A Conceptual Approximation Toward Occupational Safety and Health Within the Servitized Industry 4.0

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Abstract Present highly dynamic manufacturing environments call for adaptive and rapidly responding Occupational Safety and Health systems within the new technology-dependent production models. Emergent trends of Servitization and Industry 4.0 tend to become widely recognized and accepted in the industrial branches. The same way, the more sophisticated tendency is emerging. The Servitization of Industry 4.0 is regarded as another promising trend of manufacturing firms' transformation of business models. So this servitization-based growth in product-based firms is one of the most active research domains; it may be prone to different interpretations and a variety of conceptualizations. It suggests the new paradigm shift of management of Occupational Safety and Health (OSH) as the change will trigger new human-to-human and human-to-machine interactions and the new occupational risks will surface. This article provides an approximation to the conceptual framework of the convergence of Occupational Health and Safety and the Servitization of Industry 4.0, based on the scoping literature review, as well as it moots future areas of the research domain. Furthermore, it provides details of the principal types of the Emergent OSH approach in servitized Industry 4.0.

Keywords Industry 4.0 · Occupational safety and health · Product-service systems · Servitization · Servitized industry 4.0

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1 Introduction

The digitalization of manufacturing companies often generates new challenges such as how to not only offer better products but also capitalize the firm infrastructure and resources. This transformation tends to reconfigure the socio-technical relationships with customers and providers, as well as generates new opportunities for innovation with information technologies (IT) applied to the Smart Factory [1]. Hence, manufacturing companies need to adapt their production systems to be able to respond to the required changes in processing functions, production capacity, and dispatching of orders. In parallel, in order to satisfy customer expectations and gain a competitive advantage on the market, industrial firms have developed services that either complement or integrate the manufactured products. All of these changes bring increasing pressure on the aspects related to Occupational Safety and Health, in particular when emergent business and production models are considered. So, one can consider the OSH as a relevant factor of effective and sustainable transformation of the production systems of manufacturing firms. Although the importance of this phenomenon is widely recognized, the new approaches toward the holistic transformation of manufacturing companies are still at a very early stage.

It has been long recognized that Industry 4.0 will bring deep changes within the production and the increase of new challenges directly related to automation, digitalization, and autonomous equipment. Industry 4.0 can be defined as two possible approaches toward smart manufacturing [2]: output- and input-driven. The output approach is centered on the change in the operating framework and is also called the application pull. The input approach, the technology pull one, aims at the increasing relevance of mechanization and automation in industrial practice and use. The technology push approach is also closely related to cyber-physical production systems and networks. The technology itself serves as an enabler of the profound transformation. All of this is intended to meet more efficient processes, adding value to increasingly individualized products, and supporting managerial decisions with enriched, predictive data [3]. Industry 4.0 is considered a new industrial scenario in which cyber-physical and intelligent systems can create value along the industrial processes [4, 5].

Considering that the recent models of Industry 4.0 or Smart Manufacturing claim to introduce the Internet of Things and servitization concepts into manufacturing [6] and generate the so-called "cyber-physical systems" (CPS), where the physical systems are combined with the digital items in order to communicate and control themselves [7, 8], this stage of "smartization" of industrial environments becomes the source of vast opportunities for new forms of hybrid industrial business models [9].

Accordingly, the increasing service orientation of manufacturing companies [10, 11] alongside the digitalization of processes establishes the relation between industry servitization and Digital Transformation focusing on the value creation for the hitherto product-based business models [12] and product-service systems (PSS) [10, 13]. Providing a product accompanied by a service not only may enhance

the flexibility in production [14] but also can change the market benchmarking of manufacturing firms pinned in the tangible resource dependence [15].

It is widely agreed that technology is the basis for the modernization of manufacturing firms and due to the digitalization of the industry, the rapid progress of a service-driven economy takes place even in the product-related branches [16]. Smart servitization or "smartization" through the interconnected intelligence, automatized processes, and data transformation makes possible the advanced product-related services that can be offered by manufacturing firms [17]. As many experts consider digitalization as the necessary condition for many servitization approaches, it is widely accorded that the rise of services and the ICT-based transformation of industry come together [18].

