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Editorial

The SMEs' Journey to Industry 4.0: A Call for More IS Studies

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ABSTRACT

Although I4.0 is becoming one of the hottest topic in both management literature and industry, it is less explored in IS research, where digital transformation is nevertheless widely discussed. One must also notice here that, current I4.0 studies are less interested in the needs of SMEs to benefit from this digital phenomenon, in contrast to the extensive research on large organizations. In this introductory essay, we highlight these important gaps and call for more research that can address them together. We begin with a conceptual clarification of the I4.0 concept. We first emphasize that it should no longer be limited to manufacturing settings. We also explain that it should not be confused with the concept of digital transformation. Finally, we outline five research avenues that we believe are important to consider when studying the needs of SMEs with respect to I4.0 in the IS field: open and business model innovation powered by I4.0, success of I4.0, vulnerabilities associated with I4.0, well-being issues and sustainability powered by I4.0.

Keywords: *Industry 4.0, SME, IS Research, Digital transformation, Sociotechnical*

RÉSUMÉ

Même si l'I4.0 devient un des plu importants sujets d'actualité, tant pour la recherche en sciences de gestion que pour l'industrie, il le concept est moins exploré en systèmes d'information, où la transformation numérique est pourtant largement évoquée. De plus, les études actuelles sur l'I4.0 s'intéressent moins aux besoins des PMEs pour privilégier les grandes organisations. Dans cet essai introductif, nous soulignons ces importantes lacunes et appelons à davantage de recherches capables de les étudier ensemble. Nous commençons ainsi par une clarification conceptuelle du concept I4.0. Nous soulignons notamment qu'il ne faut plus le limiter aux paramètres de fabrication. De plus, nous expliquons qu'il ne faut pas le confondre avec le concept de transformation numérique. Enfin, nous décrivons cinq pistes de recherche qui nous semblent importantes à considérer lors de l'étude des besoins des PME en matière d'I4.0 dans le domaine des SI : l'innovation du modèle d'affaire propulsée par I4.0, la mesure du succès de I4.0, les vulnérabilités associées à I4.0, les enjeux de bien-être et enfin la durabilité propulsée par I4.0.

Mots-clés : *Industrie 4.0, PME, Recherche SI, Transformation Digitale, Sociotechnique*

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Industry 4.0 (I4.0), which contributes to the current rapid pace of digitalization, is one of the hottest topics in both academia and industry. Governments and policymakers are putting in place, plans, roadmaps, and incentives at the national or regional level to promote its adoption. In Europe, for example, at least 25 country-specific plans have been attempted (Teixeira & Tavares-Lehmann, 2022). In line with this public support, organizations are also increasing their I4.0 investments. By 2022, the global I4.0 market is estimated to be worth USD 130,9 billion (Fortune Business Insights, 2022). Such a significant interest from practitioners and policymakers has led to increased attention from academics, who have published thousands of related studies. At the time of writing, a search in the Scopus database using the keywords "*Industry 4.0*" or "*Fourth Industrial Revolution*" yielded more than 29,900 papers. However, very few of these papers were published in the field of Information Systems (IS). For example, a recent Melville *et al.* (2023) review identified only 70 papers published in reputable IS journals and conferences. The limited number of studies on this digital phenomenon in the IS field roughly suggests our less interest as a field, leading to underdeveloped IS perspectives on I4.0 (Huber *et al.*, 2022, p.2). However, as a sociotechnical field (Melville *et al.*, 2023; Sarker *et al.*, 2019), the IS discipline is in a privileged position to contribute meaningfully to the understanding of the I4.0 phenomenon (Baiyere *et al.*, 2020, 2023), to provide insights on its impact on organizations and society, and to explain how organizations can leverage this growing digital trend to create, deliver, and capture more value than before.

