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Exploring Servitization in Industrial Construction: A Sustainable Approach

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Abstract: Off-site manufacturing is emerging as an advantageous production model in the construction industry. In recent years, many tier 1 construction companies are including off-site production as part of their portfolio. Likewise, this change of model is attracting new entrants to the sector. The shift from the traditional on-site construction model to off-site manufacturing is unleashing positive impacts on projects in terms of cost, time efficiency, sustainability, and improved quality. Nonetheless, this phenomenon has yet to be analysed from the perspective of how this change in production processes influences the inclusion of services in company business models. This study explores whether and how industrialisation arises as an enabler for servitization in the construction sector. By means of an in-depth case study, our research identifies different product-service system (PSS) typologies associated with industrial construction and reveals their potential to increase additional services. Furthermore, the research sheds light on how industrial construction provides an opportunity to integrate offers and features that work towards reducing the environmental impact of construction projects and the operation and maintenance of built assets.

Keywords: off-site manufacturing; servitization; sustainability; industrial construction; product-service system; business model innovation

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1. Introduction

Over the last decade, we have seen how different industries have changed their way of conducting business by increasing customer orientation and evolving the way in which the offer of products and services is developed, integrated, and delivered [1]. In this regard, several key trends can be identified as major game changers in the literature. On the one hand, servitization usually involves a business model transformation [2,3]; on the other are digitalization, the development of industry 4.0, and sustainability, which are emerging as crucial drivers for business innovation [4,5].

In this context, the construction industry is evolving by embracing technological developments and adopting more efficient production processes [6]. Such transformations are enabling the development of industrial construction (off-site manufacturing), and are leading to changes in traditional business models [7]. Nonetheless, the deployment of product service systems (PSS) in the construction sector still remains marginal [8], while in other industries, such as manufacturing, the servitization of businesses is becoming the "new normal". This increased integration of offering services is mainly explained by two important factors: (1) service advantages: stable revenue streams, enhanced customer satisfaction, and difficulty of being replicated [9,10], and (2) the advent of the ongoing technological revolution, enabling advanced services to be introduced that are capable of bringing added value to businesses and end-customers alike [11]. However, despite such promising results, the development of servitization strategies in the construction industry remains weak. In this regard, some factors have been recognised as barriers preventing the deployment of servitization in construction: the lack of standardisation, lack of capabilities, and the need for more innovative behaviour [12]. Connecting these barriers with some key features of industrial construction drove us to assess its potential as a revitalising phenomenon that may boost the offer of integrated solutions in the construction industry.

Construction is seen as one of the most profitable industries [13], but is, however, blamed for its high energy and material consumption [14]. In this regard, the European Commission deems this industry accounts for 40% of all EU energy consumption [15]. In consequence, recent literature has been demanding increased sustainability awareness in this sector [16], and has identified the main hurdles and most capable bodies to overcome such barriers [17]. In this setting, industrial construction emerges as a production process that can lead to more sustainable construction [18].

In view of the above, it seems clear that the development of industrial construction is emerging as a solid trend that could guide the sector towards modernity in terms of business model evolution and sustainable practices. Even though studies looking into new business models that better suit these new conditions in the construction industry are gaining momentum [7], the literature on servitization in this industry remains scarce; in particular, in-depth analysis of industrial construction from the perspective of service inclusion has yet to be conducted. Hence, the introduction of off-site practices needs to be evaluated as a potential opportunity to enhance servitization in the construction sector. Furthermore, we wish to contribute to the literature by providing insight into the relationship between industrial construction and sustainability, and by identifying services/PSS that can be offered which are capable of impacting environmental potentials associated with industrial construction.

This research explores the novel advantages of industrial construction from a business model perspective (inclusion of services/PSS into business models) and contributes to a better understanding of the sustainable impacts on this new production system. Moreover, different PSS typologies are identified, which are being adopted and/or could potentially be adopted by companies operating in off-site construction. Accordingly, our research aims to address the following research issues: is off-site construction an enabler for including services in the construction industry? What PSS typologies are revealed by this new production model in construction? Does industrial construction favour construction companies in terms of sustainability orientation?

In order to address our research issues, an in-depth case study approach was employed. As part of the research protocol, a widely-accepted PSS categorisation was used to classify observed PSS typologies in industrial construction [19]. Similarly, a set of recently identified factors that have an impact on the environmental performance of industrial construction was employed to assess the sustainability orientation of off-site construction companies [14]. On the grounds of this research, we argue that adopting industrial practices is an enabler for developing servitization in the construction industry. In addition, we provided a table that shows the different emergent PSS typologies associated with industrial construction processes. Finally, the implementation of sustainable practices in industrial construction is explored, and the potential of green services/sustainable PSS in this new production process is discussed.

