This article has been accepted for publication in IEEE Transactions on Engineering Management. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TEM.2024.3383462

Linking Digital Servitization and Industrial Sustainability Performance: A Configurational Perspective on Smart Solution Strategies

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***Abstract*—Manufacturing companies are introducing innovative ways to facilitate the sustainable transition of their customers' operations. The emerging literature on digital servitization proposes numerous factors, such as the use of advanced AI analytics, orientation toward outcomes, and aligning ecosystem partnerships, which can potentially influence the sustainable performance of industrial customers. However, there is currently a lack of understanding regarding how these factors interact to result in sustainable outcomes. Hence, this study seeks to shed light on these complex relationships by identifying viable smart solution strategy configurations for achieving customer sustainable performance. Drawing on a dataset of 180 Swedish manufacturing firms, this study uses a configurational comparative method – namely, fuzzy-set qualitative comparative analysis (fsQCA) – to identify the impact of different configurations of "AI-driven optimization", "outcome orientation", "value co-creation", and "ecosystem orchestration" conditions on the realization of customer sustainable performance. This study has identified five smart solution strategies that empower manufacturers to realize sustainable performance for their customers. Among the five configurational strategies identified, the first configurational strategy appears to be the most prominent, as it is based on an outcome-based approach in which the firm uses its technological expertise and its ecosystem partnerships to take over customer operations. Thus, this study contributes to the ongoing discussion in digital servitization on its enabling role for industrial sustainability practices.**

***Index Terms*—AI-driven optimization, digital servitization, ecosystem orchestration, industrial sustainability, smart solutions.**

This paragraph of the first footnote will contain the date on which you submitted your paper for review, which is populated by IEEE. This work was supported in part by Vinnova, and in part by Formas (grant number: 2020-01791). The name of the corresponding author appears after the financial information, e.g. *(Corresponding author: Milad Kolagar).*

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I. INTRODUCTION

INDUSTRIAL manufacturers are increasingly assuming responsibility for tackling the climate crisis by prioritizing environmental sustainability in their solutions [1], [2] and by leveraging digitalization [3], [4]. A key trend in this domain is digital servitization[1] where manufacturers leverage digital technology to create new digital service offerings to support their customers [5], [6]. Although not a key focus of the extant literature, there is a growing body of evidence to suggest that digital servitization serves as a powerful catalyst to transition manufacturing toward assuming responsibility for the environmental impact of their customer operations [1], [7]. For example, the use of advanced digital technologies, such as artificial intelligence (AI) and internet of things (IoT), can facilitate the creation of sustainable offerings capable of optimizing resource usage and minimizing negative environmental impacts [8], [9].

Despite this potential, the relationship between digital servitization and sustainability is not that well understood, and there is still much uncertainty on how manufacturers can best support their customers to achieve sustainable performance [7], [10]. The digital servitization literature provides limited and opposing empirical evidence on the performance effects of digitally-enabled advanced service provision [1], [11]. Studies suggest that the relationship between digital servitization and performance is complex, non-linear, and moderated by a variety of factors [12]–[14]. Recent studies have highlighted the shortcomings of a linear approach, calling for digital servitization scholars to recognize alternative narratives [15], [16] and pursue greater variety and depth when theorizing about the digital servitization–performance relationship [10], [13]. One central question relates to how industrial providers can configure solutions to advance their customers' sustainability [17], [18]. Indeed, manufacturers have several options at their disposal for developing digitally-enabled advanced services, and the most appropriate strategy to increase sustainable performance for their customers is not clear. For example, the literature on digital servitization indicates that manufacturers may select an

[1] This new stream in the servitization literature [7], [66] has been defined as the *"transformation in processes, capabilities, and offerings within industrial firms and their associate ecosystems to progressively create, deliver, and capture increased service value arising from a broad range of enabling digital technologies, such as the Internet of things (IoT), big data, artificial intelligence (AI), and cloud computing"* [83].

artificial intelligence-based approach [19], [20]. As a result of these AI-based approaches, industrial solutions can be developed with a variety of potential benefits, which include process efficiency improvements, improved resource optimization, and the facilitation of in-depth decision making [9], [21]–[23]. Moreover, the digital servitization literature has focused on providing outcome-oriented services by industrial firms [17], [24]. The long-term nature of these types of services often makes manufacturers more inclined to act sustainably in order to benefit their customers by saving energy and reducing carbon dioxide emissions [25]. Another condition for creating sustainable value is the cooperation between manufacturers and their customers [26], [27]. Rather than being solely generated by manufacturers and providers, sustainable value is now created through having effective interactions with customers [28]. Furthermore, it has been demonstrated that manufacturers may choose to partner with complementary actors by orchestrating ecosystems [29], [30]. By doing so, firms are seeking new synergies, partnerships, and collaboration formats that will enable them to maintain their competitiveness within an ecosystem [31], [32]. It is also possible to combine these approaches in different strategy configurations [15].

In this regard, several gaps in the literature make this an important issue for further study to pursue. First, there is *a need to gain a deeper understanding of the relationship between digital servitization and sustainability and to elucidate the connection between these two concepts*. For example, Schiavone et al. (2022) considered digital service as the function of a degree of adaptation on the part of stakeholders, changes in the value chain, and digital transformation toward sustainability [33]. Similarly, Paiola et al. (2021) investigated digitally based business model innovation and networking on sustainability in manufacturing [33]. Indeed, despite the fact that there is a growing number of papers highlighting the importance of advanced AI analytics [19], [20], outcome orientation [24], [25], value co-creation [27], [28], and ecosystem orchestration [29], [30] in the digital servitization literature, there is still scant understanding of the vital and facilitating roles played by these seemingly distinct but interdependent conditions in achieving sustainable performance for the customers. These conditions are contingent on many factors, which can exert an impact on how management prepares the ground for digital servitization [34]. For example, the sustainable performance of customers is a multi-faceted concept [14], [18], which involves a high level of collaboration, connection with multiple parties, and the appropriate application of technology [35]. Moreover, AI and machine learning algorithms can be used in service design, production planning and control, solution customization, and automated multidisciplinary optimizations [21], [22], [28]. There is a lack of research into the impact of these factors on the economic, social, and environmental performance of industrial customers. Second, there is still a *lack of knowledge on effective strategy configurations that can lead to the sustainable performance of manufacturing firms*. From the results of digital servitization research, it has become increasingly clear that a direct link between digital services and performance is not always possible because it depends on the companies under study and their context [10], [14]. Indeed, a configurational approach [15], [18] is an ideal way to advance the digital servitization literature beyond overly simplistic, linear explanations and to show that industrial firms can achieve sustainable performance along several pathways. The configurational lens enables the capture of three types of causal complexity. Specifically, it captures conjunctions (i.e., different conditions acting in conjunction rather than independently), equifinality (i.e., the desired result achieved through multiple paths), and causal asymmetry (i.e., low-performing configurations are not necessarily mirror images of high-performing configurations) [34]. Understanding complex phenomena – as, for instance, achieving sustainable performance in terms of different, equifinal configurations of relevant factors – is considered a more accurate description of reality than is possible with linear and additive models [15], [16], [18].

