Everything-as-a-Service in manufacturing: a literature analysis and a definition

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Abstract: Currently, several companies are progressively transitioning from an offering focused on products to providing services and solutions, a phenomenon known as servitization. Manufacturers address this transformation in order to face competition, meet the growing demand for a more flexible offering, minimize capital expenditure, and exploit the opportunities offered by digitalization. Thus, new business models which a focus on selling the usage or outcome of a product rather than the product itself are increasingly receiving attention, as they can give companies the possibility to establish long-term partnerships with customers by providing solutions on a continuous basis in return for recurring payments. In recent years, this approach has become popular, particularly in the management community, with the term "Everything-as-a-service" (XaaS). The concept of XaaS has its origin in the information technology domain but, given the context described above, its application is becoming today more and more relevant for manufacturing companies. Various declinations of the XaaS concept in manufacturing have emerged, generally linked to the sales object and the application sector (e.g. Equipment-as-a-service, Consumable-as-service, Heat-as-a-Service, …). Moreover, the literature on this topic appears very fragmented and scattered across several similar and well-established research domains, such as servitization, integrated solutions, and product-service systems. Thus, a clear and agreed definition of the term is still lacking today and the boundaries of application are also unclear. In order to fill these gaps, this paper provides a structured analysis of the literature, in order to: i) define the current state of art, ii) identify the key elements and characteristics and iii) provide a new comprehensive definition of the XaaS paradigm in manufacturing.

Keywords: Everything-as-a-Service, Servitization, Manufacturing

1. Introduction

Industrial companies have started to realize that they can no longer depend on old business strategies that focus solely on products (Kowalkowski & Ulaga, 2024). Manufacturers are observed to be transitioning from models centered solely on products to ones that incorporate advanced lifecycle services, integrated solutions, and product-service systems, thereby expanding their portfolio offerings (Rabetino et al, 2021). In recent years, especially in manufacturing sectors, the demand for new industrial equipment has declined as customers prioritize preserving cash and minimizing capital expenditures. At the same time, there is an increasing need from consumers for flexible business models also in manufacturing industries (Pezzotta et al. 2021). Within this context, the emergence of service-oriented business models presents a favorable opportunity for these companies to increase profits and generate new competitive advantages (Adrodegari et al., 2017). Firms are thus progressively transitioning from product-focused offers to service-oriented business models (Adrodegari & Saccani 2017). This phenomenon, known as "servitization" (Vandermerwe & Rada, 1988), has been discussed in literature since the '90es and it is defined as the innovation in an organization's capabilities and processes to create added value through a shift from selling products to selling an integrated combination of products and services (PSS) (Baines et al., 2009). Despite the various benefits discussed in the literature, this transformation is complex and challenging for companies as it necessitates significant modifications in the organization's structure, culture, and competencies (Adrodegari and Saccani, 2020). To achieve success in this transition, firms must not only modify their approach from being focused on products to being focused on services, but also need to restructure their business model (Kindström 2010). Thus, in recent years, the discussion on new servitized business models have gained attention also in the managerial community where, models that offer the utilization or outcome of a product rather than the product itself (Duan et al. 2015), are often mentioned under the umbrella of the "Everything-as-a-Service" (XaaS) paradigm. The XaaS concept emerged in 2007 from the information technology domain to describe an IT delivery model that relies on the virtualization of resources. In this model, resources such as infrastructures, applications, and data are made available on-demand through the Cloud. Multiple variations of the term have arisen, typically associated with the sales object and the specific industry it is applied to (such as Heat-as-a-Service, Mobility-as-a-service, Washing-as-a-Service, Robot-as-a-Service…). While there may be variations between these notions, they all serve the purpose of defining business models in which digital technology and the cloud play a crucial role in providing on-demand products and services