This article comprises: a theoretical background providing contextualisation of the research topic by reviewing the relevant literature in the areas of servitization, green services, off-site manufacturing, and sustainable construction. The different steps of the methodology employed are then explained and the main findings presented. In the final section, the results are discussed, and the fundamental implications presented.

2. Conceptual Background

2.1. Servitization/Product-Service Systems

The servitization phenomenon highlights the fact that firms can generate new revenue streams by providing services that fulfil customer needs [5,20]. The process that companies follow to enhance their traditional offer (product-based) by adding services so as to gain differentiation [21,22] and a competitive edge [23,24] is known as servitization. Vandermerwe and Rada [23] first coined the term in the context of manufacturing, and shortly afterwards Wise and Baumgartner [25] highlighted that service provision allows companies to move down the value chain and increase customer reliability throughout the product life cycle. Subsequently, research on servitization has progressed steadily, broadening our knowledge regarding its potential and implications [26–31]. As an indicator of this trend's relevance to companies, two thirds of manufacturers in developed countries have currently adopted some kind of servitization strategy [19].

As this topic has been analysed from a multidisciplinary angle and lines of thought, slightly differing terms are coined to describe this phenomenon. For the purposes of this study, we need to consider the line of research providing the best lens to explore the degree of service integration accompanying products in company offers. So, the product-service system (PSS) concept provides suitable theoretical ground to build on. This term, defined as a "marketable set of products and services, jointly capable of fulfilling a client's need" [32], has become commonly used from the end of the 20th century onwards [33]. Moreover, the PSS is a lens commonly used to study the product-service offer in engineering industries [34,35], and when using a life-cycle approach [36]. Therefore, given the context of this study, this conceptualisation seems to be the most suitable.

Servitization encompasses a continuum ranging from basic product-oriented services to customised and process-oriented services and, ultimately, towards the provision of comprehensive solutions [37]. This is aligned with PSS logic, which stresses the need to build a joint solution for (tangible) products and (intangible) services in order to meet customer needs more efficiently [38,39]. In such a continuum, the firm-customer interface transforms from being merely a transaction-focused relationship to one oriented towards true co-engagement in terms of design, value creation, and co-development of solutions [40–42]. Seeking to clarify the nature of services that may be present in this continuum, Baines and Lightfoot [24] classify them into basic, intermediate, and advanced services. This "simple" taxonomy has taken root in the academic literature on servitization [43–47]. In parallel, the literature has also established different PSS categorisations, which identify a number of archetypes that usually evolve from product-oriented to result-oriented [19,48,49].

Recent literature on digitalization and servitization has repeatedly found that digital transformation enables the development of suitable infrastructures to deploy servitization in business [50–52]. Digital tools can be applied both at the "front-end" and "back-end" to boost and improve the extent of servitization and deliver more value to customers [21,53]. Furthermore, digitally-enabled services enhance productivity and sustainability [54]. Nevertheless, digital transformations favouring servitization have important organisational implications, and often require the implementation of new organisational forms [55,56].

2.2. Servitization in the Construction Sector

Companies operating in the construction sector differ from manufacturers in how they create value, as project activities are often characterised by a high degree of uncertainty, and interrelated with a specific context challenging the possibilities of standardisation [57]. Even so, the construction industry is not unconnected to the servitization trend. Brady et al. [58] first introduced the idea of offering combinations of products and services, "integrated solutions", to better address client requirements throughout the project's life cycle. Similarly, the literature identifies enablers which add services to the business model of project-based firms [59], and frameworks that cater for the offering of comprehensive client solutions throughout the entire project [60,61].

In the construction industry, the operational costs of an infrastructure or building usually outweigh the design and construction phase costs [62]. The above, together with the positive impact of involving the client in the project's early stages [63], led to the proposition that the adoption of business models able to encompass the different project stages was the most suitable way to unleash the sector's servitization potential [61]. In this regard, and enabled by the proliferation of Public–Private Partnerships (PPP), a trend can be seen in design and construction firms engaging in the operational stages of built assets [64].

Servitization in the construction industry is important. Recent studies in the literature look at the interplay of digitalization and service orientation [65,66], and at identifying the key challenges facing its implementation [67]. Nevertheless, its application in this sector is mainly seen from a business model perspective [54,61,68]. Yet, practices, routines, and patterns concerning how organisations in the construction sector can become more service-oriented remains largely unexplored [69], and is one of the factors driving this research.

2.3. Green Services, Green Servitization, and Sustainable PSS

The academic literature is still striving to find the benefits that servitization can bring to sustainability. Two main strands of literature look into what the positive effects of adding services to traditional product offers could bring in terms of sustainability: green servitization and sustainable PSS.

