MEP assets in a proactive manner. The main finding was that artificial intelligence applications (e.g., deep learning and neural networks) have the potential to assist facility service providers in reducing the assets' maintenance and upgrade costs alongside cost-effective operation. Refs. [93,104] echo the need to employ artificial intelligence and digital technologies to facilitate predictive maintenance in lieu of reactive maintenance. Of various facility management areas, heating, ventilation, and air conditioning (HVAC) and MEP components, in general, have received more attention regarding artificial intelligence applications with two main purposes. The first is the optimal energy performance leveraging various data and information via sensors and other means. The second is specifically focused on the predictive maintenance of MEP components, as highlighted by [41,105]. A simultaneous application of BIM and IoT in selected case studies identified the potential to have a strong and data-driven predictive maintenance framework for facilities [105], meaning an increased lifetime of MEP components and assets. These micro-level interventions within the buildings contribute to realising circularity in the facility service delivery.

In discussions around digitalising assets, there is an emphasis on the application of material passports (MP), as it can greatly assist facility managers in understanding the circular potential of materials [106]. Likewise, a digital product passport (DPP) is another tool that is envisioned to operate within the digital assets realm and has the potential to contribute towards achieving a circular economy [107]. While the concepts of MP and DPP are somewhat similar and are also used interchangeably, MP is discussed more in the context of the building sector [70]. The conceptual underpinning of both MP and DPP is based on the premise that better data and information recording of products and materials across their entire value chain will assist different actors in decision-making regarding circularity and sustainability. A rapid review of some papers [4,108,109] confirms that there exist conceptual nuances between MP and DPP. MP is focused more on construction materials and the building sector, whereas DPP involves a range of products, such as consumer goods [70]. For example, the EU has recently introduced a battery passport that pertains to DPP. Likewise, a dedicated platform created specifically to enable MP [106] has a strong focus on construction materials. Regardless of the conceptual similarities and differences, MP and DPP are a one-stop shop for different actors to access the circular economy potential of various products and materials as they digitalise assets' data and information. Thus, from the facility service providers' point of view, there is a resource and library available for them to make conscious decision-making as to how various assets' information via digital platforms such as MP and DPP can be leveraged to enable a transition towards circularity in facility management practices.

5.2.2. Reactive and Predictive Maintenance Works

Reactive and predictive maintenance works are commonplace in the delivery of facility services. Of the two prevalent maintenance types, many commercial and private clients prefer predictive maintenance over reactive maintenance, as the facility services industry has evolved considerably towards using a proactive approach [110]. Additionally, maintenance was initially viewed as one of many facility management functions. However, it is now considered a strategic matter in facility management practices [111]. The shift in the way maintenance is viewed in the context of facility service has a twofold circularity significance. First, as most researchers and practitioners agree, more predictive maintenance implies increased life of assets. Second, maintenance as a strategic issue means that it is not only considered a standalone activity/function that facility managers are required to deliver. There are performance criteria, cost considerations, and additional perspectives, such as how we leverage maintenance in the delivery of facility services that includes sustainability services. Thus, there is a circularity element in maintenance works despite the general understanding that the sustainability narrative ingrained within facility services is more inclined towards energy and water management [112].

While we know that maintenance works have a clear circularity advantage, the main question is if circularity can be one of the main objectives instead of being presented as an add-on feature in the sustainability discourse within the facility services. Ref. [112] suggests that actions aimed towards reducing energy and water consumption in buildings may enable a circular economy. The argument builds on the theoretical foundation of resource efficiency and circular economy, both of which emphasise reducing resource consumption. If we are to argue based on a similar premise, this paper identifies two main areas of maintenance works that may assist facility service providers in enabling a circular economy. The first is maintenance work targeting reduced passage of physical material from the use phase to the end-of-life phase and material recovery from end-of-life products and materials. This fits into the definition of maintenance, which is an activity targeted to retain and restore a functional unit in a specified state in which it can perform the required functions [113]. The second is maintenance work targeting reduced resource consumption, such as energy and water, via soft maintenance techniques (e.g., system optimisation). Maintenance is increasingly considered a more luring way to enable circularity and adopt sustainability practices in general [113], as restoration and refurbishment are relatively more finance intensive compared to maintenance. Furthermore, the restoration and refurbishments generate more waste, entailing additional waste management costs.

5.2.3. Renovation, Retrofitting, and Refurbishments in Existing Assets

While the terms renovation and refurbishment are used alternatively to refer to the building envelope, structural upgrades, and spatial layout changes, retrofitting is focused more on improving the building's environmental systems, including MEP components [114,115]. However, refurbishments can also be initiated with a view to improving the environmental performance of buildings [116]. As this paper intends to promote circularity applications in existing building stocks, having a proper refurbishment strategy can assist during the paradigm shift from linear thinking towards circular thinking. Refurbishment strategies are imperative for realising circularity in the existing building stock, as refurbishment occurs when parts of the building do not sufficiently meet the occupants' needs [117]. Most facility service providers operate within the realm of existing building stocks, and refurbishment is an important topic in facility management [96]. In fact, refurbishment strategies and actions are sometimes considered as essential elements of preventive maintenance, which is the preferred maintenance type. Many BIM applications in facility management focus on both refurbishments and maintenance, and on retrofitting too, with a view to improving the sustainability performance of buildings, including resource efficiency and waste management [114].

The renovation, retrofitting, and refurbishment imperative in the facility services discourse creates a strong emphasis on existing building stock's sustainability performance, mostly energy and water efficiency, as there is a cost-saving advantage. The physical waste associated with building fit-outs, strip-outs, and clean-ups that comes under one of the umbrella terms, such as renovation, retrofitting, and refurbishment, has remained a relatively less researched area [118]. In Australia, office fit-out waste contributes significantly to unsustainable landfilling [119]. This is where circularity can be materialised by facility service providers, as most of them also deliver renovation, retrofitting, and refurbishment projects in client buildings. For building retrofit and refurbishment projects, [120] proposed some practical solutions, such as employing a reusable and adaptable fit-out design, integrative planning for retrofit works and waste management, and waste benchmarking for retrofit and refurbishment projects. The suggestions were made after understanding that 'organisational commitment' remained the most fundamental issue. While the organisational commitment by building owners and commercial clients will likely pose challenges, the facility service providers are positioned to create an integrative retrofit/refurbishment project package, including waste management. The reactive maintenance and other maintenance types, too, that form a crux of facility services delivery to clients include waste management as one key facility management function [111]. Thus, an integrative project package is an apt solution in the context of facility service delivery. Furthermore, as facility service providers deliver a range of integrative retrofit/refurbishment projects, they will be able to benchmark the waste performance of retrofit/refurbishment projects, meaning more information to make a critical decision and gauge progress regarding circularity in facility services delivery.

5.3. Products' End-of-Life Management and Reverse Logistics

End-of-life management of products, and especially the strategies to retain their value, such as via repair, reconditioning, and material recovery, are fundamental elements of the circular economy [121]. Product recovery management, in particular, is increasingly considered as an important step towards transitioning to a circular economy [122]. Product recovery management refers to a management approach intended to close the loop in a product's life cycle. Thus, it creates a framework to effectively manage discarded products in a way that economic and ecological values are generated [123]. While it is a product end-of-life management technique, there are various nonmanagement methods, such as remanufacturing, repair, reconditioning, refurbishing, recycling, recovery, etc. [124]. These nonmanagement methods can be a part of an overarching product recovery management approach.