Both industrial trends, servitization and Industry 4.0, have become the objects of diverse studies [19, 20] and some conceptualization of consequence. However, till now there is still a lack of a robust bridge between the Servitization of Industry 4.0 and the resulting perspective change of Occupational Safety and Health within. In this article, we provide a new conceptual convergence perspective on the OSH in the context of servitization in Industry 4.0 which can facilitate strategists and researchers a better understanding of the scope of the required policy change and we propose further research lines. The importance of aligning human (knowledge) capital and corporate servitization and/or Digitalization strategy with the OSH performance is becoming supported by an emergent research evidence [21]. Therefore, this research aims to propose the conceptual framework of OSH approaches within the servitized Industry 4.0 according to different stages of the convergence of servitization and Industry 4.0 in the manufacturing industry.

2 The Convergence of Servitization and Industry 4.0

During the recent two decades, research on servitization in manufacturing firms has been conducted from different perspectives: industrial services [22], high-end types of product-related services [23], Service Infusion [24], PSS modularization [25], or being considered as a stage of the industry evolution [26]. Moreover, existing contributions were often focused on a generic level of service transformation in product-based firms. Pertinently, [27] argue the lack of inter-disciplinary approaches to research on servitization, being the domain fragmented into three research streams: sustainability-centered Product-Service Systems (PSS), Solution Business focused on operations management and industrial marketing, and Information System-related Service Science.

Many scholars consider the current approach to servitization still limited and as [20] argue, the contributions prescribing how to servitize manufacturing companies are the acknowledged need. Servitization covers the transformation in which manufacturing firms are increasingly changing their value propositions by offering services [28]. To be able to carry on this transformation, new additional capabilities, cultural–structural reorganization and improvement in effectiveness and efficiency

of industrial operations are usually required [29]. Furthermore, [30] determine that the consideration of both the business model and organizational change is required to meet the challenges of a wide range of organizational and environmental contexts of any manufacturing firm. Hence, the service-based strategy must be closely aligned with the manufacturing capabilities and competencies to enter into the market with a viable product-service offering.

In parallel, the Industry 4.0 challenges have arisen very rapidly both from a strategy point of view and on a production operations basis. Recent studies on Industry 4.0 [31] argue the positive input of the cyber-physical systems [32], digitization [33], and Industrial Internet of Things (IIoT) [34] to the paradigm shift of the manufacturing business model. Similar concepts surface concerning emergent Industry 4.0-based capabilities linked to cloud manufacturing, predictive analytics, or augmented reality [9]. Therefore, manufacturing firms that understand how this shift in a business model relates to the necessity of new capabilities and how it will change their internal operational processes are likely to implement effective strategies of their products and processes.

This strategy–capability alignment is also the core issue when Industry 4.0 implementation is considered [35]. Even so, the literature on servitization and Industry 4.0 nexus limits the scope of the shared area to the Digital Transformation perspective or collateral effects of servitized technologies embedded in the final products (Smart Products) within the Industry 4.0 strategy [36]. Some authors have posed the question of the contribution of specific digital tools to servitization, such as remote monitoring [37], cloud computing [30], big data [38], Internet of Things (IoT) [39], and predictive analytics [40]. The IoT, sensor technologies, and data analytics underpinning Industry 4.0 can, for example, lead to providing services of intelligent monitoring of a manufacturing plant and its maintenance.

However, the deep implications of servitization and Industry 4.0 for the value creation in manufacturing firms have made the scholars consider different aspects of both trends' implementation worth noticing. The studies aimed to analyze the present and potential connections between these two fields have been developed [40–43]. Hence, [4] propose a common framework that divides servitization into manual services, digital services, and Industry 4.0-related services, even if the conceptualization of servitization in Industry 4.0 is still lacking a more structured approach.

An overall view of industrial servitization pathway [44] in particular the Product-Service Systems raises interesting opportunities for the manufacturing firm to meet customer needs and make the organizational transition more smooth and seamless. The benefits of PSS encompass gains not only for the customers but also for the provider itself, as PSS reshapes the supply chain, manufacturing processes, maintenance, and operational procedures [45]. Nevertheless, the approach that considers PSS and servitization as a part of Industry 4.0 argues for the digital platforms as a common environment for service offering [4] along with digital feedback for manufacturing processes [36].