As part of an effort to fill these research gaps, this study aims to shed light on the complex relationships between four key conditions required to provide digitally-enabled advanced services and solutions (i.e., AI-driven optimization, outcome orientation, value co-creation, and ecosystem orchestration). These conditions can facilitate a more sustainable performance for customers. Hence, the purpose of this study is to *"explore smart solution strategy configurations in order to realize sustainable performance for industrial customers."* Also, the main research question of the study is *"what configurational strategies can industrial firms employ to provide sustainable performance to their customers?"* In doing so, we draw on an extensive survey dataset of 180 manufacturers and fsQCA analysis [36], [37] to identify different smart solution strategies that can lead to the realization of customer sustainable performance. Several important contributions have been made both to theory and to industry as a result of this study. The first contribution of this study is to the literature on digital servitization [6], [11], [35] and industrial sustainability [1], [33] by examining the relationship between digital servitization and sustainability. The second contribution is the formulation and analysis of several configurational strategies designed to provide smart solutions that support customer sustainable performance in their business operations. In our third theoretical contribution, we provide insights into the optimal smart solution strategies and how AI-driven optimization and ecosystem orchestration are intertwined. Moreover, as part of this research's contribution to managerial practice, managers and practitioners are advised to take into account the strategic vision of sustainability goals and to emphasize the importance of customer sustainable performance within their organizations. Furthermore, managers should pay particular attention to implementing a smart solution strategy based on the continuous evaluation of their ecosystem-focused and AI-focused capabilities.

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II. Theoretical Background

A. Digital Servitization for Sustainable Performance

The pursuit of sustainable development does not merely involve economic benefits for companies but a triple bottom line approach offers a combination of economic, environmental, and social performance rather than merely traditional economic benefits [33], [38]. In response to changes in environmental policies, legal regulations, and pressure from governments, customers, competitors, and other stakeholders to minimize the negative impact of operations on the environment, industrial firms are increasingly trying to adopt more sustainable practices in their decision making and daily operations [1], [2], [39]. According to recent studies, enhanced sustainability performance cannot be achieved without innovative approaches [6], [31]. Indeed, innovation is the central element that will enable businesses to improve their environmental and social performance, which in turn will enable them to evolve along the sustainability trajectory [4], [38]. For manufacturing firms, digital servitization has been identified as a transformational journey that allows them to offer more advanced digital services to their customers, which plays an essential role in enhancing customer sustainable performance [20], [35]. Advanced digital services that are based on the provision of optimized, more efficient services use reduced resources [20]. In the literature, these services have been conceptualized as “smart solutions”. Labeled under the term “smart products” in some cases [40], smart solutions have been defined as an advanced state of product-service-software systems for servitization [14], [41]. An example of how smart solutions contribute to customer sustainable performance is in reducing waste, air emissions, solid waste, toxic material consumption, and the frequency of environmental accidents by using digital optimization solutions [42]. In the same vein, this research has used service dominant (S-D) logic [43] to conceptualize the relationship between the smart solution offering and the realization of customer sustainable performance. As a scientific-cultural approach, S-D logic aims for value co-creation by assuming that services are the basis for social and economic exchange [43], [44]. In investigating the manufacturing industry in this instance, it provides a revealing lens through which to analyze the customer sustainable value as co-created in the context of digital servitization [28].

In the same vein, and throughout this research, we conceptualize customer sustainable performance as including all the economic, environmental, and social benefits [45] for customers resulting from leveraging smart solutions. In this regard, we conceptualize economic benefits for customers as including increased profitability, reduction in waste and inefficient processes, decreased manufacturing/operational costs, and enhanced productivity. Moreover, we conceptualize the environmental benefits as including help for customers to reduce their energy consumption, waste generation, and atmospheric pollution. Furthermore, the social benefits for the customer have been conceptualized as involving increased safety for their workers, removal of harmful work tasks, and improved working conditions. Overall, customer sustainable performance is complex and uncertain in manufacturing firms [1], [10], [45], and how smart solutions achieve this outcome is not well understood. Indeed, different paths exist to achieve customer sustainable performance. This suggests that further investigation is required, which is the purpose of this study.

B. A Configurational Perspective towards Customer Sustainable Performance

The configurational perspective can be adopted to shed light on the causal mechanisms underlying the success of manufacturing firms in offering sustainable performance to their customers [15], [34]. In organization research, configurational theories have been used widely to explain why some companies are successful and others are not [14], [18]. In essence, it is believed that companies achieve their strategic goals through orchestrating their organizational characteristics to achieve a sense of "fit" [46]. The notion of fit generally implies that it is not the presence of certain conditions nor their extent that determines a given outcome, but how they are aligned within that context [16], [36], [47]. Various studies related to performance success have shown that "fit" between different organizational and environmental characteristics is critical to success [2], [12], [13]. Studies in the literature have frequently utilized contingency theory [48] as their theoretical foundation, emphasizing that the performance of an organization is influenced by the context and environment in which it operates [34]. Despite acknowledging that success can be achieved in more than one way, contingency theory assumes that relationships are unidirectional and linear [15], [34], [37]. Unlike the linear approach, the configurational approach explicitly addresses nonlinearity [15], [34], where configurations are described as "inherently multidimensional entities with key attributes that are tightly interconnected and mutually reinforcing" [49]. Indeed, the assumption is that complex causality exists [50]. Generally, it is held that complex causality provides a more accurate prescription of how complex phenomena occur in reality as a result of equifinal, joint, and asymmetric causality [51], [52]. An equifinal result occurs when different configurations of causal factors produce the same outcome [34].