On the one hand, there is an overarching approach, and on the other hand, there are various methods together with a multitude of perspectives and facets, such as economic, environmental, business, technical, and market [125]. The different perspectives will impact the way facility service providers approach the end-of-life management of products, such as the extent and range of products and materials targeted. However, one common aspect in realising circularity across prioritised products and waste streams will be to enable reverse logistics, and this is where facility service providers can intervene strategically together with various market actors. Reverse logistics work in many steps, including collection, inspection, separation, reprocessing, and distribution [126]. Thus, with improved circularity as one of their main waste-management-related goals, facility service providers may be inclined to assist downstream service suppliers in strengthening the necessary waste infrastructure and assets and the collection process in general.

The importance of understanding the reverse logistics–waste-management nexus is widely acknowledged, as some studies [127–129] on waste management highlight the way they complement each other. Thus, the general perception that reverse logistics is mostly tied to the concept of supply chain management has somewhat changed, and its application in waste management is increasingly recognised. For facility service providers who emphasise improved circularity, there are threefold advantages for them to work at the interface between client facilities and downstream market actors whilst ensuring most end-of-life products leverage reverse logistics mechanisms. First, the elements of reverse logistics, such as end-of-life product collection, separation, and reprocessing, overlap with circular-economy-related and -enabling concepts, such as recycling, reuse, refurbishing, repair, and waste disposal [126,130]. Second, facility service providers bridge the collaborative platform between their commercial clients and downstream market actors. The commercial clients incur the cost of recycling, and the downstream market actors, such as the recycling facilities, receive end-of-life products from the reverse flow. In the reverse logistic system, collaboration among stakeholders is key to overcoming the challenges of achieving reverse flow [131]. There are primarily three stakeholders in reverse logistics: returners, receivers, and collectors. While the facility service providers assist returners such as their commercial clients, receivers (e.g., recycling companies) and collectors initiate the reverse for end-of-life product management (e.g., repair, recovery, recycling, etc.). Third, facility service providers will have an understanding of the facility-level waste infrastructure and assets necessary for creating a practical working relationship with downstream market actors to organise the reverse flow of end-of-life products—for example, appropriate bins, collection points, and collection intervals.

Considering the logistical function, such as collection via downstream market actors (e.g., waste collectors and recycling companies), it may be reasonable to say that facility service providers will have a major role to play in reverse logistics. Thus, building on the typology of logistical function discussed by [132], the following five activities are of primary interest to facility service providers if end-of-life product management and reverse logistics are to be put at the centre of circularity-related goals. The first is creating a list of common products and materials that appear in most maintenance works (e.g., MEP components, fast-moving consumer goods, and individual products/assets). The second, regardless of whether or not there exists a product stewardship scheme, is mapping downstream market actors and assessing the existing facility-level waste infrastructure and assets. While the second activity is relevant if there is a single facility, there may be a need to optimise collection and transportation in case of multiple facilities across a geographical scale, and this should be worked out with the downstream market actors. The third is conducting a waste infrastructure and asset-needs assessment. The fourth is understanding from downstream market actors the level of recovery they may be able to undertake from the end-of-life products—for example, full product recovery (repair and reuse), component recovery (remanufacturing), and material recovery (recycling). The final one is benchmarking the circularity of various products and material categories as more data and information are available from the downstream market actors.

6. Metrics and Performance-Improvement Criteria Relevant to the Facility Service Providers

There are several indicators used to measure circularity, and many of them are still underdeveloped [133], meaning they will continue to evolve over time. The existing metrics and indicators intend to measure circularity at various levels, such as from the individual product level to the local/regional scale. This study is about circularity in facility services—the literature on which is relatively less developed—compared to the literature on circularity performance of the built environment and construction sectors. Furthermore, this study limits itself by setting a boundary that encompasses buildings and discusses circularity metrics and indicators relating to (1) procurement necessary to operate buildings, (2) building operation (use), and (3) end-of-life product management. Section 4 has already provided a rationale for scoping, considering the facility service providers' remit revolves around products and materials handling across the three scopes.

Even at a building level, circularity measurement can be based on two methods: index based and parameter based [134]. While the parameter-based method can look at a few specific attributes (e.g., material flow, energy flow, land use, etc.), the index-based method can use multiple indicators at once to look at multiple attributes. The prevalence of circularity indicators at a company level was also reviewed and discussed by [135] by using managers' and decision-makers' perspectives. The indicators under discussion looked at various aspects of product use, from procurement to end-of-life management. There is also a performance indicator looking specifically at recycling, i.e., end-of-life management [136,137]. In fact, most existing indicators look at the micro level (e.g., products), and material flow analysis has been the preferred circularity performance measurement tool. The product-level circularity metric has used both environmental and economic attributes, such as the economic value generated from recycling/material recovery and the environmental value in terms of the quantity of materials recycled/recovered [136–138]. This way of product-level circularity measurement applies to the range of products, including building materials and MEP components.

While most metrics emphasise the measurement of both forward and reverse material flow, this study introduces a few indicators that may assist in monitoring and measuring the slowing of the forward material flow and the improved reverse material flow. Table 2 shows the metrics and performance improvement criteria across the three areas. The metrics are different to commonly used circular metrics related to the built environment and construction sectors. It is different because this study has attempted to highlight facility service functions and facility service providers' remit, although they operate within the realm of the broader built environment sector. Nonetheless, the built-environment-related metrics can be used where possible by facility service providers, as facility service is a service embedded in the operation of the built environment. Table 2 is considered to be an initial guide for facility service providers to improve their circularity performance, and as more circular actions are initiated, it has to evolve in line with developments in the circularity measurement framework in the built environment. The metrics and the performance improvement criteria have not been tested in detail, mainly because it is not the main aim of the study. However, considering the conceptual rigour required to underpin the contents of Table 2, we take a hypothetical example of managing the lighting system as part of the facility management function. Lighting is one of the important facility service areas under electrical services.

Table 2. Circularity metrics and performance improvement criteria relevant to facility services.