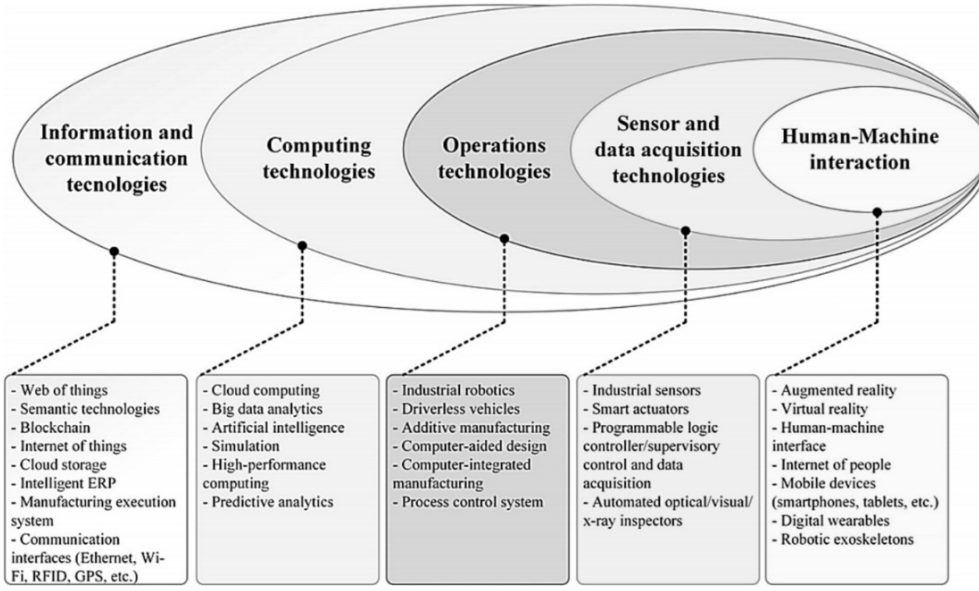
Going back to the more than 29,900 papers on I4.0, most of them focused on large organizations and overlooked small and medium-sized organizations (Somohano-Rodríguez *et al.*, 2022). However, small and medium-sized organizations (SMEs) also have good opportunities to use I4.0 to create more value (Horváth & Szabó, 2019), although they may "*feel lost as to what to do and how to do it*" (Somohano-Rodríguez *et al.*, 2022, p.1002). As the IS field seems less interested in exploring I4.0, its studies on SMEs' approach to the phenomenon are also scarce. Therefore, the aim of this special issue is to contribute to the development of the conversation in the IS field about the growing I4.0 phenomenon, especially the SMEs' approach to this phenomenon. We believe that IS research can provide knowledge about I4.0 that can be useful to both academics and practitioners in several ways. In this regard, the four major thematic areas of IS inquiry, namely the impacts of digital technology on 1- organizations, 2- technology applications, 3- individuals, and 4- society (Baiyere *et al.*, 2020; Sidorova *et al.*, 2008), could be considered in promoting I4.0-related studies within the IS field. For example, on the impacts on organizations, Mariani & Borghi (2019, p.1) regret the paucity of studies examining the managerial implications of I4.0. Regarding impacts on individuals, Neumann *et al.* (2021, p.2) lament that the centrality of human aspects is poorly reflected in the current I4.0 literature. Regarding societal impacts, Ghobakloo *et al.* (2021, p.15) note that the literature falls short in demonstrating the environmental and social sustainability implications of I4.0.

The rest of this editorial is structured as follows. First, we discuss what the I4.0 corresponds to. Next, we provide a brief history of the special issue and highlight the importance of exploring SMEs' journey to I4.0. Then, we highlight some research avenues that we consider worth exploring. Finally, the two papers of the special issue will be introduced.

1. WHAT DOES INDUSTRY 4.0 MEAN?

The concept of I4.0 was coined over a decade ago to reflect the paradigm shift resulting from the advancement and diffusion of (emerging) digital technologies in organizations and society at large (Shim *et al.*, 2022). Also referred to as the Fourth Industrial Revolution, it aims to distinguish the current era of diffusion of ubiquitous digital technologies from the previous three: 1- the First Industrial Revolution with the advent of the steam engine and mechanization, 2- the Second Industrial Revolution characterized by the diffusion of electricity and mass production, 3- the Third Industrial Revolution where information technologies and computer automation improved process efficiency, resulting in a change in approaches to production and consumption (Melville *et al.*, 2023; Neumann *et al.*, 2021; Shim *et al.*, 2022).