On the other hand, Smart PSS [46] can be considered as the intersection between PSS (as one of the servitization streams) and Industry 4.0. [12] view smart PSS as the

paradigm for a new service-oriented manner of Industry 4.0. In this paradigm shift, the core technologies of Industry 4.0 and network capabilities are largely accepted as a major enabling factor of the business model transformation [47]. Hence, the human aspects of smart PSS development (technology-push manufacturing processes and customer-centered service design) must be considered. To meet workers' capability, health, and safety, the redesign of operating processes will be required, including the shift in the scope of the OSH dimensions and the adoption of a hybrid approach based on different sets of resources and capabilities.

3 An Emergent Occupational Safety and Health Approach Within the Servitization of Industry 4.0

Frank et al. [4] supports the statement that servitization of Industry 4.0 is an emergent trend and both approaches can coexist and support each other. The most important contribution of the work by [48] is that OSH in the Industry 4.0 context requires significant input from ergonomics and human factors research. This could be based primarily on considerable advantages associated with cyber-physical systems. The authors emphasize the major role of ergonomists and engineers in the design and the operation of new systems and processes as well as in the downsizing of undesirable effects brought by industrial paradigm shift [49].

The digital products of manufacturing firms can be classified according to their hybridity (a combination of digital and physical elements), smartness (capacity to sense), connectivity (ability to enter into networks), servitization (product-service systems), and the product ecosystem (online or offline) [50]. In this regard, the Industry 4.0-related services [40] that emerged from the Digitalization-based servitization can link these two perspectives and reveal the qualified personnel intensive approach of the manufacturing company. The authors propose the set of digital capabilities required to deliver new services related to Industry 4.0 as well as the necessity to combine them with the new adjusted OSH policy.

By tradition, the OSH in the manufacturing firms focuses on safety and prevention within the interaction with physical artifacts and industrial equipment. On the contrary, interactions with tangible objects decrease in the Industry 4.0 environments to give rise to long-term synergies between humans and machines [5], with digital technologies as both the bridge and the interface [25]. Manufacturing companies can focus on different needs they may have when they prioritize the implementation of good OSH management. However, in particular when Industry 4.0 and servitization concerned the workers' participation and engagement to carry on the effective measuring workplace risk, implementing the robust framework for the OSH management [5] is a game-changing factor.

Within the Industry 4.0 servitization, in particular smart PSS perspective, the OSH can be aimed mostly to develop a whole new set of technologies and service capabilities and adapt the organizational structures and production processes so that

they reflect the cyber-physical nature of services [51]. What is more, by taking over the internal and external customers' support, servitized Industry 4.0 manufacturers have to take into account the risks inherent to digitalization, automatization, and virtualization [52]. Furthermore, those risks are related to not only the workers in an industrial plant but also those potential risks associated with providing services based on Industry 4.0 technologies.

In this work, the early stage conceptualization of OSH of servitized Industry 4.0 is pretended. This conceptualization [53] aims to become an abstract model of emergent workplace risk prevention and occupational safety management strategies within the volatile servitized Industry 4.0 environments. This matches with [54]'s focus on how to proceed with understanding a new problem by analyzing related concepts considered in former research. The theoretical perspective used to build the first approximation to the conceptual framework of Occupational Safety and Health within Industry 4.0 servitization is introduced in Fig. 1. We considered three dimensions of approximation to the OSH in servitized Industry 4.0 manufacturing firms: strategic/operational capabilities, servitization level, and Industry 4.0 adaptation level.

The necessity to consider together the strategic/operational capabilities, servitization level, and Industry 4.0 adaptation level arises from the holistic integrative focus of the analysis of significantly complex systems such as the servitized Industry 4.0 manufacturing firms. Within the context of these firms, all three dimensions are both interconnected and interdependent but to propose the specific strategy as the OSH one, it is required to delimit 3D areas according to the level of each of them. However, the higher level of Industry 4.0 or of servitization does not signify a more