	Metrics and Indicators	**Performance Improvement Criteria**
1	Procurement	Promoting a closed-loop supply chain and reduced forward material flow from the value chain's front-end
1.1	Number of product categories purchased with eco-labels and similar certifications	Increasing the range of products with eco-labels and similar certifications
1.2	Number of product categories transitioned into using a service-based approach	Increasing the share of services purchased in the total purchase of goods and services, i.e., using more product-as-a-service (PAAS) models
1.3	Number of product categories in use with well-functioning product stewardship schemes	Increasing the use of any currently operational product stewardship schemes for various product categories
1.4	Number of recycling companies involved and product categories	Increasing the purchase of recycling services and across an increased range of products

Table 2. *Cont.*

	Metrics and Indicators	Performance Improvement Criteria
2	Building operations and maintenance	Extending products/materials lifecycle
2.1	Number of artificial intelligence and digital assets applications and product/component categories covered	Increasing the range of assets, products, components, and material categories that leverage digitalisation
2.2	The ratio of predictive to reactive maintenance works	Increasing the ratio of predictive to reactive maintenance works, especially for MEPs and their components
2.3	Number of renovation and refurbishment projects 2.3 (a) quantity of waste generated for each material category 2.3 (b) recycling/recovery/landfill ratio of waste for each material category	Increasing the number of renovation and refurbishment projects, reducing the quantity of waste via component reuse, repurpose etc. and decreasing the share of waste across various waste streams/material categories ending up in landfills
3	End-of-life	Promoting the reverse material flow of products/materials from the value chain's back-end
3.1	Number of waste assets and infrastructure added for different waste streams/material categories	Increasing the number of waste assets and infrastructures necessary to enable reverse material flow for various product/material categories
3.2	Number of individual product/material categories diverted from landfills and the associated waste	Increasing the number of waste streams and product/component/material categories that are diverted from landfills and increasing the diversion quantities of associated waste
3.3	Provision of reverse logistics mechanism and product/material categories covered	Increasing the range of waste streams and/or product/component/material categories that have a functional reverse logistic mechanism

In the procurement space, facility service providers can consider purchasing lighting products with eco-labels or similar certifications. The energy star rating for lighting products (incandescent, CFL, and LED) is common across many countries that do not only look at the lighting efficiency but also at the quality aspect, meaning durable lighting products (Table 2, 1.1). Second, facility service providers can test the use of lighting as a service instead of buying lighting products if reducing material consumption is a priority (Table 2, 1.2). Third, there may be an operational product stewardship scheme designed specifically for lighting products, such as 'FluoroCycle' in Australia. As the lighting system may see a massive overhaul because of LED upgrades, using a dedicated product stewardship scheme like FluoroCycle will assist facility service providers in improving their recycling/material recovery goals (Table 2, 1.3). Finally, there could be only a small number of service suppliers in terms of lighting waste recycling, thus limiting access to them in the market. Thus, the goal is to create a two-way relationship with them to continue using them where possible, which will also strengthen the capacity of the key market actors to be able to provide uninterrupted lighting waste recycling services in the future (Table 2, 1.4).

In the building operation and maintenance space, when we talk about digitalisation, lighting products are probably the most talked-about topic, particularly in relation to IoT sensors and intelligent assets. Thus, it is about transitioning to using intelligent lighting assets, and when there is a provision of a digital product passport for lighting products, facility service providers are to leverage the resources and opportunity (Table 2, 2.1). While most lighting works are reactive, there are also planned and predictive works intended to improve the performance and durability of the lighting system. It is expected that the facility service providers keep records in the computerised maintenance system to track and calculate the ratio of predictive to reactive work orders related to the lighting system (Table 2, 2.2). Renovation and refurbishments are normally undertaken to improve buildings' life cycles, meaning fewer building materials end up in landfills. Contrary to the common understanding that renovations and refurbishments avoid building material waste, some is still generated from fit-outs and strip-out work, which are familiar to facility service providers. Some lighting works are also part of fit-outs, meaning some lighting waste as the new ones will replace the older ones. Here, the facility service providers are expected to reduce the quantity of lighting waste alongside other fit-out waste ending up in landfills. Lighting waste and the component materials, such as glass, mercury, aluminium, etc., are quantifiable (Table 2, 2.3).

On the end-of-life product management space, while we generalise the waste assets and infrastructure, some waste streams, such as the lighting waste, may need dedicated waste assets as they cannot be serviced via waste assets and infrastructures targeting common waste streams. In Australia, lighting-waste recycling companies provide separate bins and boxes to store lighting waste until collection (Table 2, 3.1). This paper talks about lighting products as a hypothetical example. However, it can be replicated across other product/material categories (Table 2, 3.2). Finally, having an appropriate reverse logistic mechanism in place is useful for facility service providers. In the case of lighting waste, when we are talking about improving the reverse flow of lighting waste, appropriate waste assets and infrastructure (e.g., lighting-waste bins/boxes), waste collector and recycling companies (e.g., lighting waste handlers), client's commitment and clear recycling/recovery targets (e.g., lighting waste as a critical waste issue), and well-defined roles for each actor are of importance (Table 2, 3.3). Obviously, there are other steps and underlying processes to enable reverse logistics, such as repair, reuse, and remanufacturing. However, these are less relevant to the hypothetical example under discussion.

7. Carbon Dividend as an Added Benefit

The carbon dividend from recycling materials is increasingly emphasised by research papers exploring the circular economy and emissions reduction linkage and narratives [139]. Previously, operational emissions received more attention compared to embodied carbon because operational emissions contributed to the major share of buildings' life cycle emissions [140]. Embodied emissions are of special interest when we talk about carbon dividends from circular interventions, as slowing the forward material flow and improving the reverse material flow, in general, will contribute to reductions in embodied emissions. Embodied emissions are associated with the extraction of resources and their processing, and they are challenging to reduce once they get into the building stock. Material contributes to approximately 50% of the buildings' and infrastructure's carbon footprint, and almost 40% of it relates to the production of materials [141]. Furthermore, in a rapidly decarbonising electricity grid that supplies electricity to buildings, the share of embodied carbon will continue to increase in buildings' life cycle carbon emission [142]. Thus, embodied carbon reduction is also identified as one of the important value drivers for the circular economy [143].

Sections 5 and 6 showed areas within the facility services where facility service providers can promote reducing forward material flow and improving the reverse material flow. The performance improvement criteria (Table 2) provided further insights into realising and gauging circularity in the delivery of facility services. While the discussions revolved mainly around materials circularity, facility service providers can also promote carbon dividends from recycling materials as an added advantage to adopting circular strategies in the delivery of facility services. A study by [143] shows areas within the whole of a building's life cycle where embodied carbon reduction opportunities can be explored—the approach and the scope: for example, the cradle-to-end-use approach, scope including use and end of life, and specific areas such as maintenance and refurbishments. Research by [144] presents embodied carbon as a long-term impact calling for considerations to address the issues right from the design phase. While the facility service providers may have the least influence in the design phase, they will have more influence to reduce embodied emissions during the use and end-of-life phases and in specific areas such as maintenance and refurbishment. In the procurement of various products and materials, as they are necessary for numerous maintenance and refurbishment works, tools like EPDs can assist in reducing embodied emissions that contribute to the total carbon stock of the building. The use of EPDs via better procurement decisions generates carbon dividends to a relatively lesser extent compared to that from recycling and material recovery, as most building materials with high embodied emissions (e.g., concrete, metals, wood, and plastics) can be recycled with high efficiency [145]. Likewise, various consumer products and MEP components have embedded carbon that can be reduced via a complete product recycling/recovery or of the problematic parts that contribute most to the total embedded carbon [146]. Reuse of components, recycling, and material choice (e.g., via EPDs) are considered effective material efficiency strategies targeting buildings, vehicles, and electronic products [141].