Since the UN published the seminal report titled "Our Common Future", also known as the Brundtland Report [70], sustainability has become one of the major challenges facing humanity. According to Bocken et al. [71], the inclusion of sustainability in modern management has been made possible thanks to the development of the Triple Bottom Line model created by Elkington in 1997 [72]. However, to date, services seem to be partially excluded from this new vision. A recent report developed by the European Parliament's Committee on Internal Market and Consumer Protection (IMCO) recognised that, despite the service sector's contribution to the Gross Domestic Product (GDP) and job creation, around 65–85 percent in mature economies, services have not been sufficiently considered as part of the green transition, green economy, or green growth [73]. The report also outlines the importance of creating standards and clear definitions around what a green service is in order to address the challenge of greening the economy [73].

At present, a well-established definition of green services proves difficult to find in the literature. Cocca and Ganz [74] argue that this term derives from the concept of sustainable development, which includes three major fields of action: economic, ecological, and social (as in the Triple Bottom Line model). Built on this logic, green services are defined as services included "in the offering or use of which the key target criterion is ecological sustainability". One way in which these green services could materialise is in the form of eco-efficiency (creating goods and services whilst using fewer resources and creating less waste and pollution) [75]. Another way of conceptualising green services is by encompassing them under the umbrella of services associated with cleaner production methods [76]. Chen et al. [77] elaborate on the discussion by including the concept of the life cycle to help define a product or service's greenness, taking greenness as being associated with minimising negative environmental effects throughout the entire life cycle. It is also interesting to note that Opazo-Basaéz et al. [54] introduce the concept of green servitization as the result of deploying a servitization strategy that integrates green services.

The relationship between sustainability and PSS has been widely discussed in the literature. Initially, PSS were considered intrinsically sustainable as it was assumed that their contribution implied client solutions without involving physical ownership, which subsequently meant lower resource consumption [78]. This thesis was rejected by Tukker and Tischner [38], who state that "it is a myth that PSS equals sustainability". They argue that a PSS is not sustainable "per se", and that the "promising" positive effects on the environment, society, and economy must be evaluated on a case-by-case basis [79,80]. The category of sustainable in a PSS must be intentionally sought by providers [81] and integrated in a suitable business model [80,82–85]. Accordingly, sustainable PSS would be given a distinctive PSS category defined as "alternative socio-technical systems that can provide the essential end-use function (. . .) and attempt to create designs that are sustainable in terms of environmental burden and resource use" [82]. Moreover, the use of eco-efficient products in the joint offer (product-service) is associated with sustainable PSS [82]. This remark is meaningful for the purpose of this article because prefabricated modules can be seen as eco-efficient products as opposed to elements built using traditional construction methods.

Vezzoli et al. [81] elaborate on this topic by stressing that sustainable PSS prove promising because they are associated with reduced resource use, which could result in reduced costs and favour access of lower income segments to PSS solutions, thus improving social inclusion. Needless to say, these results clearly align with the Triple Bottom Line approach, on which the academic literature on sustainable PSS is based [77,86–90].

Two further aspects should be mentioned before concluding this section, taking into account the construction sector's features. On the one hand, introducing PSS into this industry could reduce waste generation, improve efficiency, decrease environmental impacts, and increase social responsibility [91]. On the other, increased focus of construction on the whole project life cycle may help to explore PSS contributions to the circular economy [64,90,92–94].

2.4. The Emergence and Development of Industrial Construction

Despite being an important strategic sector for the global economy [13], the construction industry is struggling to keep up with the overall growth of economic productivity [95]. The literature identifies a weak innovative culture [96], sluggish digitalization [97,98], skills shortages [99], and the lack of standardisation [100] as key factors determining the industry's current productive inefficiency.

In this context, the emergence of two new paradigms in the sector, industrialisation and digitalization, should drive a transformation that is capable of addressing the aforementioned issues, and of increasing productivity [101]. Industrialisation in construction is not entirely new. The application of industrial processes has been seen as a means to increase competitiveness, efficiency, and better meet market demand in the sector since the 1960s [102]. Gann [103] described the benefits of industrialisation in construction as analogous to those seen in other sectors, such as the automotive industry. Industrial construction can improve quality, shorten delivery times, and reduce waste [104]. Similarly, the use of modular, standardised elements enables new, specific client-oriented, and project-oriented solutions to be offered [42]. However, despite the benefits listed, industrial production processes in construction are being implemented more slowly than expected [105].

Finally, it is important to point out that the concept of industrial construction is a holistic practice which includes a set of overlapping concepts used in both the industrial and academic literature; off-site manufacturing [106], off-site construction [107], modular construction [108], or modern methods of construction (MMC) [109].

2.5. Sustainable Production Processes in Construction

In a recent report, the United Nations Environment Programme (UNEP) states that the buildings and construction sector account for "39% of total carbon dioxide emissions" [110]. Such shocking figures highlight the urgent need to improve traditional construction methods and built assets operations. One of the main approaches to address this environmental issue is to implement industrial fabrication processes, that is, the use of prefabricated modules made in a controlled environment, which are then transported to the construction site for assembly [111].