(Classen et al. 2023). The notion of Xaas is closely connected also to different and more flexible revenue mechanisms, such as subscription-based or pay-per-x models: in the latter, for example, the customer pays on the basis of the actual use of the (Pay-per-use) or the performance of the machine (Pay-per-performance) or the output actually produced (Pay-per-outcome). Within this perspective, in manufacturing sectors, the application of the XaaS paradigm therefore falls in the servitization transformation as it translates into business models where the manufacturer takes full responsibility for all activities necessary to ensure the equipment functions properly and customers pay based on equipment usage or output (Gebauer et al., 2017). As mentioned, these models can represent an innovative element for providers of manufacturing goods, customers, and the environment. Manufacturers and service providers gain advantages from continuous income throughout the lifespan of the product. Moreover, they are presented with a heightened potential to improve innovation. By selecting usage- and outcome-oriented models and sharing platforms, customers can obtain access at reduced upfront costs, thereby further decreasing the total cost of ownership (TCO). The implementation of XaaS models improves customer relationships by encouraging partnerships, thus creating competition with traditional models in terms of customer experience and loyalty due to the enduring nature of the relationship. Indeed, such durability facilitates collaboration and co-creation of shared value. From the environmental point of view, the retention of ownership of the asset by companies and the lifecycle responsibilities include an incentive to implement levers that are typical of the circular economy paradigm (Bressanelli et al. 2018). XaaS models in fact effectively optimize resource productivity and lifetime value by reducing material usage, minimizing waste, and lowering operational expenses (Gebauer et al., 2017).

In sum, although the focus on 'as-a-service' (*aaS) models appears recent in manufacturing, the underlying concepts of XaaS are not new or unfamiliar. There are various research domains that over the years, in different forms and with different names, have referred to this paradigm (e.g. Servitization; servitized-business models; use-oriented PSS; usage-oriented PSS; Equipment-as-service; Product-as-a-sevice;…). It is not surprising therefore that the literature on this topic is scattered and fragmented, lacks coherence and structure, failing to offer a clear definition of the term that effectively emphasizes its key attributes in manufacturing. Moreover, from a practical point of view, companies struggle to apply the paradigm because it is often poorly understood and misinterpreted (Relayr 2022). To fill all these gaps, this paper provides a descriptive analysis of existing literature to determine the current status of the topic, identify the key elements and characteristics, and present a clear definition of the XaaS paradigm in the manufacturing industry.

The paper is organized as follows: section 2 provides an in-depth description of the methodology adopted; section 3 highlights the main findings that arose from the descriptive analysis, and chapter 4 provides a definition of XaaS. The paper concludes with chapter 5, containing the conclusions.

2. Methodology

To address the identified gaps a literature review was conducted. Following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) methodology (Moher et al., 2009), articles dealing with the XaaS in manufacturing were retrieved from the academic database Scopus, specifically focusing on the manufacturing sector. For this purpose, several keywords were used, classified into three distinct groups: XaaS Paradigm, the main research topic, Manufacturing sector and Servitization, to better delineate the research field. The research was conducted following the four phases of the PRISMA standard:

1. *Identification*: search queries were created by combining the three categories with the "AND" and "OR" operators and searched in the "Title, Abstract, and Keywords" fields. Table 1 displays the keywords that yielded valuable outcomes for the analysis. As a result, 243 initial articles were obtained. After eliminating duplicates and restricting the search to English-language articles, conference papers, reviews, books, and book chapters, the final number of articles amounted to 186.

Table 1: Research keywords

Topic	Keywords
XaaS Paradigm	As-a-service, *aaS, Everything-as-a-service, Equipment-as-a-service, pay-per*, use-oriented, outcome-oriented, result*-oriented, subscription, Rental, outcome-based
Manufacturing	Manufacturing, Machinery, Product centric, durable good*, manufacturer*, industrial compan*, capital good*
Servitization	Servitization, servitisation, PSS, Product Service System*, Integrated solution*, Hybrid offering*, service transition, service infusion