Moreover, the concept of conjunctional causation refers to the fact that a causal condition might not affect the outcome by itself, but only when it is combined with other causal conditions [34], [47]. Indeed, it may have opposing effects when combined with other factors [15]. Furthermore, asymmetric causation implies that the presence or absence of an outcome can be attributed to various combinations of causal factors [34]. As a consequence, failure to offer customer sustainable performance is not just a mirror image of success. Thus, we can argue that the sustainable performance success of customers is not only determined by "fit" between contingency factors but also by equifinality, conjunctural causation, and asymmetry [52]. Currently, there is a dearth of studies in the digital servitization literature stream that examine sustainable performance from a configurational

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perspective and account for causal complexity [29]. In fact, the studies that do exist can be criticized for focusing exclusively on financial performance [7], [53] or non-financial outcomes [52], [54] in offering advanced services. As far as we are aware, no previous research has examined the factors presented in this study or has evaluated how these factors might impact customer sustainable performance from a configurational standpoint. A need continues to exist for research on conditions that contribute to a higher level of customer sustainable performance. Therefore, the following sub-sections aim to introduce a variety of conditions that contribute to customer sustainable performance, including *AI-driven optimization*, *outcome orientation*, *value co-creation*, and *ecosystem orchestration*. Furthermore, Fig. 1 illustrates how we conceptualized these conditions and the study's outcome variable.

1) AI-driven Optimization: Artificial intelligence is considered a key technology in the development of manufacturing in the context of Industry 4.0 [21], [22]. It involves utilizing electronic equipment to mimic human intelligence capabilities [19], [55]. It enhances the industrial firms' decision-making power based on both real-time and historical data [23], and it accelerates the process of value co-creation for firms [20] with minimal human intervention [19]. A major characteristic of the new generation of artificial intelligence is its cognitive and learning potential and its ability to integrate information from different sources to generate knowledge and apply it effectively [19], [56]. In managing customer operations, AI has also proved useful in forecasting, inventory management, finance, sales, logistics and supply chain management, and risk management [17], [56]. Data visualization techniques and use of different dashboards allow the organization to decompose information and gain a better understanding of the business context, while predictive analytics allow it to identify business opportunities and capitalize on them [19], [56]. Indeed, an organization's overall health can be positively affected by the use of artificial intelligence [14], [19], [56]. In fact, the use of artificial intelligence can enable a system to assimilate and analyze data, gaining knowledge and insight from it [19], [57]. As a result of this knowledge, certain objectives in the manufacturing industry can be achieved. Moreover, it is possible to manage the product lifecycle using big data technologies [19], [20]. AI is capable of facilitating organizations to revitalize the project goals on a regular basis and to put a sharper focus on continuous improvement by optimizing resource usage and managing assets more effectively [21], [56]. While emerging technologies, such as AI, are becoming more popular, there is still ambiguity regarding how these technologies can impact the sustainable performance [10], [13], [58] of customers. In light of these arguments, we present the following:

Proposition1. AI-driven optimization is a condition that can improve customer sustainable performance when combined with other enabling conditions for the development of smart solutions.

2) Outcome Orientation: It is becoming increasingly prevalent for manufacturers to offer outcome-based services and offerings as innovative means to improve the business performance of their customers while helping them to achieve more sustainable performance [25]. Currently considered to be one of the most advanced forms of servitization [24], [25], outcome-oriented offerings are a testament to the shift from a transactional to a relational relationship between service providers and customers [34]. On the technical side, in order for outcome orientation to be implemented successfully, providers must not only use monitoring technologies to ensure that outcomes are achieved [24] but also leverage resources to facilitate the management of customer's maintenance function and the implementation of preventive measures [59]. Moreover, from a relational perspective, operations and incentives of the contracting parties are intertwined as providers and customers realign their value-creation and value-capture mechanisms by moving towards outcome orientation [29]. Indeed, outcome-oriented offerings and services can be defined as service business models [60] in which at least some of the provider's payment [61] is determined by functional results [24]. This type of offering can be most clearly recognized in Rolls-Royce's "power by the hour", which bills customers according to engine usage hours [60], [62]. Many engineering companies, including Hitachi, Caterpillar, and Bombardier, charge customers based on the number of hours their equipment is used [62], [63]. In this regard, smart solution providers are often able to identify and diagnose operational problems in a customer's organization (the business model and processes of which the customer might be unaware) and offer proactive solutions designed to assist the customer in overcoming them [34]. Additionally, they will be able to provide services to operate the products sold to their customers as well as operating their

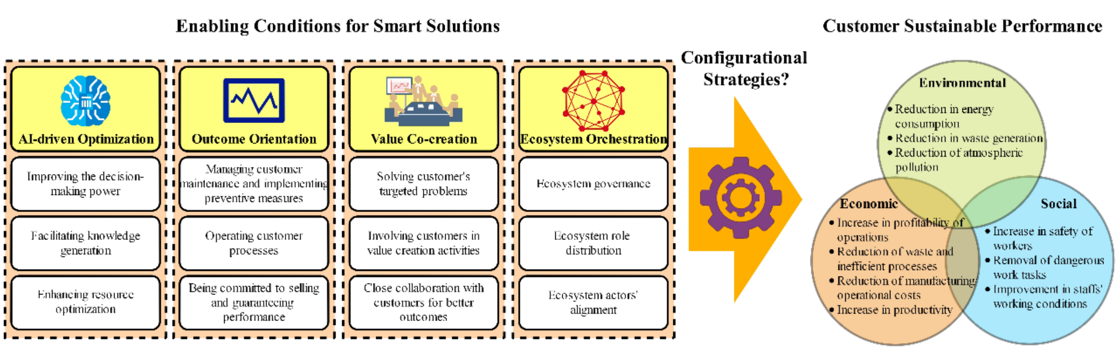

Fig. 1. A summary of the research purpose and conceptualization of different constructs

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processes. As part of this offering, outsourcing services and performance guarantees are provided, as well as selling performance to the customer [53]. It is our preference, in line with Schaefers et al. (2020), to use the prefix “outcome” because the term “performance” is ambiguous and varies depending on the context in which it is used (e.g., engine performance or act performance) [64]. Several studies indicate that outcome orientation offers manufacturing companies considerable potential for profit [24], [25], [65]. Taking these arguments into account, we develop the following:

Proposition 2. Outcome orientation is a condition that can improve customer sustainable performance when combined with other enabling conditions for the development of smart solutions.