Several studies have looked into the advantages of introducing off-site manufacturing as opposed to traditional construction in different countries: Australia [112], China [113], Hong Kong, and Singapore [114]. In these studies, apart from cost, quality, and delivery time, the authors try to shed some light on the environmental benefits of industrial construction. More specifically, Cao et al. [113] quantified the sustainable benefits when using off-site construction methods: an overall reduction of 36% in resources employed, 21% in energy use, 6.6% in health damage, and 3.5% in ecosystem damage.

In order to achieve sustainable benefits throughout the project life cycle, the design phase proves to be a key stage in industrial construction processes. Coordination and sustainable awareness of the project underway during the design stage is crucial in order to prevent drawbacks and make the method greener [114]. Given the importance of design, and even more so, the significance of proper coordination between the design and other project phases, implementing Building Information Modelling (BIM) provides companies the chance to measure sustainability performance [115], facilitating the sustainable design process [116]. Indeed, the interoperability provided by BIM is considered a major enabler for coordinating sustainability information in a construction project [117,118].

The current literature now identifies the positive effects of industrial construction. Nonetheless, much work remains to be done to reduce waste, cut greenhouse gas emissions, and minimise noise and dust in order to become a more sustainable industry [114].

3. Research Method

3.1. Context

Industrial construction accounts for just 1% of the sector's business volume in Spain, while this percentage rises to 9% in Germany and reaches 50% in Sweden [119]. Such poor performance has brought about the recently formed Spanish Association for the Industrialisation of Construction, made up of 40 companies at different stages of the industrial construction value chain [120].

The unit of analysis in this research is one of the 5 off-site manufacturers belonging to the above association. The firm (anonymised as Company H for the purposes of this research) is a young company set up in 2015. One of Company H's important features is that it was created as a spin-off from a large corporation. The parent organisation manufactured prefabricated concrete modules for electrical substations as one of its business activities and, prompted by their product quality and acquired knowledge of the industrial process, the opportunity was seen to enter the construction sector by setting up Company H.

Currently, Company H targets large developers, and has so far delivered approximately 100 houses. Its current production capacity stands at 50 houses per year, but production is aimed to double by 2023 and reach a production capacity of 200 houses per year by 2025. In terms of workforce, 84 people currently work in the company, 60 on the factory floor and 24 as office staff.

3.2. Method

Given that the phenomena observed is contemporary, and the study exploratory, an inductive research approach was followed. This research strategy is considered a suitable method to create new theoretical propositions from case-based evidence [121]. A case-study research strategy is understood as the empirical investigation of a phenomenon within its context [122]. This method is widely cited as an effective tool to analyse complex, ongoing processes [123], and allows researchers to achieve a better understanding of contextual information (i.e., company culture, organisational structure, historical background) [124].

3.2.1. Research Protocol

This study employed a single case-study approach to gain insight into the development and implementation of industrial construction from a threefold perspective: customer orientation, service inclusion, and environmental performance. In order to conduct our research, a protocol comprising 4 stages was followed: (1) identification of a suitable case study, (2) instrument development, (3) interview and secondary data collection, (4) data analysis and data triangulation. These phases are explained in greater detail below.

3.2.2. Case Selection

Company H was selected as our unit of study for three reasons that made this case suitable for achieving our research objectives: (1) the company had already been operating for six years, and has been well-established since the entry of industrial construction on the Spanish market; (2) the company belongs to a cluster created to share knowledge, and work together towards the strategic positioning of industrial construction; (3) the firm has an industrial background that enables the effects of a lack of industrial culture to be isolated.

These three factors also prove our case to be of special interest in order to understand the context of industrial construction and its associated sustainable practices. Via this case, current practices, offers, and operational patterns were seen, and the refreshing perspective of a newcomer to the construction sector gained.

3.2.3. Instrument Development

Interviews are seen as a reliable source of information when conducting a case study [122]. In our study, a semi-structured approach was used to gather information. Hence, our research is qualitative. Primary data was collected via an in-depth interview. The interview was structured around 4 modules: (1) context and characterisation of industrial construction, (2) client orientation, (3) service orientation, (4) sustainability orientation. The first two modules included open-ended questions, while the modules researching service offers and sustainability consisted of a combination of open-ended questions and checklists to assess both the PSS typologies and implementation of actions related to environmental potentials of off-site construction more concisely. The two checklists were drawn up by building on previous research; the PSS typologies defined by Neely [19] and implemented by Zott and Amit [48] were used to define a list of different PSS, whose implementation was assessed in our case (see Supplementary Materials). In the case of sustainable actions, the presence/absence of actions associated with previously identified environmental factors in industrial construction was checked [14].