2. *Screening*: an initial screening was conducted by reviewing the titles and abstracts of papers and eliminating those that were not relevant to the research objective. In this instance, the researchers employed two main exclusion criteria: papers that were not pertinent to the manufacturing sector of physical goods in a broad sense (motivation 1), and articles that did not provide a comprehensive description of the XaaS paradigm or any of its specialized aspects (motivation 2).
3. *Eligibility:* the resulting articles were thoroughly examined to ensure that their content was in line with the research scope.
4. *Included*: 6 Articles that were not directly related to the keywords chosen, but were referenced in several selected articles, such as the publications by Tukker in 2004 and 2015, were included using the snowballing strategy

The final pool consists of 91 articles (Figure 1). The papers selected were thereafter utilized in the studies conducted in Section 3, and to identify the key characteristics that form the basis of the definition of XaaS brought out in Section 4.

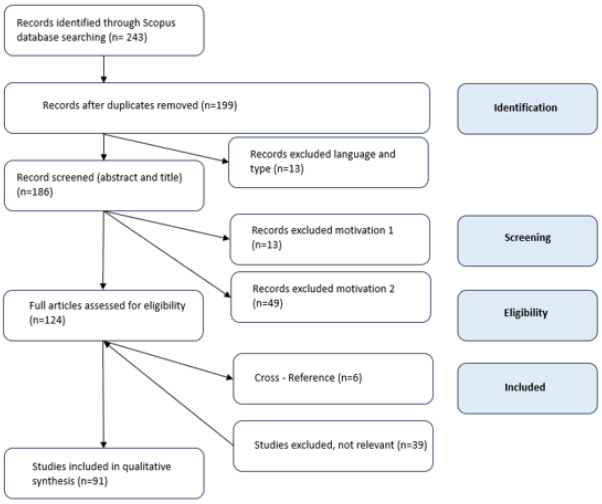

Figure 1: Literature review steps

3. Main evidences

The analysis encompassed a descriptive and thematic examination of all pertinent articles. The descriptive analysis employed a deductive technique, which involved categorizing the articles based on various criteria such as year, number of citations, paper type, subject area, methodology used and relevant sector. The purpose was to detect any patterns or trends. The theme analysis, however, followed an inductive approach to provide a definition of XaaS by examining the key features of this paradigm.

The analyzed articles were all published between 2004 and June 2023 (extraction period) (Figure 2). In particular, there is a notable surge in publications throughout the period from 2018 to 2022, with over 58 percent of the sample being released within this timeframe. This highlights how the phenomenon is recent and evolving and how it has been identified, particularly recently, using the *aaS language, especially in the context of digitization. Moreover, an analysis of the most cited papers throughout those years reveals an increasing emphasis on the *aaS model and its correlation with the circular economy (Yang et al., 2018; Souza-Zomer et al., 2018).

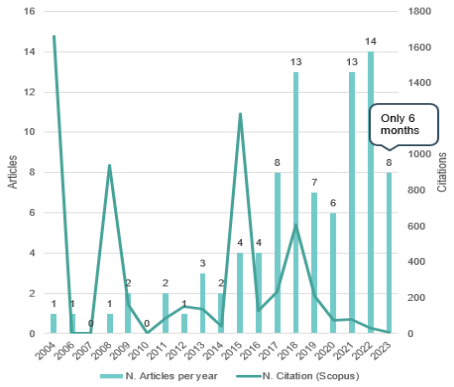

Figure 2: Temporal article distribution and number of citations

Conversely, Figure 3 illustrates the temporal distribution segmented by the type of articles under consideration. It should be noted that the number of reviews has been increasing (though still very low) in recent years, highlighting the growing interest in characterizing the XaaS paradigm.