3) Value Co-creation: As part of digital servitization, relationships are instrumental in understanding customers' needs and objectives in order to balance the uniqueness of their situation with the capabilities of the service provider [27], [28]. In line with the service-dominant logic [43], [44], changing the logic from a goods-based paradigm to a service-based paradigm that places value at the heart of customer interactions entails customer involvement in customizing services [66]. In this regard, value can be characterized as an experiential concept that cannot solely be created by the service provider, but it is generated cooperatively by the beneficiaries (e.g., customers). Consequently, this makes the provider an intermediary or facilitator of value creation and the customer a co-creator [27]. In this context, value co-creation can be conceptualized as a collaborative process involving various actors (e.g., solution providers and customers) in reciprocally beneficial resource integration [29], [32]. In essence, value co-creation in digital servitization means that both the digital servitizing firm and the customer participate actively in the process of creating value through direct interaction with one another [67]. The provider must develop the skills to take responsibility for the processes on the customer side, understand their expectations, design services to solve their targeted problems, and estimate the risk of failure with such projects [68]. On the other hand, customers must overcome their fear of losing control over their data and of not having sufficient knowledge initially to function in a data-based relationship if they want to achieve sustainable performance. This means they may resist introducing new data-driven solutions [35], [57]. Accordingly, prior studies point out that, in the case of digital servitization, value is co-created in ecosystems and not just in provider–customer dyads [29], [69]. Indeed, value co-creation occurs beyond the boundaries of individual organizations and involves various stakeholders who have access to discrete data and play different roles in processing. As a result, it remains necessary to determine how the ecosystem should be orchestrated so as to facilitate the co-creation of value. We therefore present the following:

Proposition 3. Value co-creation is a condition that can improve customer sustainable performance when combined with other enabling conditions for the development of smart solutions.

4) Ecosystem Orchestration: Since its inception in the management literature, orchestration has been regarded as a fundamental concept for understanding the evolution of ecosystems [29], [30]. Throughout the literature, orchestration has been defined as “a set of activities aimed at configuring multiple actors into a network as well as directing and managing the processes of value creation and value capture” [70]. There has been significant research on this concept with a focus on maximizing the use of shared resources and resource complementarities [5], [29], [30]. It is acknowledged in the literature that ecosystem orchestration involves a diverse range of evolving actions aimed at redefining and revising the stakes of actors in realizing and implementing digital services and solutions [29], [35]. There is, indeed, a necessity for a central firm to act as an “orchestrator” and organize platforms for communication between participating companies and customers, to maintain the collaboration, to define the roles and responsibilities of different actors, and to facilitate innovation within the ecosystem [29], [71]. It is, therefore, an essential part of orchestration to enforce the rules of the game and ensure that other partners adhere to them [72]. In addition, there is a need to agree on the ecosystem performance goals and formulate some rules and regulations for governing the ecosystem. Moreover, different ecosystem roles should be assessed and assigned in relation to the capabilities and offerings of different actors, and the responsibilities need to be mutually negotiated by keeping a global ecosystem perspective in mind. Furthermore, different actors should be aligned in order to facilitate the realization of new value propositions, ensure the revenue flow, and align the risk/reward distribution to create a win-win relationship [29]. In order to enable digital service innovation, it is imperative that data and digital technologies are used in a conscious and collaborative manner by various stakeholders in the ecosystem [35], [57]. The processes that orchestrate ecosystems have not been fully explained in pertinent studies, although some have offered accounts of how ecosystems may be described [29]. Therefore, there is a need for clarity on how such changes take place and which mechanisms should be applied to orchestrate an ecosystem of interdependent actors for the purpose of developing smart solutions to promote customer sustainable performance in the manufacturing industry. Accordingly, we propose the following:

Proposition 4. Ecosystem orchestration is a condition that can improve customer sustainable performance when combined with other enabling conditions for the development of smart solutions.

III. Methodology

A. Sample and Data Collection

As part of our study, we examined the different configurations of *AI-driven optimization*, *outcome orientation*, *value co-creation*, and *ecosystem orchestration* conditions that can lead to a higher customer-sustainable performance in a sample of 1,500 Swedish manufacturing firms. An industry-

Table I
Constructs and items, including reliability and validity information

Constructs and items	Factor loadings	Cronbach's alpha	AVE
AI-driven Optimization (AIO)		0.92	0.65
We are using BDA-AI for enhancing decision-making power.	0.85		
We can easily integrate information from different sources using BDA-AI.	0.88		
We routinely use data visualization techniques to assist users or decision makers to understand complex information.	0.72		
Our dashboards give us the ability to decompose information to help root cause analysis and focus on continuous improvement.	0.74		
We have optimized resource usage and utilize assets in a better manner by leveraging BDA-AI.	0.85		
The BDA-AI project goals are reviewed regularly based on the dynamic business environment.	0.78		
Outcome Orientation (OO)		0.84	0.68
We are managing the customer's maintenance function.	0.70		
We offer services for operating the product sold to the customer.	0.81		
We offer services for operating customer's process.	0.86		
We are providing outsourcing services.	0.72		
We are providing performance guarantees.	0.67		
We are selling performance without selling the actual product.	0.61		
Value Co-creation (VC)		0.85	0.59
Our services are designed to solve the targeted problem of our customer.	0.78		
The starting point for value creation is meeting customer needs with the services we provide.	0.81		
Customers are strongly involved in our value creating service activities.	0.75		
We collaborate closely with our customers to reach better service outcomes.	0.72		
Ecosystem Orchestration (EO)		0.94	0.66
We have agreed on ecosystem performance goals (e.g., KPIs for all actors) with our partners.	0.75		
We have formulated rules and regulations for governing the ecosystem.	0.72		
We have assessed different ecosystem roles in relation to capabilities and offerings.	0.79		
We have negotiated the responsibilities between different actors.	0.83		
We have considered inter-organizational roles (i.e. front-/back-end) with global ecosystem perspective.	0.82		
We have aligned different actors for the realization of new value propositions.	0.82		
We have ensured the revenue flow between different actors in the ecosystem.	0.89		
We have aligned the risk/reward distribution among different actors for creating the win-win relationship.	0.82		
Customer Sustainable Performance (CSP)		0.89	0.62
We have helped our customers in reducing their energy consumption.	0.71		
We have helped our customers in reducing their waste generation.	0.72		
We have helped our customers in reducing their atmospheric pollution.	0.63		
We have negotiated the responsibilities between different actors.	0.76		
We have helped our customers in reducing their waste and inefficient processes.	0.71		
We have helped our customers in decreasing their manufacturing/operational costs.	0.79		
We have helped our customers in increasing their productivity.	0.75		
We have helped our customers in increasing the safety of their workers.	0.65		
We have helped our customers in removing their dangerous work tasks.	0.71		
We have helped our customers in improving the working conditions of their staff.	0.68		