3.2.4. Interview and Secondary Data Collection

The interview took place in March 2021 and was structured around the 4 modules mentioned above. The questionnaire contained a total of 20 open-ended questions and 2 checklists. Company H's CEO and the Innovation Manager of the parent organisation (responsible for creating spin-offs in the group) were interviewed. Due to Covid-19 restrictions, the interview was conducted online. Comprehensive notes were taken throughout the interview, providing useful insight for the study.

Data collected from the interview was completed and contrasted with information from different secondary sources: company reports, websites, social media channels, industrial reports, architectural journals, and news from reliable business newspapers.

3.2.5. Data Analysis and Data Triangulation

Finally, the information gathered in the interview was analysed and the findings organised using the same module structure. The data obtained via the checklists was compiled into two tables in order to show the results clearly. It is important to mention that our case study draws from multiple sources (primary and secondary data), and data triangulation was applied as the strategy to validate the primary information collected in the interview [125,126].

4. Findings

As previously mentioned, the unit of study is a company belonging to an industrial construction cluster, and has been operating in off-site construction for the last 5 years. Therefore, this is a representative case whose findings admit a certain degree of generalisation. This section presents our findings according to the four modules defined in the interview: context and characterisation of industrial construction, client orientation, service orientation, and sustainability orientation.

4.1. Context and Characterisation of Industrial Construction

Company H identified some barriers preventing the implementation of industrial construction in the current context. As this company is a spin-off of a large manufacturer, some key hurdles facing the application of industrial processes in the construction sector were pointed out:

> *"Culture in the construction industry is still far away from industrial concepts such as the value chain or orientation towards processes. In addition, this sector is not fully aware of the importance of the supply chain".*

> *"Diversity and low product and process standardisation were the main barriers preventing the implementation of industrial processes that we encountered when we joined the construction industry."*

Similarly, company H is aware of some of its capabilities, conferred by its industrial background, which are not commonly found in companies operating in the built environment. It is thought that the arrival of organisations with manufacturing expertise in the construction industry could have a positive impact:

> *"The fact that manufacturers are joining the construction industry could be positive, we can bring solid knowledge to industrial organisation and more experience in relation to industrial processes, purchasing management and the development of specialised auxiliary industries."*

Additionally, despite still being in its infancy, the company is convinced that industrial construction will bring benefits to the sector:

> *"We see increased efficiency and reduced uncertainty (in terms of cost, quality and delivery times) as the main advantages."*

In such a context, their view is that in order to succeed in this industrialised construction process, holistic management of the entire project is required:

> *"As all phases are interrelated (design, manufacturing, logistics, transport, assembly and operation), integrated vision and high performance in each and every project phase are required".*

4.2. Client Orientation

Company H operates in the B2B segment, currently oriented exclusively toward large developers, who are its only client segment. Regarding client-orientation in its production process, the company manufactures to order following a basic variety of configurations. In particular, four design types (XS, S, M, and L) are offered, depending on the surface area to be occupied by the building. The catalogue allows a certain degree of customisation:

> *"In our catalogue, we offer variations for façade cladding, interior distribution, area, height and quality of materials".*

Moreover, according to experience, Company H identified key factors driving their clients (large developers) to opt for industrial construction:

> *"Our clients are attracted by the offer of a robust, high-quality product at a set price (because the contract price is the liquidation price), shorter deadlines to finalise the project (between 10 and 12 months shorter than traditional construction)" and "a significant reduction in after-sales incidents".*

Moreover, Company H often aligns its production rate to the construction developer's rate of sales. A show house is also offered, which helps clients better commercialise a property development by allowing the end-customer to envisage the final result.

4.3. Service Orientation

With regard to service orientation, Company H acknowledges the need to offer services throughout all project phases (Conceptualisations–Design–Execution–Operations/Maintenance). What is more, it is thought that offering services facilitates the integration of the different project stages:

> *"In our case, we offer all kinds of services related to the different project phases; from project conceptualisation to after-sales services".*

As part of the interview protocol, a list of different product-service offers was included in order to check those included in Company H's current portfolio. The list was open to interviewees so as to enable the inclusion of any other PSS offers not initially listed. Subsequently, the offers were classified according to PSS typologies [19,48]. Thus, Table 1 identifies and classifies the PSS offered by a company implementing industrial construction.

Table 1. Identified product-service systems (PSS) in industrial construction (adapted from Neely, 2008 [19], and Zott and Amit, 2010 [48]).

Product-Service Systems (PSS) in Industrial Construction				
Integration-oriented PSS *Product with additional services/services complementing manufactured products*	Product-oriented PSS *Services directly connected to products*	Service-oriented PSS *Product and services coupled together as an inseparable entity*	Use-oriented PSS *Services delivered via product functions*	Result-oriented PSS *Services replacing products*
Transportation and delivery	*Design/architecture consultation*	*Services connected with building's energy consumption*		*Project Management*
Item traceability	*Technical consultation*	*Services connected with building operations*		*Turnkey projects*
	Technical Services			
	Assembly			
	Planning tools			
	Building Information Modelling (BIM) services			

The degree of digital servitization in company H was also assessed. Although software is used to implement BIM, the full potential of applying BIM is not fulfilled. The use of BIM in Company H is restricted to the design phase, and is not used as an enabler to add services throughout the project life cycle. Moreover, Company H is not considering the development of home automation and/or offering digitally advanced services.