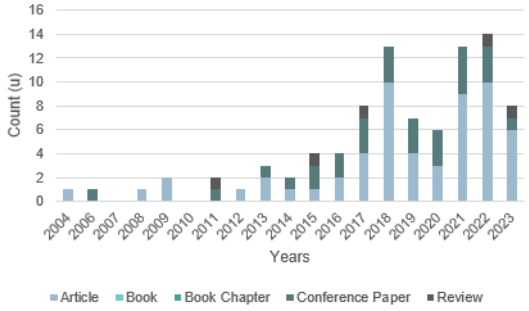

Figure 3: Type distribution

Analysis of the Scopus database reveals that 44 percent of the published papers relate to the Economic and Business sectors, with 17 articles in the former and 23 in the latter. The engineering field is represented by 16 articles. It is important to note that a journal might be associated with multiple subject areas. Figure 4 illustrates the distribution of papers across various subject areas, demonstrating the interdisciplinary nature of the issue and confirming the fragmented state of the literature about this topic.

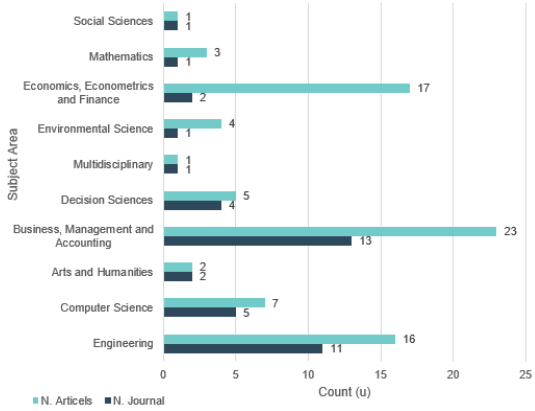

Figure 4: Classification according to the Scopus database

Analysis reveals that the topic of XaaS is predominantly addressed in the domains of economics, finance, and

engineering. Although the promising implications for the environment, the topic has not yet been studied by the environmental sciences.

The 91 final papers were categorized based on their methodological approach into two categories: "theoretical" (24) or "empirical"(67). Furthermore, within each group, qualitative and quantitative approaches were differentiated. The theoretical articles were subsequently divided into three distinct subgroups: i) literature reviews (6), ii) conceptual development (14), both qualitative approaches, and iii) analytical models (4), employing quantitative methods. Articles in the first category provide a comprehensive analysis of studies on a specific subject. The second category focuses on constructing interpretive models for research topics. Lastly, articles included in the third category present computational and mathematical models aimed at understanding the behavior of a system. Empirical papers were categorized into three subcategories for the qualitative approach: case studies (49), action research (3), and expert panels (2). For quantitative methodology, they were separated into three subcategories: survey (1), panel data analysis (3), and analytical model (9). Case studies, action research, and expert panels are methods used to examine the features and the context of a subject in real practice through interviews and comparisons with specialists. On the other hand, quantitative analysis relies on gathering and analyzing numerical data to comprehend, depict, and derive conclusions about a phenomenon of interest using surveys, simulations, and mathematical models.

Out of the publications that were analyzed, 74% were categorized as empirical; this demonstrates how little focus is placed on the conceptualization of the XaaS paradigm, and how this work aims to fill this gap by giving a more comprehensive description of the concept and a definition. Among these empirical papers, 73% employed case studies as a methodology (49 articles). This is due to the widespread focus on organizations that have already successfully implemented this model, in order to identify best practices, challenges, and necessary adaptations and for comprehending the phenomena and establishing recommendations for companies interested in pursuing this approach. This is further supported by the number of works dedicated to employing conceptual development (14) or suggesting a mathematical model derived from empirical data (9). Focusing only on empirical papers, it is notable that the majority of the publications (51) focus on cross-sector cases. For instance, Karatzas et al. (2022) examine 41 manufacturing enterprises, while Weking et al. (2018) compare 15. There are only 16 articles that specifically focus on one sector. Upon examining the distribution of sectors depicted in Figure 5, it is evident that the industrial machinery and equipment sector was the most reviewed, with a total of 53 instances. The automobile industry, on the other hand, had 28 cases, making it the second most frequently investigated sector. Several studies, however, examined the sectors of household appliances and consumer electronics (21) as well as defense, aviation, and aerospace (20). These results confirm the strong propensity of OEMs to embrace this paradigm. They also demonstrate its wide presence in various sectors, such as the automotive sector, with car-sharing and mobility-as-a-service; the appliance sector, with revenue models such as pay-per-wash; and the aviation sector, the birthplace of Rolls Royce's power-by-the-hour program. Furthermore, 42 percent of the publications focus on business-to-business (B2B) companies, 31 percent on business-to-consumer (B2C) industries, and the remaining articles encompass both categories. As expected, the majority of the cases (36) relate to Original Equipment Manufacturers (OEMs) and, in a broader sense, companies that produce finished goods.