While the facility service providers can contribute to enabling circularity across various product categories and building materials, and these generate carbon dividends, the question remains as to how the carbon dividends are accounted for and possibly reported to the clients. A study by [147] reviewed methods to calculate embodied-carbon-related buildings, which shed light on the frequent use of tools like life-cycle analysis (LCA). In fact, LCA is presented as a mainstream method for the calculation of embodied carbon in buildings [148]. LCA can be a time- and resource-demanding tool, especially if the sustainability service is integrated thinly with the delivery of facility services. As an initial step, the use of EPDs can provide insights into understanding how carbon dividends are being created with better material choices. Additionally, references to credible databases such as Environmental Performance in Construction (EPiC) in Australia can be a useful resource. The EPiC database is managed by the University of Melbourne and is funded via the Australian Research Council [149]. Amidst all the existing resources, such as the EPDs and EPiC, facility service providers can also use LCA specifically for estimating the carbon dividends if it is a part of the service delivery framework, as agreed with their commercial clients.

8. Conclusions, Limitations, and Further Studies

As part of conceptualising circular facility management, this study identified scopes and areas within the building operation where facility service providers can consider delivering sustainability services. In conceptualisation and the associated discussions around circularity in facility services, this paper pointed at the subtle difference that sets circularity in facility service apart from the general consideration of circularity in the built environment—for example, facility service as a service stream, facility service providers remit, and various building operation functions that can be both hard and soft services. Thus, suffice it to say that circularity applications in facility management can be viewed and approached slightly differently from our common understanding of circularity applications for the built environment sector—the literature on which is well-developed. Thus, this research contributes to strengthening the theoretical foundation in relation to circularity in facility services.

8.1. Conclusions

To conclude, this study provides four key insights to the relevant academic researchers and facility service practitioners willing to understand more about circularity in facility services. First, different perspectives on delivering facility services (e.g., management, maintenance, sustainability services, market interactions, etc.) can be referenced as a pragmatic basis to materialise the concept of circularity in facility services. Second, whilst the scopes and areas of circularity considerations in facility services can have an arbitrary boundary, they should primarily focus on building operations, as this is the realm where the facility operates and functions optimally. Third, while there is a multitude of areas across procurement, use, and end-of-life products, considerations can be made in focus areas (and scopes, too) where the extent and impact of circularity-related actions can be more significant. For example, the areas within the 'use' and 'end-of-life' are more operational in nature than 'procurement'. Likewise, actions, such as maintenance and refurbishments and enabling reverse logistics, may garner more circular benefits than purchasing products with eco-labels and EPDs. Contrastingly, the product as a service can create more impact than simply adding a few waste assets and infrastructures. Finally, the circularity performance measurement in facility services can be presented and communicated to reflect important facility management functions, such as maintenance, procurement, and waste management.

8.2. Limitations and Further Studies

The theoretical nature of this study limits the testing of the concept with facility service providers via qualitative research techniques (e.g., interviews and focused group discussions). While the theoretical approach may have limited the validation of the concept of circularity in facility services, conceptualization and identification of potential circularity-oriented actions are the main objective of this study. Thus, as a way to undertake further studies on this topic, it is suggested to use qualitative research techniques involving facility service providers. Moreover, this study uses a hypothetical example of a lighting system to discuss the application of the proposed metrics. Again, as further studies, there is a possibility to take a range of product and material categories to test how the performance metrics do in research and in practice if intended to be applied by facility service providers. The application of the proposed circularity performance metrics may highlight the scopes/areas that use and generate quantitative data.

This study assumes that facility service is the most significant service stream to improve circularity performance in building operations. The assumption builds on the premise that the facility service as a standalone service stream is broad in nature, covering most functions required to operate buildings optimally. Thus, future studies with a similar focus can look at the comparative significance of various service streams—for example, comparison with the IT and digital service providers' roles in improving the circularity performance of building operations.

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References

1. Vasilca, I.S.; Nen, M.; Chivu, O.; Radu, V.; Simion, C.P.; Marinescu, N. The management of environmental resources in the construction sector: An empirical model. *Energies* **2021**, *14*, 2489. [CrossRef]
2. Zhou, Z.; Zhang, S.; Wang, C.; Zuo, J.; He, Q.; Rameezdeen, R. Achieving energy efficient buildings via retrofitting of existing buildings: A case study. *J. Clean. Prod.* **2016**, *112*, 3605–3615. [CrossRef]
3. Kharas, H. *The Unexpected Expansion of the Global Middle Class an Update*; Global Economy and Development Program at the Brookings Institution: Washington DC, USA, 2017.