> *"Nowadays, offering digital services connected with building automation, or offering other smart services, is not at the forefront of our priorities".*

In conclusion, it is important to stress the conviction expressed by company H regarding the fact that implementing industrial construction enables the inclusion of services in the sector:

> *"From our perspective, industrial construction demands all kinds of services".*

4.4. Sustainable Orientation

The information gathered by our case study clearly shows solid links between industrial construction and the increased sustainability awareness in the sector. In particular, commitment to sustainable practices is a firm belief held by Company H, and is stated as such:

> *"All our buildings are delivered with a Class A Energy Performance Certificate (the most efficient). Moreover, in some cases we also include the internationally recognised BREEAM Certificate (Building Research Establishment Environmental Assessment Methodology). Such practice does not response to any particular business strategy, it responds to our company values".*

Besides providing improved environmental performance throughout the building's lifespan, industrial construction is showing itself as a greener process as opposed to traditional methods in the built environment. Company H quantifies environmental advantages in relation to both execution and building operations:

"We estimate a reduction of 60% in CO2 emissions in the execution phase due to less waste and better waste management, lower resource and energy consumption and less transportation. We also quantify a reduction of 30% in CO2 emissions throughout the lifespan thanks to improved thermal insulation and improved efficiency throughout the whole system".

In this regard, following on from work conducted by Kedir and Hall (2019) [14], 18 factors affecting the environmental performance of industrialised housing were evaluated in Company H. Table 2 summarises these environmental potentials, setting out which are considered as being currently offered.

Table 2. Environmental potentials in company H's offer (source: adapted from Kedir and Hall, 2019 [14]).

Environmental Factors Considered by Company H		
Phase	**Factors**	**Present (✔) /Absent (✕)**
A. System design	A1. Efficiency (Design strategies used to reduce the amount of materials used in construction)	✔
	A2. Product modularity (Design strategy aiming to create both variable and standardised elements in a product)	✔
	A3. Coordination of super-and sub-structure (Material consumption below ground heavily depends on above-ground design. Such structures must therefore be coordinated.)	✕
B. Material design	B1. Embodied energy (The amount of energy required to produce a building component)	✔
	B2. Dematerialisation (The concept of building a structure using less material while still serving the same or similar purpose)	✕
	B3. Durability (Refers to building materials and their long-term environmental performance)	✔
C. Manufacturing and logistics	C1. Waste reduction (Via controlled processes of manufacturing building elements in a factory environment)	✔
	C2. Production system impacts (Reduction of environmental impacts driven by the type of production system used)	✔
	C3. Green supply chain management (Coordination among key stakeholders such as suppliers, manufacturers and contractors so as to manage environmental performance)	✔
D. Transport and assembly	D1. Equipment (Addresses the energy consumed by equipment used during transport and assembly of off-site elements)	✕
	D2. Location (The impact associated with transporting building elements)	✔

Table 2. *Cont.*

Environmental Factors Considered by Company H		
Phase	**Factors**	**Present (✔) /Absent (✕)**
E. Operation	E1. Operational energy (Energy consumed during the use phase of buildings)	✔
	E2. Supplementary elements (Adding elements not considered core to the functionality of a building, such as solar panels to reduce operational energy)	✕
F. End of Life	F1. Reusability and recyclability (The potential of housing structures to be reused or recycled for further use)	✕
	F2. Service-based industry (The industry structure transformation from products to services)	✔
G. Support and hindrance of industrial housing	G1. Customer demand (The end-users' requirements and desires to buy housing)	✕
	G2. Building codes (The regulatory requirements placed on materials and designs, often at state or local level)	✔
	G3. Policies and incentives (The regulatory and statuary requirements, in addition to special benefits granted for housing projects)	✕

5. Discussion

This research was conducted to better understand the context and characteristics surrounding industrial construction, and determine its potential as an enabler for the servitization and deployment of sustainable practices.

The findings from this case study corroborated the presence of some barriers preventing industrial production processes from being implemented in the construction sector. Specifically, the presence of a culture which is not open to industrial paradigms, together with a lack of standardisation were seen as the main obstacles. This observation is coherent with previous literature, which listed the lack of an innovative culture [96] and low standardisation [100] as factors burdening productivity in the construction industry. Our findings therefore suggest that the arrival of manufacturing companies in the construction market could revitalise the latter. The positive impact of integrating actors with an industrial mindset in the construction sector has already been addressed in the literature, which points out their influence on enhancing innovation [127,128].