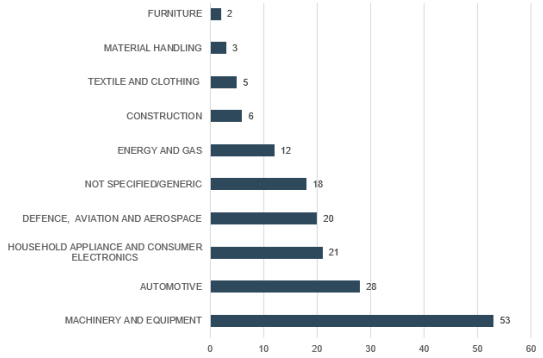

Figure 5: Sector distribution (empirical papers)

Finally, in line with the objectives of this paper, we scrutinized the different papers to identify papers that provide a "definition" of the *aaS models discussed. The 17 papers selected are discussed in detail in the following section.

4. Defining XaaS in manufacturing

To define the concept of XaaS, we analyzed the papers that provided an initial definition of the phenomenon, investigating the key common features. To this initial analysis, which covered 17 of the initially selected papers, additional seminal articles reporting common examples of XaaS, but not specifically related to the manufacturing sector and therefore excluded from the review, were then added to confirm the characteristics identified in the first phase. Mourtzis et al. (2021, p. 332) define Manufacturing-as-a-Service as "an integrated set of products and services offering added value to industrial applications (..) requires an example shift towards selling functionality rather than selling products" while Mustonen et al. (2019, p. 1) assert that the Product-as-a Service (PaaS) is a business model where "a physical product is transformed into a means of production." Wasserbaur et al. (2023, p. 2), illustrate the example of Heat-as-a-Service (HaaS), which emphasizes the transition from the "transactional sale of boilers to offering integrated solutions that deliver heat and comfort to domestic households" while Buerkle et al. (2023, p. 2) described the Robot-as-a-service (RaaS) asserting how "Similar to other "as-a-service" theorems, the characteristic of RaaS is to rent software or computing hardware, rather than acquiring it". Thus, these definitions encompass the **integrated solution** characteristic of the servitized models, wherein the product, in this case, is conceptualized and promoted as a service. Furthermore, the focus of the offer shifts towards delivering a **value-**

added service that gives the customer exactly what they want, thereby fulfilling their requirements. In the XaaS concept, therefore, X can represent either a product (such as Tires-as-a-Service), a service (such as Heat-as-a-Service), or a functionality (such as mobility-as-a-service). Duan et al. (2015) introduce the notion of XaaS specifically within the context of Information Technology and in particular of the Cloud Computing paradigm. The enabling factor in this definition is therefore technology, and in particular cloud computing that offers **on-demand access** (Monetti & Maffei, 2023). According to Duan et al. (2015), cloud computing is recognized as an as-a-service model: Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS) are typical examples. Vandermerwe & Erixon (2023, p. 484) highlight how "thanks to everything being in the cloud, customers can get exactly what they want, without having to own content or infrastructure". Therefore, in this definition, we discover an extra characteristic of the XaaS model, which is the provider's **retention of ownership** over the asset, software, and infrastructure necessary to provide the service, as well as the **assumption of risks** that were traditionally borne by the customers (Gebauer et al., 2017). By examining the most common definitions in the literature about PSS, Servitization, and related concepts in this topic it emerges that while the aspects of integrated solution and value-added can also be found in the more common definitions of Servitization and PSS (Tukker and Tischner, 2006; Baines et al., 2007; Vandermerwe & Rada, 1988), the on-demand aspect is a defining factor of the paradigm, enabling both a change of mindset regarding the concept of asset ownership and the possibility of establishing a **relation-based approach** to the customer. Many of the benefits associated with XaaS paradigm adoption for the customer and the company, as well as for the environment, illustrated previously, are related in fact to the ability to establish trust between the parties. The technology behind the XaaS model makes it possible to analyze the customer's choices, tastes, and needs and provide targeted and personalized service (Kowalkowski & Ulaga, 2024). In addition, it enables timely and preventive intervention in case of failures and provides necessary assistance at all times (Monetti & Maffei, 2023). The aaS model is commonly linked to several pricing systems, including subscription, fixed fee, and pay-per-x, which are determined based on the agreement between the consumer and the company. However, at its core, the frequency remains, setting it apart from one-time transaction models that do not facilitate the establishment of client relationships. Based on the above consideration, we have defined the as-a-service model as "*an integrated solution, available on demand, that, through a value-added offering, provides the customer with exactly what they want when they need it*". The main XaaS features that emerged are illustrated in Table 2.