based random selection was conducted from companies in the manufacturing segment, known as SNI code 28 (manufacture of machinery and equipment). The study of these segments of industry is a prominent feature of research on digital servitization [34]. As a further safeguard, we selected companies with more than 20 employees to exclude micro-enterprises that are unlikely to manufacture products and provide advanced services. In this way, small, medium, and large manufacturing companies were included in the sampling process while micro-enterprises were excluded since they tend to offer lower levels of digitally enabled smart services and solutions. To encourage participation in the study, the researchers used an online platform to send cover letters by email and a link to the questionnaire to each CEO and general manager. Following the initial contact, two reminder emails were sent to selected firms, and we phoned them to encourage them to participate. Our sample of 1,500 companies received 192 responses from the CEOs and general managers, of which 180 were complete and usable for analysis. Furthermore, the questionnaire was pilot tested by three academic researchers and two manufacturing industry managers to ensure that each item matched the dimension being measured.

Except for one scale (i.e., ecosystem orchestration), the questionnaire used scales from the literature to measure the conditions and the level of customer sustainable performance in the sampled firms. The scale for AI-driven optimization was adapted from the research by Bag et al. (2021) [56]. We utilized a six-item scale, and we included items such as "we routinely use data visualization techniques to assist users or decision makers to understand complex information." The scale for outcome orientation was adapted from Abou-foul et al., (2020) [53] and included six items measuring, for example, the extent to which those firms "offer services for operating customer processes." The measure of value co-creation was adapted from Brax et al. (2021) [67] and had four items measuring, for example, the extent to which "customers

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are strongly involved in our value creating service activities." In addition, the scale for ecosystem orchestration was inspired and developed by Kolagar et al. (2022) [29] and had eight items measuring, for example, the extent to which the manufacturing firm has "aligned the risk/reward distribution among different actors to create the win-win relationship." Furthermore, the measure of customer sustainable performance was adapted from Pesch et al. (2021) [45] and had ten items measuring, for example, the extent to which the manufacturing firms "have helped the customers to reduce their waste generation." Additionally, for all multiple-item measures, the items were scored on a 7-point Likert-type scale using the anchors of "strongly disagree" to "strongly agree."

Furthermore, we have used statistical methods based on congeneric approaches that argue for the increase in accuracy estimation and representativity of latent constructs in order to verify the validity and reliability of the data [73], [74]. In this context, we have used the free online CLC estimator tool [75] to assess several indicators of latent constructs, such as factor loading, Cronbach's alpha, and average variance extracted (AVE) [73]. A full list of items is shown in Table I as well as the results obtained from using the CLC tool. Based on the item factor loadings, each item was evaluated on its reliability, and all exceeded 0.6, which indicates satisfactory reliability. By evaluating the internal consistency of the constructs with Cronbach's alpha, it was determined that they were credible since they were greater than 0.7. Also, the AVE values were all acceptable and well above 0.5, thus supporting convergent validity, ensuring consistency of results across different measurement tools [76].

B. Data Analysis using Fuzzy-set Qualitative Comparative Analysis

In order to explore the propositions of this research, the fuzzy-set qualitative comparative analysis (fsQCA) approach is employed, which integrates fuzzy set theory and fuzzy logic with the qualitative comparative analysis (QCA) technique [15], [34], [77]. This approach identifies patterns of elements (i.e., configurations) between the independent and dependent variables and goes beyond traditional variance analyses and multiple regression analysis [34]. A pattern of independent variables may also lead to solutions that are not identified by MRAs because their contribution to the outcome is limited to a small percentage of the cases as opposed to the main effect, which is present in every case. This is due to the limitations of regression-based methods, which are the main advantages of configurational analysis and fsQCA [15], [34], [52]. In regression-based methods, a net effect approach is taken in examining the effects among factors of interest, and variables in a competing environment are examined. It is evident from the covariance between the variables in a model that the presence or absence of one variable influences the effect of the other variables as well as the expected outcome. This highlights the importance of applying configurational analysis, which is based on the concept [50]. Two types of configuration are available in fsQCA. They have been created with both necessary and sufficient conditions, and they provide multiple solutions that explain the same outcome, depending on whether the configurations are present, absent, or on a "do not care" basis (i.e., either present or absent). As a result of necessary and sufficient conditions, we are able to distinguish between components that are core (i.e., conditions with a high causality) and components that are peripheral (i.e., conditions with a low causality) [51]. Accordingly, adopting a mixed approach, such as fsQCA [15], is a useful way to triangulate the findings and gain a better understanding of the relationships and processes at play in the rapidly evolving field of digital servitization.

IV. Results and Discussion

A. Necessity Analysis

Necessity and sufficiency analyses form the foundation of configurational path analysis. They show the core antecedent conditions if any exist [34]. Necessity means that a condition always occurs when an outcome is produced. Consistency indicates a condition's ability to lead to that specific outcome [36], [37]. Hence, it is an indicator of the degree to which the condition is a subset of the outcome. Also, coverage is a means of measuring how much of an outcome is explained by a particular causal condition and indicates the empirical relevance of a consistent subset [36], [37]. According to Ragin (2008), a condition is considered necessary when its consistency score exceeds the recommended value of 0.9, accompanied by coverage scores greater than 0.8 [78]. Table II presents the consistency and coverage of all conditions for the presence and absence of customer sustainable performance.

Table II
Analysis of necessary conditions

	Presence		**Absence**	
Conditions tested:	**Consistency**	**Coverage**	**Consistency**	**Coverage**
AIO	0.70	0.73	0.59	0.56
~AIO	0.57	0.60	0.72	0.69
OO	0.76	0.77	0.59	0.54
~OO	0.55	0.59	0.75	0.74
VC	0.78	0.79	0.59	0.54
~VC	0.55	0.59	0.77	0.76
EO	0.74	0.77	0.62	0.59
~EO	0.60	0.63	0.76	0.73

Note: AIO = AI-driven Optimization, OO = Outcome Orientation, VC = Value Co-creation, EO = Ecosystem Orchestration; "~" indicates the negation of the condition.