By following the portrait of industrial construction painted by this case study, clear orientation towards the Business to Business (B2B) segment can be found, with exclusive focus on large construction developers. The rationale seems to be that large developers can easily perceive the value of off-site construction (time reduction, cost saving, and increased quality). However, this operation at B2B level may be constraining the inclusion of other services. According to Wise and Baumgartner [25], one of the advantages of offering services is that it allows companies to increase interactions with customers throughout the product life cycle. As long as offering services is not oriented towards the building end-users, service complexity and the integration of digitally-enabled services are lower. This is in alignment with the conceptualisation of advanced services as those supporting customers, as opposed to basic product support services [24]. This current orientation towards large developers in industrial construction also has implications regarding the greenness of offering services. A model oriented more towards end-users would increase the demand of green services due to the higher sustainability awareness of people who use and/or inhabitant a building [68,112]. Therefore, we believe that these three dimensions—service complexity, presence of digitally-enabled services, and service greenness—correlate positively with offering services oriented towards the building end-users. More specifically, we believe that the full potential of smart and green services will only be fulfilled when industrial construction adopts a Business to Client (B2C) model (Figure 1).

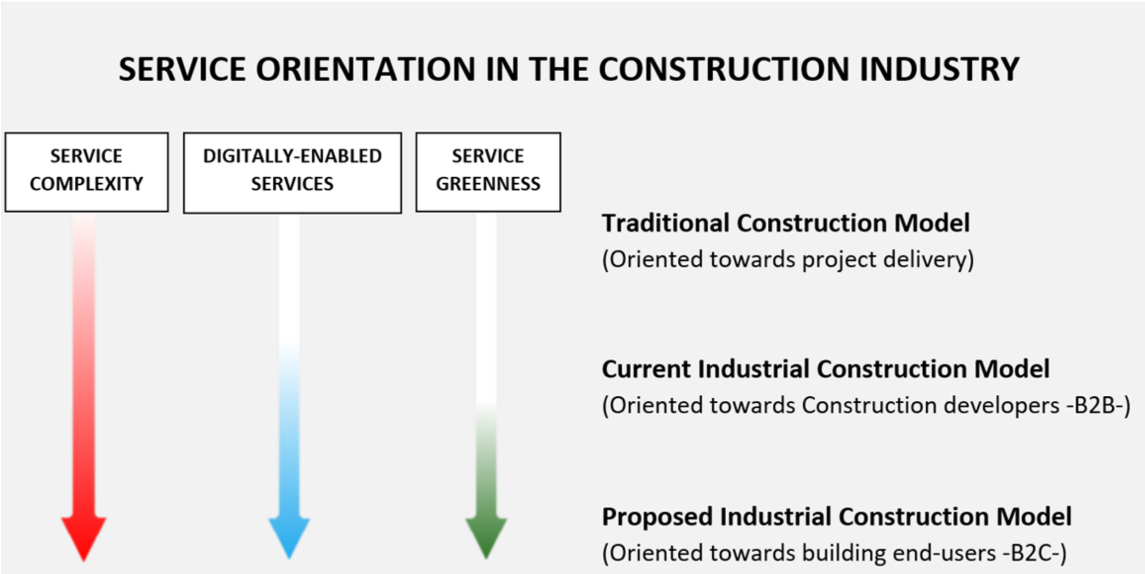

Figure 1. Evolution and future perspective of service orientation in the construction industry (source: by authors).

Another important aspect presented in our findings confirms that holistic management of the entire project is required in order to unlock advantages for industrial construction. The literature on servitization in the construction sector sustains that integrating different project phases enables the inclusion of services into the company business model [59,65]. It therefore seems reasonable to affirm that implementing a production process that boosts the integration of project phases will benefit service inclusion.

Regarding PSS, a range of different PSS are offered throughout the different project stages, and throughout the building life cycle. This contrasts with the difficulties involved in deploying servitization in the built environment when applying traditional delivery models and conventional construction methods [8]. When analysing the PSS typologies offered, it can be seen that most are classified as product-oriented PSS. In fact, the majority of the PSS offered complements the product or are connected to the product (Table 1). Hence, they can be classified as basic and intermediate services [24]. It can be inferred from the results that the degree of digital servitization is low, and, as yet, no smart services or advanced services incorporating building automation are offered. Industrial construction should take advantage of working in a controlled environment in order to increase the presence of embedded sensors that enable smart services to be offered.