Figure 1: Digital technologies that may fit with I4.0 (from Yang *et al.*, 2023, p.4)



The concept of I4.0 is often associated specifically with manufacturing organizations. In this line, it refers to the adoption and use of various digital technologies, such as the Internet of Things (IoT), Additive Manufacturing, Artificial Intelligence (AI), and Big Data Analytics (BDA), in these organizations to drive changes in processes, products, work, etc. (Huber *et al.*, 2022; Lemstra & de Mesquita, 2023; Tortorella *et al.*, 2023). Figure 1 illustrates the variety of digital technologies that can fit into this approach. Several authors (e.g., Huber *et al.*, 2022; Lemstra & de Mesquita, 2023) see this as a digital transformation of the manufacturing industry, with traditional factories being transformed into smart factories. This conceptual approach requires at least two comments.

First, it is acknowledged that I4.0 is relevant to other industries and is therefore no longer limited to manufacturing. For example, Lemstra & de Mesquita (2023,

p.4) report that several studies consider I4.0 to have applications in smart cities and smart services. Similarly, Ghobakhloo *et al.* (2021) note that I4.0 has significant implications in various industries such as energy, transportation, healthcare, and agriculture. In addition, the trade press is full of related terms such as supply chain 4.0, logistics 4.0, marketing 4.0, retail 4.0, finance 4.0, hospitality 4.0, tourism 4.0, healthcare 4.0, etc. Some of these terms are also discussed by academics. For example, Kotler *et al.* (2017) consider that marketing 4.0 relies on the connectivity of artifacts and AI to improve marketing productivity. On retail 4.0, Liao & Yang (2020) note that it enables consumers to use the Internet to collect, pay, and share information about their purchases. Regarding logistics 4.0, Winkelhaus & Grosse (2020) note that it has evolved from I4.0 to reflect the use of digital technologies in logistics systems to improve the sustainable satisfaction of individualized customer demands without increasing costs. They consistently view I4.0 as an overarching term (Winkelhaus *et al.*, 2022, p.346). Similarly, we believe that I4.0 should be seen as a meta-concept that links across fields and integrates all other 4.0 approaches tailored to different fields and industries. In this respect, I4.0 cannot be limited to manufacturing organizations only (Culot *et al.*, 2020). For example, Melville *et al.* (2023, p.741) explain that I4.0 enables physical artifacts or machines to emulate human cognition and communication through smartness and connectivity. They add that these human capabilities acquired by artifacts or machines can be used in numerous environments such as the office, home, entertainment, medicine, and so on. Consequently, they define I4.0 as the "*widespread emergence of machines possessing human-like capabilities to discern, decide, create, and collaborate, engendering social and economic transformation*" (Melville *et al.*, 2023, p.734). In the same vein, Culot *et al.* (2020) note that I4.0 is also mentioned to reflect profound changes in consumer behavior and society driven by emerging technologies. As a meta-concept, I4.0 should also be conceptualized as socio-technical, i.e., a system that brings together both humans and digital technologies that interact with each other (Melville *et al.*, 2023; Sarker *et al.*, 2019). As such and regardless of industry, I4.0 should enable organizations to achieve both instrumental (work efficiency, economic gains, etc.) and humanistic (well-being, job satisfaction, etc.) outcomes (Melville *et al.*, 2023; Sarker *et al.*, 2019). Unfortunately, as Melville *et al.* (2023, p.737) lament, neither current practitioner discourse nor academic research sufficiently considers the humanistic dimension.