We tested necessity for the presence of each condition (and also for the absence of each condition). Taking AI-driven optimization as an example, we will explain it in greater detail. According to the analysis, AI-driven optimization leads to a moderate consistency (70%) in terms of high customer sustainable performance when AI is used. As a result, AI-driven optimization contributes to the presence of the outcome to a considerable extent. Further, AI-driven optimization covers 73% of the cases in which high customer sustainable performance is observed. This suggests that AI-driven

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optimization explains a substantial proportion of the present cases of the outcome. In the absence of AI-driven optimization, there is moderate consistency (57%) in the absence of high customer sustainable performance. This indicates that the absence of AI-driven optimization contributes to the absence of the outcome to some extent. Furthermore, AI-driven optimization covers 60% of the cases where high customer sustainable performance is not achieved. According to this, although the absence of AI-driven optimization contributes to the absence of the outcome, it is not the sole determinant responsible for it. In this regard, no one solitary condition fully explains the high level of customer sustainable performance, as the consistency and coverage values of all conditions for customer sustainable performance are lower than the thresholds. This verifies all four of the research propositions and indicates that manufacturing firms may achieve high customer sustainable performance under different configurations of "AI-driven optimization", "outcome orientation", "value co-creation", and "ecosystem orchestration" conditions. Moreover, the absence analysis indicates that none of the conditions in isolation fully account for the absence of high customer sustainable performance, emphasizing the necessity for synergistic combinations of conditions to achieve the desired outcome. Based on these results, further path analysis was conducted.

B. Sufficiency Analysis

A sufficiency analysis was conducted following the necessity analysis in order to determine whether the cases displaying the conditions constitute a subset of those displaying the outcome. Indeed, sufficiency refers to the explanatory strength of the condition in explaining the occurrence of the outcome [34]. In doing so, sufficiency analysis was performed using the truth table to obtain the possible configurations that explain the presence of superior customer sustainable performance. As shown in Table III, the overall consistency is 0.82, and each path configuration exceeds 0.85, which is above the recommended threshold of 0.80 [78]. Furthermore, the overall coverage of 0.72 confirms that these combinations of causal conditions account for 72% of cases.

Here, we discuss all the configurations that represent paths to high customer sustainable performance in manufacturing firms. According to configuration 1, well-managed outcome orientation in the firm and the active utilization of AI-driven optimization, accompanied by a high level of ecosystem orchestration, are determinant factors for high customer sustainable performance in 57% of cases. This conclusion has a consistency of 0.88. According to configuration 2, 38% of cases suggest that firms able to integrate outcome orientation with ecosystem orchestration achieve high customer sustainable performance. This conclusion has a consistency of 0.85. According to configuration 3, 37% of cases suggest that high customer sustainable performance occurs in manufacturing firms with high usage of outcome orientation accompanied by high focus on AI-driven optimization. This conclusion has a consistency of 0.86. Moreover, configuration 4, which is based on 34% of cases, demonstrated that a high usage of AI-driven optimization combined with a high focus on value co-creation processes, even without focusing on outcome orientation, can act as determinant factors for high customer sustainable performance. This conclusion has a consistency of 0.89. According to configuration 5, 32% of cases suggest that firms able to integrate the usage of outcome-oriented offerings with managing their relations through value co-creation achieve high customer sustainable performance. This conclusion has a consistency of 0.90.

Table III
Configurations for high customer sustainable performance

Configurations	**1**	**2**	**3**	**4**	**5**
AI-driven optimization	●		●	●	○
Outcome orientation	●	●	●	○	●
Value co-creation		○	○	●	●
Ecosystem orchestration	●	●			○
Raw coverage	0.57	0.38	0.37	0.34	0.32
Unique coverage	0.17	0.01	0.01	0.04	0.04
Consistency	0.88	0.85	0.86	0.89	0.90
Solution coverage	0.72				
Solution consistency	0.82				

Note: As per the notation of Fiss (2011), the solutions are grouped by their core structures: black circles indicate the presence of the condition; white circles indicate the absence of the condition; blank spaces indicate that the condition may be present or absent (i.e., it is irrelevant).

C. Configurational Strategies Leading to a High Level of Customer Sustainable Performance

Taking into account the interaction between "AI-driven optimization", "outcome orientation", "value co-creation", and "ecosystem orchestration" conditions, the analysis resulted in five main configurational strategies for manufacturers seeking high levels of customer sustainable performance, as illustrated in Fig. 2. We describe the fundamental logic of these strategies below.

The first configurational strategy (CS1) builds on high *AI-driven optimization, ecosystem orchestration, and outcome orientation*. As part of this advanced strategy, incumbent firms utilize their technical superiority to develop competencies and solutions for customers, with the solutions tending to have a service focus where the provider and ecosystem partners take over customer operations. This strategy creates integrated smart solutions on top of an advanced AI platform by leveraging a network of complementary ecosystem partners and their resources, capabilities, and services to operate customer processes sustainably. Thus, manufacturers leverage internal capabilities and their ecosystems to drive synergistic effects in generating differentiated and value-added sustainable smart solutions that can meet the evolving needs and expectations of their customers over the long term [35], [41].

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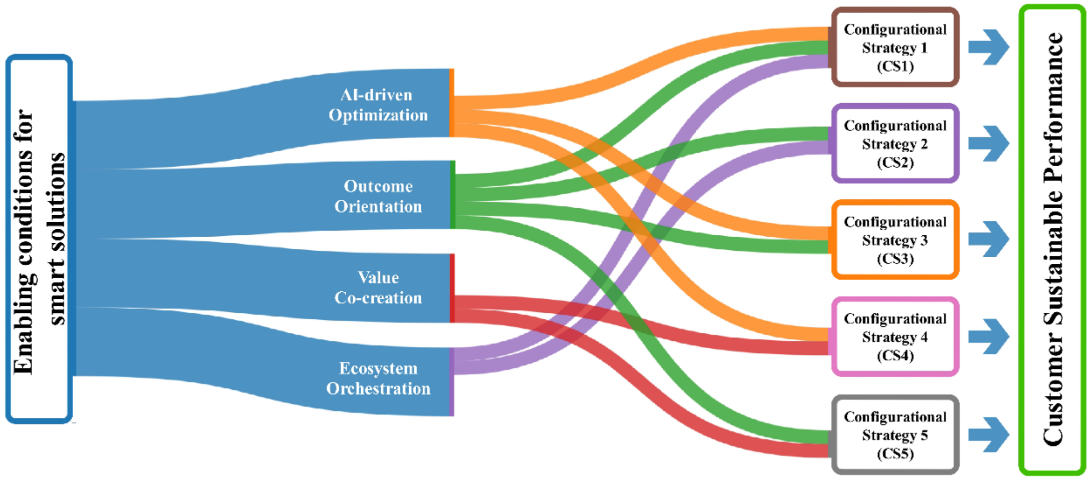