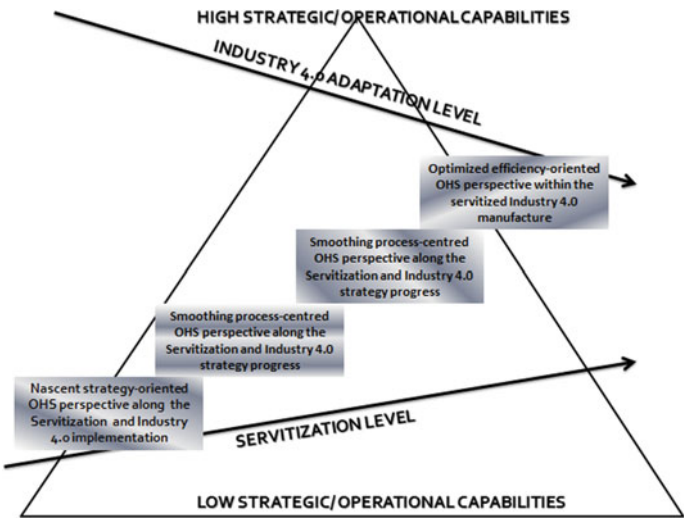

Fig. 1 A conceptual framework of OSH within the servitized Industry 4.0 (*Source* authors' own elaboration based on Torrecilla-García et al. [55])

favorable situation for the company, in particular, in face of the OSH policy. Consequently, it can be argued that a sophisticated business model of industry required a specific set of strategic and operational capabilities to be able to respond to the challenges of the hybrid approaches and reach the competitiveness and productivity improvements alongside the more effective OSH strategies.

The relevant output of the integration of servitization and Industry 4.0 perspective into the OSH strategy and processes emphasizes the servitized manufacturers' need to undertake new or different responsibilities within the wider context: a business, technology, process, and person intertwined one. Within this wider context, we identify four main challenge areas that servitized Industry 4.0 manufacturers should consider in order to allocate adequate efforts and resources.

Based on the conceptual framework, we develop the first approximation [56] to the classification of emergent OSH approaches as shown in Table 1.

By adapting the reference framework of the operations strategy presented in different researches, the four novel approaches have been proposed and characterized. The major challenge for the correct classification lied in the precise differentiation of the most relevant operational/strategic capabilities. The first approach, called initially *Nascent strategy-oriented OSH perspective along the Servitization and Industry 4.0 implementation,* requires a very specific perspective of OSH from the bottom line and the alignment of a new service-based strategy with existing manufacturing capabilities and competencies.

The second one, *Adaptive, strategy-oriented, Industry 4.0-related Servitization OSH perspectives,* is closely related to companies with advanced strategies of Industry 4.0 and servitization but limited capabilities, in particular strategic ones. This situation forces these firms to look for new ways to adapt current resources and internal policies to develop and enhance the transition from the traditional OSH perspective toward the OSH scope based on the integration of CPS with the smart PSS approach.

A further one is an approach of *Smoothing process-centered OSH perspective along the Servitization and Industry 4.0 strategy progress.* The embedded operational capabilities of the firm allow gradual and adjustable placement of adequate OSH strategies when servitization and Industry 4.0 implementation processes come together. Digitalization marks a shift in thinking about the human–machine risk perception and subsequently risk prevention when digital or user-centered services related.

Finally, in the case of optimal levels of all three dimensions—what could be considered the servitized Industry 4.0 organization—the approach of *Optimized efficiency-oriented OSH perspective within the servitized Industry 4.0 manufacture* may be considered as a strategic tool both to improve the occupational safety and to increase the efficiency of all production processes including the OSH. Strategic capabilities-centered servitization is carried out through automatization, virtualization, or digitalization. Hence, new workplace hazards arise as well as the OSH needs to provide easy on-demand adjustment possibilities.

We summarize that the OSH policy can be considered as a facilitation factor of the efficient implementation of the servitized Industry 4.0 strategy if the mentioned

Table 1 An emergent occupational safety and health framework in servitized industry 4.0