Second, it is important to look, albeit briefly, at the conceptual clarity between I4.0 and digital transformation, as the latter is increasingly discussed in the IS field (Baiyere *et al.*, 2023; Piccoli *et al.*, 2022; Vial, 2019). Although there is no equivocal definition of digital transformation in the IS literature, there are nevertheless four suggested properties. 1- *Digital technologies*. Digital transformation can result from a wide range of digital technologies and resources that have the potential to expand the possibilities of human action (Baiyere *et al.*, 2023). They are touted as digital because they are completely non-material or contain non-material components and are at least partially composed of bitstrings (Baiyere *et al.*, 2023; Faulkner & Runde, 2019; Piccoli *et al.*, 2022). They are also modular (i.e., they have the ability to operate independently as units in larger systems while interacting with other units in the systems to deliver expected outputs), encapsulate value (i.e., they have no intrinsic value beyond the functionalities and capabilities

they encapsulate to support value creation, human imagination, creativity, and action), and are accessible via a programmatic bitstring interface (i.e., they are accessed via a programmatic interface rather than a manual or physical interface) (Markus & Rowe, 2023; Piccoli *et al.*, 2022). Various technologies fit these properties, including the so-called SMACIT technologies (social, mobile, analytics, cloud, Internet of Things), which are increasingly studied in IS research (Markus & Rowe, 2023; Vial, 2019). 2- *Two intertwined levers*. Digital transformation involves the simultaneous coexistence of digitization and digitalization (Baiyere *et al.*, 2023). Digitization refers to the creation of digital artifacts based on bitstrings. It may involve the duplication, conversion, or replacement of a physical or analog artifact with a digital copy (Baiyere *et al.*, 2023; Holmström *et al.*, 2019). It may also occur first, before its physical counterpart. Sometimes, it may even take place without being subsequently duplicated in the physical world (Affogbolo, 2022; Baskerville *et al.*, 2020). Digitalization, on the other hand, builds on this digitization to achieve new goals, rearrange, or fundamentally change processes, the way business is done, and so on (Baiyere *et al.*, 2023; Fabian *et al.*, 2023; Holmström *et al.*, 2019). The two are intertwined, interrelated, and essential to shaping digital transformation (Baiyere *et al.*, 2023). For example, digitizing artifacts does not mean that the way that business is done will suddenly become digital. This can only be achieved by undertaking the second part of the process, which is digitalizing (Baiyere *et al.*, 2023). Similarly, digitalizing cannot be undertaken without digitizing. 3- *Deep change*. Digital transformation should correspond to a metamorphosis, a major or radical change in form, or a deep structure change (Markus & Rowe, 2023). This property is probably the most recognized in the current IS literature on digital transformation. It is reflected in the use of frames by scholars such as radical change of business model, redefinition of value proposition, and reshaping of organizational identity as a result of intertwined digitization and digitalization (Baiyere *et al.*, 2023; Markus & Rowe, 2023). 4- *Beyond organizations*. The concept of digital transformation should not be confined to organizations. It encompasses metamorphoses resulting from digitization and digitalization that occur in various entities, including industries or business areas, events, or even society as a whole (Baiyere *et al.*, 2023; Karanasios, 2022; Vial, 2019).

As can often be seen in the literature, I4.0 is roughly consistent with these four properties. In particular, the various digital technologies that can be incorporated into the I4.0 have been illustrated above. Likewise, it has been recalled that the human-like capabilities emulated in I4.0 can be used in a variety of environments (Melville *et al.*, 2023). In addition, many studies have mentioned digitization (Horváth & Szabó, 2019; Lemstra & de Mesquita, 2023; Tortorella *et al.*, 2023) and digitalization (Ghobakhloo *et al.*, 2021; Huber *et al.*, 2022) aspects of I4.0. Regarding the driven changes, some contributions (Frank *et al.*, 2019) explained that I4.0 may entail or lead to reshaping the business model towards a service-oriented approach (Ghobakhloo *et al.*, 2021; Horváth & Szabó, 2019). Such a shift is consistent with the deep change property described above (Markus & Rowe, 2023). However, many of the changes resulting from I4.0 are not deep or radical enough to result in a novel identity as some contributions (Baiyere *et al.*, 2023; Wessel *et al.*, 2021) point out. For example, it is questionable whether the four I4.0 affordance categories identified by Melville *et al.* (2023), namely expansive decision-making, creativity automation,