Fig. 2. Configurational strategies toward customer sustainable performance

The second configurational strategy (CS2) builds on high levels of *ecosystem orchestration* and *outcome orientation* in the absence of *value co-creation*. Accordingly, firms that embrace this strategy are required to form new partnerships and collaborate in the ecosystem in order to obtain the necessary resources and capabilities to provide optimal customer service [29]. To carry out this strategy, it is important to agree on performance goals (e.g., KPIs) with the customers and to develop rules and regulations that govern the ecosystem, so that operational performance guarantees can be provided to the customers in a sustainable manner. Furthermore, providers must assess the various ecosystem roles in relation to capabilities and offerings and negotiate the responsibilities of different ecosystem partners to ensure sustainability. Furthermore, organizations must consider inter-organizational roles (including front-end and back-end roles) in conjunction with global ecosystem perspectives to manage customer operations. A key component of this process is to align diverse ecosystem actors and to assure revenue flow among them, in addition to distributing the risks and rewards fairly when operating customer processes. By leveraging the resources and capabilities within the ecosystem, manufacturing firms can optimize their service delivery processes for their customers and improve their overall sustainability potential.

The third configurational strategy (CS3) builds on high *AI-driven optimization* and *outcome orientation* in the absence of *value co-creation*. By integrating information obtained from several sources, firms following this strategy are able to improve their customers' decision-making power through the use of advanced AI analytics. Additionally, they use data visualization techniques to help their customers understand complex information so their decision-making processes are improved. As a result, dashboards can be developed, which decompose information for root cause analysis, thereby strengthening their concentration on continuous improvement of customer operations. A significant benefit is that providers are able to optimize resource usage in their customer operations by leveraging advanced AI analytics and to help them utilize assets in a more sustainable manner. Moreover, the findings are consistent with prior research demonstrating the importance of outcome orientation and the use of advanced AI analytics to improve performance, including revenue growth and customer satisfaction [79]. This can result in providers having to invest in advanced artificial intelligence analytics. The purpose is to integrate AI into their outcome-oriented efforts to take over customer operations as a means of supporting the changes that are occurring in today's dynamic business environment.

The fourth configurational strategy (CS4) builds on high *AI-driven optimization* and *value co-creation* in the absence of *outcome orientation*. Thus, firms following this strategy involve their customers in the design, development, and implementation process of creating smart solutions that address the specific needs of customers. By using advanced AI analytics, manufacturers use machine learning algorithms to analyze customer data and identify useful patterns for co-creating tailored applications and digital services in collaboration with their customers. Among the key benefits of a digital co-creation strategy is the ability to provide companies with access to massive amounts of data, improve their informed decision-making capabilities, and increase their efficiency. Moreover, the use of AI can assist in developing new applications and improving existing products and customer services [69], [80] in the interests of greater sustainability. By fostering a sense of ownership of the co-created solutions, this strategy not only allows customers to have greater input in forging their own products and services but also leads to a more dynamic relationship between manufacturer and customer.

And finally, the fifth configurational strategy (CS5) builds on high levels of *value co-creation* and *outcome orientation* in the absence of *AI-driven optimization* and *ecosystem orchestration*. Thus, firms following this relational strategy try to distance themselves from a one-size-fits-all mindset in order to obtain a thorough understanding of their customers' needs. By tailoring customized and high-value smart solutions that meet the specific needs of customers, this strategy aims to

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differentiate firms from their competitors and enhance their customer-oriented outcomes [24], [35]. As part of their commitment to sustainability, they offer assistance to their customers by managing their operations in a manner that reduces energy consumption, waste generation, and air pollution. Similarly, the providers boost the profitability of their customers' operations and reduce waste and inefficient processes under the economic pillar of sustainability. By doing so, they are able to reduce customer manufacturing costs and increase their productivity. Using this strategy, the providers are able to enhance worker safety in the customer's organization, eliminate dangerous work tasks, and improve working conditions. The distinctive feature of this strategy is that providers do not rely on their digital competencies or ecosystem partnerships, which would limit the scalability of such offerings to a small group of high-value customers, such as key accounts. Thus, the providers are able to engage with customers who place a high value on sustainability and are more likely to collaborate closely with them.

V. Implications

A. Theoretical Contributions

In light of the discussion above, this study makes a number of important contributions to the literature on digital servitization [35], [81] and industrial sustainability [10], [82] in a variety of ways. With the help of fsQCA, this study provides a clearer picture of the diverse strategic approaches that manufacturing firms in Sweden are adopting.

First, this study contributes to the aforementioned literature streams by *examining the relation between digital servitization and sustainability*. Our study has attempted to conceptualize this relationship, which is viewed as being important but under-appreciated. The prior literature has begun to emphasize the link between different individual conditions analyzed in this study (i.e., AI-driven optimization, outcome orientation, value co-creation, and ecosystem orchestration) and their impact on sustainability [10], [33]. However, a question that remains unanswered is whether digital servitization leads to sustained performance. This article adopted a niche perspective on this relationship by examining how and in which ways digital servitization can improve the sustainable performance of industrial firms. As it turns out, this study's unique contribution to the link between digital servitization and sustainability is also a consequence of the conceptualization of sustainability. Our study has taken a view on customer sustainable performance that tends to be an important dependent variable (DV) since the digital servitization literature focuses on products and services that are intrinsically related to customers' experiences and interactions. Throughout this process, we have emphasized that there is no one-size-fits-all pathway for this relationship, and a variety of different conditions exert an influence on it. For this reason, we adopted a configurational approach to determine the answer by employing fuzzy set qualitative comparative analysis. As a result, this study not only examines the relationship between digital servitization and sustainability – which is an important topic to explore – but it also conceptualizes it by focusing on customer operations, a topic that is highly relevant to both research fields.