4. Munaro, M.R.; Tavares, S.F.; Bragança, L. Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment. *J. Clean. Prod.* **2020**, *260*, 121134. [CrossRef]
5. Ghisellini, P.; Cialani, C.; Ulgiati, S. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod.* **2016**, *114*, 11–32. [CrossRef]
6. Kirchherr, J.; Reike, D.; Hekkert, M. *Conceptualizing the Circular Economy: An Analysis of 114 Definitions. Resources, Conservation and Recycling*; Elsevier B.V.: Amsterdam, The Netherlands, 2017. [CrossRef]
7. López Ruiz, L.A.; Roca Ramón, X.; Gassó Domingo, S. The circular economy in the construction and demolition waste sector—A review and an integrative model approach. *J. Clean. Prod.* **2020**, *248*, 119238. [CrossRef]
8. *ISO 41001:2018*; Facility Management—Management Systems—Requirements with Guidance for Use. International Organization for Standardization (ISO): Geneva, Switzerland, 2021. Available online: https://www.iso.org/standard/68021.html (accessed on 22 February 2023).
9. International Facility Management Association (IFMA). What Is Facility Management? 2023. Available online: https://www.ifma.org/about/what-is-fm/ (accessed on 22 February 2023).
10. Pasek, J.; Sojkova, V. Facility management of smart buildings. *Int. Rev. Appl. Sci. Eng.* **2018**, *9*, 181–187. [CrossRef]
11. Limble. A Complete Guide to Facilities Management. 2021. Available online: https://limblecmms.com/blog/facilities-management/ (accessed on 1 March 2023).
12. BIFM. *Sustainability in Facilities Management Report*; The British Institute of Facilities Management: Hertfordshire, UK, 2016; pp. 1–25. Available online: http://www.bifm.org.uk/bifm/knowledge/sustainabilityinfm/2016 (accessed on 3 September 2022).
13. Atkin, B.; Brooks, A. *Total Facility Management*; John Wiley & Sons, Incorporated: Hoboken, NJ, USA, 2015.
14. Graubner, C.-A.; Pelzeter, A.; Pohl, S. A new approach to measure sustainability in German facility management. *Facilities* **2016**, *34*, 28–42. [CrossRef]
15. Pelzeter, A.; Sigg, R. CO_2 emissions from facility services. *Facilities* **2019**, *37*, 216–233. [CrossRef]
16. Kinkaid, D. Integrated Facility Management. *Facilities* **1994**, *12*, 20–23. [CrossRef]
17. Chotipanich, S. Positioning facility management. *Facilities* **2004**, *22*, 364–372. [CrossRef]
18. Johannes, K.; Voordijk, H.; Wakkee, I.; Aranda-Mena, G. Implementing organisational change in a digitalising facilities management organisation through stewardship interventions. *J. Facil. Manag.* **2022**. *ahead-of-print*. [CrossRef]
19. Hernandez, M. Toward an Understanding of the Psychology of Stewardship. *Acad. Manag. Rev.* **2012**, *37*, 172–193. Available online: http://www.jstor.org/stable/23218837 (accessed on 7 March 2023). [CrossRef]
20. Sherwin, D. A review of overall models for maintenance management. *J. Qual. Maint. Eng.* **2000**, *17*, 5–25. [CrossRef]
21. Taillander, F.; Sauce, G.; Bonetto, R. Methods and tools for building maintenance planning arbitration. *Eng. Constr. Archit. Manag.* **2011**, *19*, 343–362. [CrossRef]
22. Shen, W.; Hao, Q.; Xue, Y. A loosely coupled system integration approach for decision support in facility management and maintenance. *Autom. Constr.* **2012**, *25*, 41–48. [CrossRef]
23. Asare, K.A.B.; Liu, R.; Anumba, C.J. Building information modeling to support facilities management of large capital projects: A critical review. *Facilities* **2022**, *40*, 176–197. [CrossRef]
24. Circle Economy. Facilities Management in a Circular Economy. 2014. Available online: www.circle-economy.com/wp-content/uploads/2015/01/FacilityManagementInACircularEconomy.pdf (accessed on 7 March 2023).
25. Lehtonen, T. Attributes and Success Factors of Partnering Relations—A Theoretical Framework for Facility Services. *Nord. J. Surv. Real Estate Res.* **2014**, *2*. Available online: https://journal.fi/njs/article/view/41487 (accessed on 8 March 2023).
26. Lehtonen, T.; Salonen, A. Procurement and relationship management trends in FM services. In Proceedings of the IMP Conference, Rotterdam, The Netherlands, 1–3 September 2005.
27. Franciosi, C.; Iung, B.; Miranda, S.; Riemma, S. Maintenance for sustainability in the industry 4.0 context: A scoping literature review. *IFAC-PapersOnLine* **2018**, *51*, 903–908. [CrossRef]
28. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.; Horsley, T.; Weeks, L.; et al. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Ann. Intern. Med.* **2018**, *169*, 467–473. [CrossRef]
29. Molina-Maturano, J.; Speelman, S.; De Steur, H. Constraint-based innovations in agriculture and sustainable development: A scoping review. *J. Clean. Prod.* **2020**, *246*, 119001. [CrossRef]
30. Petticrew, M.; Roberts, H. *Systematic Reviews in the Social Sciences: A Practical Guide*; John Wiley & Sons: Hoboken, NJ, USA, 2008.
31. Seuring, S.; Müller, M.; Westhaus, M.; Morana, R. Conducting a literature review—The example of sustainability in supply chains. Research methodologies in supply chain management. In *Collaboration with Magnus Westhaus*; Springer: Berlin/Heidelberg, Germany, 2005; pp. 91–106.
32. Mayring, P. *Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution*; Springer: Berlin/Heidelberg, Germany, 2014.
33. Flick, U. *An Introduction to Qualitative Research*; Sage: Newcastle upon Tyne, UK, 2022.
34. Huang, C.H.; Liu, S.M.; Hsu, N.Y. Understanding global food surplus and food waste to tackle economic and environmental sustainability. *Sustainability* **2020**, *12*, 2892. [CrossRef]
35. Elmualim, A.; Pelumi-Johnson, A. Application of computer-aided facilities management (CAFM) for intelligent buildings operation. *Facilities* **2009**, *27*, 421–428. [CrossRef]