human-artifact relationship, and inter-machine teaming, really correspond to metamorphoses or identity reshaping. Concerning the human-artifact relationship, Melville *et al.* (2023, p.745), for example, argue that it reflects a *subtle*[1], though significant, shift from previous human-computer interactions. Nevertheless, and as argued in several papers (Baiyere *et al.*, 2023; Besson & Rowe, 2012; Markus & Rowe, 2023; Wessel *et al.*, 2021), to be considered transformational, the shift does not have to be subtle, but rather radical, profound. Lemstra & de Mesquita (2023) also point out that I4.0 leads to changes such as continuous process improvement, improved workplace safety, etc. Obviously, such changes cannot be considered transformational either. They are more in line with IT transformation[2], a "*process of implementing technologies that allow internal organizational processes to be digitized … to improve operational efficiency among other productivity gains*" (Baiyere *et al.* 2023, p.472). Unlike digital transformation, which reshapes the identity and value proposition, IT transformation supports or enhances the existing identity and value proposition (Wessel *et al.*, 2021, p.116).

Considering these developments, it is more appropriate to say that I4.0 encompasses both IT transformation and digital transformation. In other words, and depending on the objectives defined, I4.0 can take the form of IT transformation or, rather, digital transformation. This duality makes I4.0 a complex and multifaceted concept (Culot *et al.*, 2020, p.12).

After these clarifications on what I4.0 is, we will now look at the genesis of this special issue.

2. SPECIAL ISSUE GENESIS

A few years ago, the board of AIM (French Association for Information Management) issued a call for proposals to create Special Interest Groups (SIGs) within the French IS scholarly community to develop intellectual interest and conversation around a variety of topics relevant to the field of Information Systems, both classical and emerging. Among the objectives assigned to these SIGs, one was to coordinate special tracks at the annual AIM conferences that would discuss papers related to the topics of interest of the SIGs. Another goal was to promote discussion of their topics beyond the conferences. At the time of the call, the conversation around I4.0 had gained momentum in sister disciplines such as operations management, innovation management, and technology management, where the topic was increasingly being explored through dozens of papers published in top-tier journals in those disciplines. At the same time, surprisingly, the IS discipline seemed to show very little interest in this emerging topic. The field's leading outlets, the *Senior Scholars' List of Premier Journals* (AIS, 2023), have explicitly published nothing on this salient topic, which was also poorly discussed at the field's major conferences. Given this insufficient discussion on I4.0 in the IS field, the guest editors of this special issue submitted a proposal to the AIM call. A few months later, our proposal was accepted. In line with the objectives, a special track has been proposed at each AIM annual Conference since then, i.e., in 2019. In this way, we succeeded in starting the conversation about I4.0 in the French IS scholarly community. But we were still not satisfied. The leading journals in the field continued to show little interest. For

[1] Emphasis added.

[2] The term "*IT transformation*" is proposed by Baiyere *et al.* (2023, p.472). While relevant beyond the organizational context to some extent, it is a synonym for the "*IT-enabled organizational transformation*" more often discussed in IS research (Besson & Rowe, 2012; Vial, 2019; Wessel *et al.*, 2021).

example, the work of Melville *et al.* (2023), which reviewed the journals mentioned by the *AIS College of Senior Scholars*, the *AIS Affiliated Journals* (including *Systèmes d'Information et Management*), and thirteen other leading IS journals, identified only thirty papers published through 2021 (before July). Since our goal as SIG coordinators is also to promote the topic beyond the AIM annual conferences, we decided to propose a special issue, which we also chose to focus specifically on SMEs.

Although SMEs represent more than 90% of businesses, 50-70% of the workforce, and more than 50% of GDP worldwide (Fabian *et al.*, 2023; Mandviwalla *et al.*, 2021), they are often underexplored in the I4.0 literature (Somohano-Rodríguez *et al.*, 2022). However, as a former policymaker from the French Ministry of Economy and Finance[3] pointed out, large organizations "*do not have the monopoly on I4.0. SMEs are still a largely untapped source*". Nevertheless, scholars have identified some characteristics of SMEs that may hinder their ability to take advantage of I4.0. For example, several studies (Fabian *et al.*, 2023; Horváth & Szabó, 2019; Mandviwalla *et al.*, 2021; Soni *et al.*, 2022) have highlighted their relative lack of size and capital (whether economic, social, human, or organizational capital). At the same time, SMEs have certain characteristics that may help them to embrace I4.0 more easily, such as flexibility and smallness (Fabian *et al.*, 2023). Thus, it may be necessary to consider a dual perspective (both facilitators and impediments) to fully explore the SMEs' journey to I4.0.