Emergent OSH approach type	Main characteristics	Framework source references
Nascent strategy-oriented OSH perspective along the Servitization and Industry 4.0 implementation	New service-based strategy aligned with the manufacturing capabilities and competencies	Xu and Duan [32]
		Li et al. [57]
	Technology-push manufacturing processes and customer-centered service design	Moeuf et al. [35]
	Information System-related service approach	Romero et al. [52]
	Original bottom line OSH perspective	Kowalkowski et al. [10]
Adaptive, strategy-oriented, Industry 4.0-related Servitization OSH perspective	Transformation of manufacturing production systems	Frank et al. [4]
		Dolgui et al. [58]
	Strategic capabilities-centered servitization through automatization, virtualization, or digitalization	Fargnoli et al. [25]
	PSS modularization and digital platform interfaces	Wiesner et al. [45]
	OSH scope transits from CPS to smart PSS approach	Podgórski et al. [49]
Smoothing process-centered OSH perspective along the Servitization and Industry 4.0 strategy progress	New service-based strategy aligned with the manufacturing capabilities and competencies	Visnjic et al. [41]
	Technology-push manufacturing processes and customer-centered service design	Rymaszewska et al. [12]
	Information System-related service approach	Martinez et al. [13]
	Original bottom line OSH perspective	Coreynen et al. [44]
		Marilungo et al. [47]
Optimized efficiency-oriented OSH perspective within the servitized Industry 4.0 manufacture	Transformation of manufacturing production systems	Frank et al. [4]
		Ardolino et al. [40]
	Strategic capabilities-centered servitization through automatization, virtualization, or digitalization	Kamp et al. 2017
	PSS modularization and digital platforms interfaces	Mueller et al. [5]
	OSH scope transits from CPS to smart PSS approach	Durugbo [29]

strategy is explicitly grounded on the premises of correlation between operational/strategic capabilities, servitization grade, and Industry 4.0 level. However, the aforementioned emergent approach approximation requires the further research as well as needs to be contrasted with real OSH strategies of servitized Industry 4.0 manufacturing firms.

4 Conclusion and Future Work

The servitized Industry 4.0 based on smart connected systems and servitization is gradually becoming the new stage of the evolution of manufacturing companies that want to broaden their sources of revenue streams and compete on a wider market with different rules than raw materials cost and productivity. The human factors provide a stepping stone for the companies not only to be able to implement correctly the servitization and Industry 4.0 but above all also to carry on the adequate OSH strategies in that new volatile but still industrial environment.

The transition to both services-related and Industry 4.0 business models involves significant challenges that render a substantial impact on the OSH policy in manufacturing firms. The perspective shift of OSH in servitized Industry 4.0-related manufactures requires consistent alignment of strategic/operational capabilities, servitization processes, and Industry 4.0 adaptation within the business models and operational policies of companies. In order to show the relevance of integrative perspective and interdependence between the OSH policy and Industry 4.0 servitization, this paper addresses the gap in this field by developing a preliminary conceptual framework that includes four emergent approaches applicable in manufacturing firms. Therefore, this research determines that there are differences among the OSH approach in correlation to the levels of capabilities' intensity, servitization, and Industry 4.0 implementation degree.

With regard to a different grade of implementation of servitized Industry 4.0, we infer that as Servitization and Industry 4.0 level increase the OSH strategy takes an important role in effectiveness and productivity metrics. So, it can be said that the emergent approaches of OSH within the servitized Industry 4.0 become an even more relevant factor of competitive advantage for manufacturing companies. On the other hand, the OSH policy implementation, adjusted along the transformation toward Industry 4.0 or servitization, requires a new bottom line risk and occupational hazard prevention perspective.

The contribution of this paper lies in a scoping review of existing research on servitization and Industry 4.0 from the prism of emergent requirement related to the OSH policies. The present proposal of the conceptualization of the four types of new OSH approaches is clearly focused on the operational and strategic capabilities that the company has at its disposition or need to acquire. The proposal seems sound, as it synthesizes the existing research evidence and confronts it with the OSH management in manufacturing companies.

Notwithstanding the former, as an initial conceptual study, this research mainly looks at the general strategic aspects, while many other factors of OSH in servitized manufactures should be taken into account in the future as well. In particular, the empirical evidences leading to a robust model of OSH policy implementation in servitized Industry 4.0 manufacturing firms are required. It is also pertinent to seek to understand how the holistic perspective of the smart PSS can shape the new horizons of efficient OSH strategies in manufacturing firms. As yet, the approach relies on conceptual justification and requires further in-field validation. However, nowadays the empirical validation of the proposal provides another challenge in the face of a scarce number of manufacturing firms that can be classified as servitized Industry 4.0 companies.

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