36. Nielsen, S.B.; Sarasoja, A.-L.; Galamba, K.R. Sustainability in facilities management: An overview of current research. *Facilities* **2016**, *34*, 535–563. [CrossRef]
37. Jensen, P.A. Design integration of facilities management: A challenge of knowledge transfer. *Archit. Eng. Des. Manag.* **2009**, *5*, 124–135. [CrossRef]
38. Barret, P. Achieving strategic facilities management through strong relationships. *Facilities* **2000**, *18*, 421–426. [CrossRef]
39. Nelson, M.M. The emergence of supply chain management as a strategic facilities management tools. In *Facilities Management Innovation and Performance*; Alexander, K., Atkin, B., Brochner, J., Haugen, T.I., Eds.; Spon Press: London, UK, 2004; pp. 83–94.
40. Nazali Mohd Noor, M.; Pitt, M. The application of supply chain management and collaborative innovation in the delivery of facilities management services. *J. Facil. Manag.* **2009**, *7*, 283–297. [CrossRef]
41. Sanzana, M.R.; Maul, T.; Wong, J.Y.; Abdulrazic, M.O.M.; Yip, C.C. Application of deep learning in facility management and maintenance for heating, ventilation, and air conditioning. *Autom. Constr.* **2022**, *141*, 104445. [CrossRef]
42. Labib, A.W. World-class maintenance using a computerised maintenance management system. *J. Qual. Maint. Eng.* **1998**, *4*, 66–75. [CrossRef]
43. Patwardhan, A.; Verma, A.K.; Kumar, U. A survey on predictive maintenance through big data. In *Current Trends in Reliability, Availability, Maintainability and Safety*; Springer: Cham, Switzerland, 2016; pp. 437–445.
44. Fleischmann, M.; Bloemhof-Ruwaard, J.M.; Dekker, R.; Van der Laan, E.; Van Nunen, J.A.; Van Wassenhove, L.N. Quantitative models for reverse logistics: A review. *Eur. J. Oper. Res.* **1997**, *103*, 1–17. [CrossRef]
45. Pokharel, S.; Mutha, A. Perspectives in reverse logistics: A review. *Resour. Conserv. Recycl.* **2009**, *53*, 175–182. [CrossRef]
46. Linton, J.D.; Klassen, R.; Jayaraman, V. Sustainable supply chains: An introduction. *J. Oper. Manag.* **2007**, *25*, 1075–1082. [CrossRef]
47. Govindan, K.; Soleimani, H.; Kannan, D. Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future. *Eur. J. Oper. Res.* **2015**, *240*, 603–626. [CrossRef]
48. Junghans, A. State of the art in sustainable facility management. In Proceedings of the 6th Nordic Conference on Construction Economics and Organisation, København, Denmark, 13–15 April 2011.
49. Carter, J.R.; Narasimhan, R. Is purchasing really strategic? *Int. J. Purch. Mater. Manag.* **1996**, *32*, 20–28. [CrossRef]
50. Carter, C.R. Purchasing and social responsibility: A replication and extension. *J. Supply Chain. Manag.* **2004**, *40*, 4–16. [CrossRef]
51. Kirchoff, J.F.; Tate, W.L.; Mollenkopf, D.A. The impact of strategic organizational orientations on green supply chain management and firm performance. *Int. J. Phys. Distrib. Logist. Manag.* **2016**, *46*, 269–292. [CrossRef]
52. Bell, J.E.; Mollenkopf, D.A.; Stolze, H.J. Natural resource scarcity and the closed-loop supply chain: A resource-advantage view. *Int. J. Phys. Distrib. Logist. Manag.* **2013**, *43*, 351–379. [CrossRef]
53. Arora, A.; Arora, A.S.; Sivakumar, K.; Burke, G. Strategic sustainable purchasing, environmental collaboration, and organizational sustainability performance: The moderating role of supply base size. *Supply Chain. Manag.* **2020**, *25*, 709–728. [CrossRef]
54. Amaro, A.C.S.; Barbosa-Póvoa, A.P.F.D. Close loop supply chains: Managing product recovery portfolio. *Comput. Aided Chem. Eng.* **2006**, *21*, 1875–1880. [CrossRef]
55. Zhu, Q.; Geng, Y.; Lai, K.H. Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. *J. Environ. Manag.* **2010**, *91*, 1324–1331. [CrossRef]
56. Meehan, J.; Bryde, D. Sustainable procurement practice. *Bus. Strategy Environ.* **2011**, *20*, 94–106. [CrossRef]
57. Xu, L.; Jia, F.; Yan, F.; Chen, L. Circular procurement: A systematic literature review. *J. Clean. Prod.* **2022**, *365*, 132845. [CrossRef]
58. Qazi, A.A.; Appolloni, A. A systematic review on barriers and enablers toward circular procurement management. *Sustain. Prod. Consum.* **2022**, *33*, 343–359. [CrossRef]
59. Shekarian, E. A review of factors affecting closed-loop supply chain models. *J. Clean. Prod.* **2020**, *253*, 119823. [CrossRef]
60. Mishra, J.L.; Hopkinson, P.G.; Tidridge, G. Value creation from circular economy-led closed loop supply chains: A case study of fast-moving consumer goods. *Prod. Plan. Control* **2018**, *29*, 509–521. [CrossRef]
61. Rubio, S.; Chamorro, A.; Miranda, F.J. Characteristics of the research on reverse logistics (1995–2005). *Int. J. Prod. Res.* **2008**, *46*, 1099–1120. [CrossRef]
62. Meis-Harris, J.; Klemm, C.; Kaufman, S.; Curtis, J.; Borg, K.; Bragge, P. What is the role of eco-labels for a circular economy? A rapid review of the literature. *J. Clean. Prod.* **2021**, *306*, 127134. [CrossRef]
63. Boyer, R.H.W.; Hunka, A.D.; Linder, M.; Whalen, K.A.; Habibi, S. Product Labels for the Circular Economy: Are Customers Willing to Pay for Circular? *Sustain. Prod. Consum.* **2021**, *27*, 61–71. [CrossRef]
64. Akenji, L.; Briggs, E. Sustainable Consumption and Production: A Handbook for Policymakers. 2015. Available online: https://sustainabledevelopment.un.org/content/documents/1951Sustainable%20Consumption.pdf (accessed on 8 March 2023).
65. Marrucci, L.; Daddi, T.; Iraldo, F. The integration of circular economy with sustainable consumption and production tools: Systematic review and future research agenda. *J. Clean. Prod.* **2019**, *240*, 118268. [CrossRef]
66. Ibáñes-Forés, V.; Pacheco-Blanco, B.; Capuz-Rizo, S.F.; Bovea, M.D. Environmental Product Declarations: Exploring their evolution and the factors affecting their demand in Europe. *J. Clean. Prod.* **2016**, *116*, 157–169. [CrossRef]
67. Secher, A.Q.; Collin, C.; Linnet, A. Construction Product Declarations and Sustainable Development Goals for Small and Medium construction Enterprises. *Procedia Cirp* **2018**, *69*, 54–58. [CrossRef]
68. Ganassali, S.; Lavagna, M.; Campioli, A.; Saporetti, S. Green Public Procurement and Construction Sector: EPD and LCA based benchmarks of the whole-building. In *Designing Sustainable Technologies, Products and Policies*; Benetto, E., Gericke, K., Guiton, M., Eds.; Springer International Publishing: Berlin/Heidelberg, Germany, 2018; pp. 503–513.

69. Umweltbundesamt Umweltdeklaration von Bauprodukten (UUB). Available online: https://www.umweltbundesamt.de/themen/wirtschaft-konsum/produkte/bauprodukte/umweltdeklaration-von-bauprodukten (accessed on 15 May 2022).
70. Adisorn, T.; Tholen, L.; Götz, T. Towards a Digital Product Passport Fit for Contributing to a Circular Economy. *Energies* **2021**, *14*, 2289. [CrossRef]
71. Barber, K.D.; Beach, R.; Zolkiewski, J. Environmental Sustainability: A Value Cycle Research Agenda. *Prod. Plan. Control* **2012**, *23*, 105–119. [CrossRef]
72. Tukker, A. Product Services for a Resource-Efficient and Circular Economy—A Review. *J. Clean. Prod.* **2015**, *97*, 76–91. [CrossRef]
73. Kjaer, L.L.; Pigosso, D.C.; Niero, M.; Bech, N.M.; McAloone, T.C. Product/service-systems for a circular economy: The route to decoupling economic growth from resource consumption? *J. Ind. Ecol.* **2019**, *23*, 22–35. [CrossRef]
74. Krikke, H. *Value Creation in a Circular Economy: An Interdisciplinary Approach. Decent Work and Economic Growth*; Springer Nature: Cham, Switzerland, 2020; pp. 1–15.
75. Parida, V.; Burström, T.; Visnjic, I.; Wincent, J. Orchestrating industrial ecosystem in circular economy: A two-stage transformation model for large manufacturing companies. *J. Bus. Res.* **2019**, *101*, 715–725. [CrossRef]
76. Spring, M.; Araujo, L. Product biographies in servitization and the circular economy. *Ind. Mark. Manag.* **2017**, *60*, 126–137. [CrossRef]
77. Matschewsky, J.; Kambanou, M.L.; Sakao, T. Designing and providing integrated product-service systems-challenges, opportunities and solutions resulting from prescriptive approaches in two industrial companies. *Int. J. Prod. Res.* **2018**, *56*, 2150–2168. [CrossRef]
78. Jensen, J.P.; Remmen, A. Enabling circular economy through product stewardship. *Procedia Manuf.* **2017**, *8*, 377–384. [CrossRef]
79. Lane, R.; Watson, M. Stewardship of things: The radical potential of product stewardship for re-framing responsibilities and relationships to products and materials. *Geoforum* **2012**, *43*, 1254–1265. [CrossRef]
80. Schroeder, H.M. Developments in the recycling industry and the growth of product stewardship: The role of enterprise information systems. *Int. J. Prod. Lifecycle Manag.* **2012**, *6*, 65–78. [CrossRef]
81. Ashby, A. Developing closed loop supply chains for environmental sustainability: Insights from a UK clothing case study. *J. Manuf. Technol. Manag.* **2018**, *29*, 699–722. [CrossRef]
82. UNEP, U. *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*; UNEP: Nairobi, Kenya, 2011.
83. Grillitsch, M.; Hansen, T. Green industry development in different types of regions. *Eur. Plan. Stud.* **2019**, *27*, 2163–2183. [CrossRef]
84. Nousiainen, M.; Junnila, S. End-user requirements for green facility management. *J. Facil. Manag.* **2008**, *6*, 266–278. [CrossRef]
85. Curtis, J.; Walton, A.; Dodd, M. Understanding the potential of facilities managers to be advocates for energy efficiency retrofits in mid-tier commercial office buildings. *Energy Policy* **2017**, *103*, 98–104. [CrossRef]
86. Elmualim, A.; Valle, R.; Kwawu, W. Discerning policy and drivers for sustainable facilities management practice. *Int. J. Sustain. Built Environ.* **2012**, *1*, 16–25. [CrossRef]
87. Alhola, K.; Ryding, S.O.; Salmenperä, H.; Busch, N.J. Exploiting the potential of public procurement: Opportunities for circular economy. *J. Ind. Ecol.* **2019**, *23*, 96–109. [CrossRef]
88. Altenburg, T.; Assmann, C. (Eds.) *Green Industrial Policy*; Concept, Policies, Country Experiences; UN Environment: Geneva, Switzerland; German Development Institute/Deutsches Institut für Entwicklungspolitk (DIE): Bonn, Germany, 2017.
89. Akhimien, N.G.; Latif, E.; Hou, S.S. Application of circular economy principles in buildings: A systematic review. *J. Build. Eng.* **2021**, *38*, 102041. [CrossRef]
90. Çimen, Ö. Construction and built environment in circular economy: A comprehensive literature review. *J. Clean. Prod.* **2021**, *305*, 127180. [CrossRef]
91. Pomponi, F.; Moncaster, A. Circular economy for the built environment: A research framework. *J. Clean. Prod.* **2017**, *143*, 710–718. [CrossRef]
92. Esposito, M.; Tse, T.; Soufani, K. The circular economy: An opportunity for renewal, growth, and stability. *Thunderbird Int. Bus. Rev.* **2018**, *60*, 725–728. [CrossRef]
93. Araszkiewicz, K. Digital technologies in Facility Management–the state of practice and research challenges. *Procedia Eng.* **2017**, *196*, 1034–1042. [CrossRef]
94. Adams, K.T.; Osmani, M.; Thorpe, T.; Thornback, J. Circular economy in construction: Current awareness, challenges and enablers. In *Institution of Civil Engineers-Waste and Resource Management*; Thomas Telford Ltd.: London, UK, 2017; Volume 170, pp. 15–24.
95. Giama, E.; Mamaloukakis, M.; Papadopoulos, A.M. Circularity in production process as a tool to reduce energy, environmental impacts and operational cost: The case of insulation materials. In Proceedings of the 2019 IEEE 4th International Conference on Smart and Sustainable Technologies (SpliTech), Split, Croatia, 18–21 June 2019; pp. 1–5.
96. Chan, E. Building maintenance strategy: A sustainable refurbishment perspective. *Univers. J. Manag.* **2014**, *2*, 19–25. [CrossRef]
97. SmartMarket Report. The Business Value of BIM for Owners, McGraw Hill Construction. 2022. Available online: http://www.i2sl.org/elibrary/documents/Business_Value_of_BIM_for_Owners_SMR_(2014).pdf (accessed on 1 December 2022).
98. Wong, J.K.W.; Ge, J.; He, S.X. Digitisation in facilities management: A literature review and future research directions. *Autom. Constr.* **2018**, *92*, 312–326. [CrossRef]
99. Arayici, Y. Towards building information modelling for existing structures. *Struct. Surv.* **2008**, *26*, 210–222. [CrossRef]