Table 2: XaaS main features

Main features	References
Integrated solution	Azcárate-Aguerre et al. (2022); Bettoni et al. (2018); Buerkle et al. (2023); Chiarot et al. (2022); Mustonen et al. (2019); Opresnik & Taisch (2015); Perruzzini & Germani (2014); Peruzzini et al. (2013); Pulkkinen et al. (2019); Sanchez et al. (2023); Wasserbaur et al. (2023); Yang et al. (2009)
Value-added service	Bettoni et al. (2018); Perruzzini & Germani (2014); Peruzzini et al. (2013); Sanchez et al. (2023)
On-demand access	Buerkle et al. (2023); Mourtzis et al. (2020); Peruzzini & Germani (2014); Peruzzini et al. (2013); Webb & Bil (2011); Yang et al. (2009)
Ownership retention and risk assumption	Buerkle et al. (2023); Huang et al. (2020); Opresnik & Taisch (2015); Pulkkinen et al. (2019)
Relation-based approach	Mourtzis et al. (2020); Opresnik & Taisch (2015); Peruzzini & Germani (2014); Peruzzini et al. (2013); Pulkkinen et al. (2019); Webb & Bil (2011); Weking et al. (2018); Yang et al. (2009)

5. Conclusion

The XaaS paradigm is gaining interest due to its potential to promote sustainable practices and circular economy strategies (Tukker, 2015; Matschewsky, 2019). Additionally, it is closely linked to the digital transformations that are significantly impacting the current market (Rapaccini and Adrodegari, 2022). Especially in manufacturing companies, the model effectively captures the potential benefits of digitization, artificial intelligence, and automation processes (Mourtzis et al., 2020). The existing literature in this field is still undergoing development, but it is fragmented and does not place much emphasis on the conceptualization aspect of the phenomena. However, knowing this aspect is crucial for comprehending the fundamental features and establishing clear boundaries of the topic. Moreover, many common definitions and examples used in literature such as access/outcome/performance-focused models are employed as different synonyms of XaaS cases (i.e. the power-by-the-hour by Rolls-Royce, Tires-as-a-Service by Michelin, carsharing by ShareNow, Pay-per-Part by TRUMPF, or Lighting-as-a-Service by Signify) (Schaefers et al., 2021). This research tries to address these gaps by conducting a structured literature analysis and offering a definition of the notion of XaaS. From a managerial and practical point of view, this paper helps manufacturing companies to better understand this phenomenon and related characteristics in order to apply the XaaS paradigm within their organization more effectively and consciously. In addition, a clear definition helps to delineate the boundaries for future research focused on developing a framework for implementing the XaaS paradigm in the manufacturing sector. However, this work is subject to limitations as it is only a first step aimed at providing an initial definition limited to the manufacturing domain. Future research will involve a deeper investigation of the characteristics to more precisely delineate the boundaries of the paradigm.

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