Finally, in terms of sustainability orientation, the results clearly show that industrial construction involves far more sustainable production processes, as claimed by recent literature [112–114]. From the observations of environmental factors considered by company H, it can be concluded that the vast majority of the environmental potentials in industrial construction are being taken into account. Even so, there is room for improvement regarding the materials used, and building disposal (end-of-life phase); aspects which require further consideration on the part of off-site construction companies. In addition, and on the basis of our findings, offers of proper green services cannot be identified, rather, the application of eco-efficiency [129]. This observation could be linked to two factors: on the one hand, underdeveloped digitalization that may constrain offers of green services and, on the other, a lack of demand for these kinds of services by clients (large developers). This may also occur due to the lack of sophistication in the market [130], that is, construction developers are implementing industrial processes while keeping their traditional mindset (without considering specific end-user needs). Therefore, it seems that the market will only evolve and become more sophisticated when end-users are fully aware of the potential benefits of off-site manufacturing, and only then would industrial construction show its benefits in full.

5.1. Implications for Managers and Other Stakeholders

According to our findings, market demand for off-site construction comes primarily from large developers and, subsequently, the market offer attempts to meet the main business demands in terms of cost, quality and time. This has implications for the development of servitization in the construction industry through off-site manufacturing because off-site construction companies fail to reach end-users. Therefore, they are not going far enough down in the value chain, which is one of the main advantages of offering services.

In addition, it can be seen that there is room to add services throughout the entire construction process (from conception to demolition) if building contractors and developers are able to change their traditional mindset, and involve end-users in value co-creation from a project's early stages (i.e., co-design). Moreover, building end-users should gain awareness of the potential value that services enabled by industrial construction may bring. In this regard, smart services connected with a building's inhabitation (service-oriented PSS) seem to be the services that could soon be demanded by end-users. These kinds of services could also lead to more sustainable use of basic resources (i.e., water, energy, waste generation). Moreover, some off-site manufacturers could become operators in the near future by offering house renting, whilst maintaining ownership of the building (use-oriented PSS).

In terms of sustainability, there are clear, positive effects of off-site manufacturing on the reduction of CO2 emissions given its eco-efficiency compared with traditional construction methods. Clear suitability awareness was also observed in our case, as well as a clear commitment to offering sustainability certification for buildings. However, offering proper green services remains immature, and probably relates to the lack of orientation towards end-users. It is also considered that the entry of new players in the market, particularly building operators, could enhance the development of green services in industrial construction.

To sum up, industrial construction is emerging as a door that is open to servitization deployment in the construction industry, but there is still much room for improvement to unlock the full benefits of servitization and achieve higher levels of sustainability (economically, socially, and environmentally). In this regard, a higher degree of collaboration between the academic world, public sector, and private sector could help to disseminate results, good practices, and success cases.

5.2. Limitations and Future Research Lines

This research constitutes an explorative analysis of the degree of servitization in industrial construction and its associated environmental potential. As a single case study approach is employed to address our research scope, the main limitation of this study is that the outcomes cannot be generalised. Hence, we must acknowledge that the results, albeit relevant, should be considered as indicative only. The applicability of our conclusions to the industrial construction industry as a whole would require a robust quantitative approach. Another limitation regarding our qualitative approach could be the authors' bias when interpreting data.

There are also two aspects related to our unit of analysis that are worth highlighting in this context of limitations: the first is the lack of maturity in industrial construction in Spain, and the second is the fact that the case selected is a young company whose business model may still be in the process of evolving.

In order to complete the results obtained in this research, additional inquiries would need to be carried out on the three axes of concern in this article: off-site manufacturing, servitization, and sustainability. Thus, an empirical study considering a representative sample of key actors in industrial construction—off-site construction companies, building developers, and end-users—would offer more solid and generalisable results. Moreover, a multinational benchmark analysis would shed light on the commonalities and/or disparities of markets at different development stages.

Our research process identified two additional areas of academic work in relation to the gaps that motivated this study. The first would be to look into the question of whether a change from a B2B model to an end-user-oriented model (B2C) would encourage value co-creation, co-design practices, greener and customised services and, ultimately, greater development of industrial construction. The second area where further research would be recommended is the analysis of factors that may favour a change in the traditional mindset of the construction sector and enable off-site manufacturing growth.

6. Conclusions

The interlinking between servitization and industrial construction is an area that has barely been researched [131]. Our study reveals the emergence of a new context in the construction sector where modern construction methods are playing a key role in boosting innovation and enabling business transformation. Based on our findings, it can be argued that the industrialisation of construction is driving a paradigm shift towards service orientation. Nonetheless, the PSS typologies observed reveal a model that currently focuses on product-oriented PSS. In this regard, it should be pointed out that the lack of digitally-enabled services burdens the presence of use/result–oriented PSS.

This study explored the orientation towards services in industrial construction in accordance with a sustainable approach. The transition towards sustainable construction is still recognised as a challenge. Nevertheless, the implementation of sustainable PSS and integration of green services in off-site construction companies provide a promising opportunity.

Finally, it should be pointed out that more focus on building end-users could be crucial so that the full potential of servitization can be unleashed, leading to the implementation of sustainable actions and green services being offered.

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