100. Akcamete, A.; Akinci, B.; Garrett, J.H. Potential utilization of building information models for planning maintenance activities. In Proceedings of the International Conference on Computing in Civil and Building Engineering, Nottingham, UK, 30 June–2 July 2010; Volume 2010, pp. 151–157.
101. Cong, Z.; Allan, L.; Menzel, K. Business Models for Decentralised Facility Management Supported by Radio Frequency Identification Technology. In *Computing in Civil Engineering*; American Society of Civil Engineers: Reston, VA, USA, 2011; pp. 323–330.
102. Hu, Z.-Z.; Zhang, J.P.; Yu, F.Q.; Tian, P.L.; Xiang, X.S. Construction and facility management of large MEP projects using a multi-scale building information model. *Adv. Eng. Softw.* **2016**, *100*, 215–230. [CrossRef]
103. Marzouk, M.; Zaher, M. Artificial intelligence exploitation in facility management using deep learning. *Constr. Innov.* **2020**, *20*, 609–624. [CrossRef]
104. Carvalho, T.P.; Soares, F.A.; Vita, R.; Francisco, R.D.P.; Basto, J.P.; Alcalá, S. A systematic literature review of machine learning methods applied to predictive maintenance. *Comput. Ind. Eng.* **2019**, *137*, 106024. [CrossRef]
105. Cheng, J.C.; Chen, W.; Chen, K.; Wang, Q. Data-driven predictive maintenance planning framework for MEP components based on BIM and IoT using machine learning algorithms. *Autom. Constr.* **2020**, *112*, 103087. [CrossRef]
106. Building As Material Banks (BAMB). D1 Synthesis of the State-of-the-Art: Key Barriers and Opportunities for Materials Passports and Reversible Building Design in the Current System. 2016. Available online: http://www.bamb2020.eu/wp-content/uploads/2016/03/D1_Synthesis-report-on-State-of-the-art_20161129_FINAL.pdf (accessed on 8 March 2023).
107. Walden, J.; Steinbrecher, A.; Marinkovic, M. Digital product passports as enabler of the circular economy. *Chem. Ing. Tech.* **2021**, *93*, 1717–1727. [CrossRef]
108. Hoosain, M.S.; Paul, B.S.; Raza, S.M.; Ramakrishna, S. Material passports and circular economy. In *An Introduction to Circular Economy*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 131–158.
109. WBSCD. The EU Digital Product Passport. 2023. Available online: https://www.wbcsd.org/Pathways/Products-and-Materials/Resources/The-EU-Digital-Product-Passport (accessed on 8 March 2023).
110. Myeda, N.; Kamaruzzaman, S.; Pitt, M. Measuring the performance of office buildings maintenance management in Malaysia. *J. Facil. Manag.* **2011**, *9*, 181–199. [CrossRef]
111. Fraser, K. Facilities management: The strategic selection of a maintenance system. *J. Facil. Manag.* **2014**, *12*, 18–37. [CrossRef]
112. Windapo, A.O.; Moghayedi, A. Adoption of smart technologies and circular economy performance of buildings. *Built Environ. Proj. Asset Manag.* **2020**, *10*, 585–601. [CrossRef]
113. Allen, K. The Link between Maintenance and a More Sustainable World. 2021. Available online: https://www.fiixsoftware.com/blog/maintenance-and-sustainability-framework/ (accessed on 16 February 2023).
114. Ilter, D.; Ergen, E. BIM for building refurbishment and maintenance: Current status and research directions. *Struct. Surv.* **2015**, *33*, 228–256. [CrossRef]
115. Gultekin, P.; Chimay, J.A.; Leicht, R.M. Case study of integrated decision-making for deep energy-efficient retrofits. *Int. J. Energy Sect. Manag.* **2014**, *8*, 434–455. [CrossRef]
116. Ma, Z.; Cooper, P.; Daly, D.; Ledo, L. Existing building retrofits: Methodology and state-of-the-art. *Energy Build.* **2012**, *55*, 889–902. [CrossRef]
117. Fernandes, J.; Ferrão, P. Urban Metabolism-Based Approaches for Promoting Circular Economy in Buildings Refurbishment. *Environments* **2023**, *10*, 13. [CrossRef]
118. Forsythe, P.; Ahmadian Fard Fini, A. Quantifying demolition fitout waste from Australian office buildings. *Facilities* **2018**, *36*, 600–617. [CrossRef]
119. Fini, A.A.F.; Forsythe, P. Barriers to reusing and recycling office fit-out: An exploratory analysis of demolition processes and product features. *Constr. Econ. Build.* **2020**, *20*, 42–62.
120. Li, M.; Yang, J. Analysis of interrelationships between critical waste factors in office building retrofit projects using interpretive structural modelling. *Int. J. Constr. Manag.* **2014**, *14*, 15–27. [CrossRef]
121. Bocken, N.M.; Olivetti, E.A.; Cullen, J.M.; Potting, J.; Lifset, R. Taking the circularity to the next level: A special issue on the circular economy. *J. Ind. Ecol.* **2017**, *21*, 476–482. [CrossRef]
122. Alamerew, Y.A.; Brissaud, D. Modelling and assessment of product recovery strategies through systems dynamics. *Procedia CIRP* **2018**, *69*, 822–826. [CrossRef]
123. Thierry, M.; Salomon, M.; Vannunen, J.; Vanwassenhove, L. Strategic issues in product recovery management. *Calif. Manag. Rev.* **1995**, *37*, 114–135. [CrossRef]
124. Alamerew, Y.A.; Brissaud, D. Circular economy assessment tool for end of life product recovery strategies. *J. Remanufacturing* **2019**, *9*, 169–185. [CrossRef]
125. Ziout, A.; Azab, A.; Atwan, M. A holistic approach for decision on selection of end-of-life products recovery options. *J. Clean. Prod.* **2014**, *65*, 497–516. [CrossRef]
126. Hanafi, J.; Kara, S.; Kaebernick, H. Reverse logistics strategies for end-of-life products. *Int. J. Logist. Manag.* **2008**, *19*, 367–388. [CrossRef]
127. Wiel, A.V.D.; Bossink, B.; Masurel, E. Reverse logistics for waste reduction in cradle-to-cradle-oriented firms: Waste management strategies in the Dutch metal industry. *Int. J. Technol. Manag.* **2012**, *60*, 96–113. [CrossRef]