Second, this study contributes by *proposing and analyzing several configurational strategies aimed at providing smart solutions for manufacturing firms* in order to enhance their customers' sustainable performance. As described in the digital servitization literature, smart solutions providers are at the top of the transformation spectrum [14]. Moreover, the results of this study have demonstrated that these particular types of provider may hold the potential to provide sustainable services. It is still unclear, however, which specific strategies they can use to assume this responsibility. Having conducted a thorough analysis of the relevant literature, this study has determined that these solution providers must deal with a number of enabling conditions for smart solutions. Among the enabling conditions are AI-driven optimization, outcome orientation, value co-creation, and ecosystem orchestration, all of which must be considered when paving the way for digital servitization. The literature still lacks an understanding of the different strategies that can be employed to provide smart solutions. Studying smart solutions is important, and there is a growing body of literature [14] claiming that a configurational strategy represents an important aspect of how to engage in different forms of smart solutions. Therefore, building on configurational theory [15], this research has identified five configurational strategies to address this gap and to provide smart solutions that can lead to the higher sustainable performance of industrial customers.

Lastly, this study *provides insights into the most optimal smart solution strategies and the interplay between AI-driven optimization and ecosystem orchestration*. Based on the five smart solution strategies identified, the first configurational strategy (CS1) appears to be the most prominent because it is based on the outcome-based approach, which is the ability to take over customer operations using the firm's technological competence and the ability to align its ecosystem partnerships. As a result of the study, it was evident that focusing on the delivery of outcomes, which involves taking over customer operations, is the path to achieving sustainable service operations. Another important factor to consider is the interaction between using advanced AI analytics and orchestrating an ecosystem of partners in order to operate customer processes under the consideration of sustainability. Accordingly, we found that the second and third most dominant configurational strategies (CS2 and CS3) center on these two critical conditions. Indeed, manufacturing companies can choose to go with the first configurational strategy (CS1) if they have the potential to utilize both conditions to take over customer operations in an environmentally friendly and sustainable manner. Nevertheless, if the company has to choose between using AI-driven optimization and ecosystem orchestration, based on their current position in the market and having the appropriate technological and relational resources, the company may opt for either a configurational strategy based on ecosystems

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(CS2) or an artificial-intelligence-driven approach (CS3). From the results of the study, it was determined that having the right artificial intelligence competencies to facilitate the decision-making process and a suitable position within the ecosystem and market are two critical conditions for manufacturing firms to achieve sustainable service operations. A crucial point, however, is that neither of these conditions are sufficient on their own. They must be coupled with other conditions. A good example is AI-driven optimization, which needs to be coupled with other conditions, such as outcome orientation, to create value that can enhance the sustainable performance of customer operations. Indeed, similar logic can be applied to other factors.

B. Managerial Implications

There are two noteworthy implications of this study for practitioners in terms of achieving high customer sustainable performance. First, sustainability goals are an important topic for discussion, and advanced digital service providers should devote more attention to valuing this aspect of their customers' needs. It is important that managers and practitioners consider this strategic vision and ensure high priority is given to customer sustainable performance. Achieving these goals requires the development of effective strategies to ensure long-term competitiveness for manufacturing companies. In light of this fact, our paper presents five equifinal causal configurations as modifiable paths and strategies that can be used to achieve high levels of customer sustainable performance. The paper shows that an optimal strategy rather than the best strategy can be deployed. As a result, the desired outcome is context specific and dependent on the digital and relational capabilities and ecosystem of an organization. In fact, managers can adjust their strategies in different environments according to the prevailing conditions. When faced with the dilemma of limited resources and energy, they should prioritize their resource allocations to promote the development and utilization of core conditions to the greatest extent possible in those environments. Second, managers must be more attentive to the critical role of advanced AI analytics and orchestrating ecosystem partnerships, both of which represent different approaches to providing smart solutions in order to enhance customer sustainable performance. The question of when should a firm pursue each of these strategies remains to be decided. There may still be challenges associated with pursuing the first configurational strategy (CS1), and not all companies possess the competencies and capabilities to manage both their ecosystem-oriented competencies and their AI-oriented competencies. It may be advantageous for the firm to pursue the second configurational strategy (CS2) when it has some legitimacy and power. Otherwise, it may be challenging and, thus, better to prioritize other strategies. Furthermore, for a firm to consider the third configurational strategy (CS1), it must have the technical capability and a solid digital backbone in its customer operations. If neither of these strategies can be implemented by the organization, then it should focus on a niche customer and choose the fifth configurational strategy (CS5).

C. Limitations and Future Research

This study has several limitations that should be taken into account when interpreting the results. First, the study is based on a limited sample of manufacturing firms in a specific geographic region, and the results may not be generalizable to other regions or industries. Furthermore, the study relies on self-reported data, which may be subject to bias. Additionally, the study focuses on the use of AI in service-delivery processes and the provision of operational performance to customers and does not consider the broader implications of AI for the manufacturing industry. Future research could explore the impact of AI on other areas of the manufacturing business, such as product design and development, supply chain management, and marketing. Moreover, the study considers AI as one of the technologies that can have significant impacts on the sustainable performance of manufacturing customers. Researchers may explore the influence of other digital technologies, such as the Internet of Things (IoT), big data, and cloud computing, on the performance of manufacturing firms as well as the effect of their integration on their performance in future research. Another area for future research is investigating the impact of different types of governance structure on the performance of manufacturing firms in the context of digital servitization. This could include a more in-depth examination of the different types of governance mechanism and how they are used to align the interests of all stakeholders and ensure the proper functioning of the ecosystem. Finally, future research could explore the impact of government policies and regulations on the digital servitization process and the sustainable performance of manufacturing firms. This could include an examination of how different government policies and regulations affect the ability of manufacturing firms to adopt and implement digital technologies, and how they impact the sustainable performance of the ecosystem as a whole.

Accordingly, the results of this study provide insights into the evolution of different configurational strategies that are influenced by AI-driven optimization, outcome orientation, value co-creation, and ecosystem orchestration in order to provide smart solutions that can shape customer sustainable performance. Further research is required to investigate these topics in greater detail and to provide more generalizable findings as a result of the limitations discussed above. In doing so, further research is recommended to determine whether the findings of this study are generalizable to other conditions and settings. Researchers may examine how changing the industry context and geographical region of the case companies will affect the results. In addition, this will allow researchers to examine the impact of different factors such as the cultural context, different rules and regulations, and technological maturity on the achievement of customer sustainable performance.

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