128. Zhang, Y.M.; Huang, G.H.; He, L. An inexact reverse logistics model for municipal solid waste management systems. *J. Environ. Manag.* **2011**, *92*, 522–530. [CrossRef] [PubMed]
129. Peña-Montoya, C.C.; Bouzon, M.; Torres-Lozada, P.; Vidal-Holguin, C.J. Assessment of maturity of reverse logistics as a strategy to sustainable solid waste management. *Waste Manag. Res.* **2020**, *38* (Suppl. S1), 65–76. [CrossRef]
130. Pumpinyo, S.; Nitivattananon, V. Investigation of barriers and factors affecting the reverse logistics of waste management practice: A case study in Thailand. *Sustainability* **2014**, *6*, 7048–7062. [CrossRef]
131. Santos, S.M.; Ogunseitan, O.A. E-waste management in Brazil: Challenges and opportunities of a reverse logistics model. *Environ. Technol. Innov.* **2022**, *28*, 102671. [CrossRef]
132. Meade, L.; Sarkis, J.; Presley, A. The theory and practice of reverse logistics. *Int. J. Logist. Syst. Manag.* **2007**, *3*, 56–84. [CrossRef]
133. 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]
134. 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]
135. Janik, A.; Ryszko, A. Circular economy in companies: An analysis of selected indicators from a managerial perspective. *Multidiscip. Asp. Prod. Eng.* **2019**, *2*, 523–535. [CrossRef]
136. Di Maio, F.; Rem, P.C. A robust indicator for promoting circular economy through recycling. *J. Environ. Prot.* **2015**, *6*, 1095. [CrossRef]
137. Linder, M.; Sarasini, S.; van Loon, P. A metric for quantifying product-level circularity. *J. Ind. Ecol.* **2017**, *21*, 545–558. [CrossRef]
138. Park, J.Y.; Chertow, M.R. Establishing and testing the "reuse potential" indicator for managing wastes as resources. *J. Environ. Manag.* **2014**, *137*, 45–53. [CrossRef]
139. 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]
140. Ng, S.T.; Wong, J.M.; Skitmore, M. Challenges facing carbon dioxide labelling of construction materials. In *Institution of Civil Engineers-Engineering Sustainability*; Thomas Telford Ltd.: London, UK, 2013; Volume 166, pp. 20–31.
141. Hertwich, E.G.; Ali, S.; Ciacci, L.; Fishman, T.; Heeren, N.; Masanet, E.; Asghari, F.N.; Olivetti, E.; Pauliuk, S.; Tu, Q.; et al. Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics—A review. *Environ. Res. Lett.* **2019**, *14*, 043004. [CrossRef]
142. Castro, R.; Terranova, E.; Bruce-Hyrkäs, T.; Pasanen, P. *The Embodied Carbon Review—Embodied Carbon Reduction in 100+ Regulations & Rating Systems Globally*; Bionova Ltd.: Helsinki, Finland, 2018.
143. Malmqvist, T.; Nehasilova, M.; Moncaster, A.; Birgisdottir, H.; Rasmussen, F.N.; Wiberg, A.H.; Potting, J. Design and construction strategies for reducing embodied impacts from buildings–Case study analysis. *Energy Build.* **2018**, *166*, 35–47. [CrossRef]
144. Lützkendorf, T.; Foliente, G.; Balouktsi, M.; Wiberg, A.H. Net-zero buildings: Incorporating embodied impacts. *Build. Res. Inf.* **2015**, *43*, 62–81. [CrossRef]
145. Hossain, M.U.; Ng, S.T. Influence of waste materials on buildings' life cycle environmental impacts: Adopting resource recovery principle. *Resour. Conserv. Recycl.* **2019**, *142*, 10–23. [CrossRef]
146. Song, J.S.; Lee, K.M. Development of a low-carbon product design system based on embedded GHG emissions. *Resour. Conserv. Recycl.* **2010**, *54*, 547–556. [CrossRef]
147. De Wolf, C.; Pomponi, F.; Moncaster, A. Measuring embodied carbon dioxide equivalent of buildings: A review and critique of current industry practice. *Energy Build.* **2017**, *140*, 68–80. [CrossRef]
148. Khan, S.A.; Alam, T.; Khan, M.S.; Blecich, P.; Kamal, M.A.; Gupta, N.K.; Yadav, A.S. Life Cycle Assessment of Embodied Carbon in Buildings: Background, Approaches and Advancements. *Buildings* **2022**, *12*, 1944. [CrossRef]
149. Crawford, R.H.; Stephan, A.; Prideaux, F. *Environmental Performance in Construction (EPiC) Database*; The University of Melbourne: Melbourne, Australia, 2019.