Beyond their characteristics that may hinder or facilitate their adoption and use of I4.0, it is important to further explore and document SMEs' approach to I4.0 for at least two reasons. 1- As members of (large) value networks where upstream suppliers and downstream customers are likely to use I4.0, SMEs face a survival challenge (Soni *et al.*, 2022; Tamvada *et al.*, 2022). They need to adapt to their value networks in order to continue to survive, be competitive, and succeed. Therefore, I4.0 is seen as imperative, vital for them (Fabian *et al.*, 2023; Mandviwalla *et al.*, 2021; Tamvada *et al.*, 2022). However, they may feel lost about what to do and how to do it (Somohano-Rodríguez *et al.*, 2022). As IS scholars, our works can inform and support them. 2- There is a gap in the literature in terms of developing theories and frameworks that can "sufficiently"[4] inform practitioners and academics about how SMEs embrace I4.0 (Soni *et al.*, 2022; Yang *et al.*, 2023), and the resulting value to them and their stakeholders. As Culot *et al.* (2020) point out, I4.0 is a complex and multifaceted concept. Examining this concept through the contextual lens of SMEs is likely to add another layer of complexity. Theories, potentially next-gen[5] theories, are then needed to make sense of this complexity (Burton-Jones *et al.*, 2021). Next-gen theories are typically expected to "*provide novel ways of thinking that are so sufficiently different they shift existing patterns of theorizing*" (Burton-Jones *et al.*, 2021, p.303) and to better account for emerging and complex phenomena such as I4.0 in SMEs. They may *replace* classical theories to better explain or account for a phenomenon, *reformulate* existing theories by significantly unpacking or modifying them to provide new and better insights, *extend*

[3] See the January 6, 2020, Lesechos.fr press release entitled "L'industrie 4.0 n'est pas une option pour notre économie".

[4] Burton-Jones *et al.* (2021, p.302) call for new theorizing when existing theories are insufficient to account for changes occurring in the contemporary world, such as the effects of I4.0.

[5] Next-generation.

current theories by significantly expanding them to explain or reveal a new or emerging phenomenon (Burton-Jones *et al.*, 2021, p.303). In next-gen theorizing, scholars may also choose the strategy of *envisioning*, i.e., offering bold new theoretical perspectives to open up a new world (Burton-Jones *et al.*, 2021, p.301,303). All of these theorizing strategies are suitable to further illuminate SMEs' approach to I4.0.

In the next section, we suggest five research avenues where scholars can potentially draw on next-gen theorizing to better illuminate the adoption and use of I4.0 in SMEs.

3. RESEARCH AVENUES

In line with the four major thematic areas of IS inquiry mentioned above, we present five research avenues that we believe can shed more light on SMEs' approach to I4.0: 1- open and business model innovation resulting from I4.0, 2- I4.0 success, 3- I4.0-related vulnerabilities, 4- I4.0 impacts on well-being, 5- I4.0 effects on sustainability. The aim of these five research avenues is not to comprehensively explore the phenomenon of interest. Rather, they correspond to some of the issues we believe are key to exploring how SMEs are using I4.0.

Avenue 1. Open and business model innovation resulting from I4.0

In the specific context of crises and pandemics that the world has experienced in recent years, previous academics pointed out that SMEs were among the first to adopt open innovation (OI) initiatives (Bajkó *et al.*, 2022). The influence of OI on both sustainable growth and competitiveness of firms has been highlighted many times (Barret *et al.*, 2021; Obradovic *et al.*, 2021). However, to achieve their best, firms need other stakeholders such as governments or universities (Patrucco *et al.*, 2022).

In addition to OI research, the role of a process-based approach in innovating the business model (BM) itself through business model innovation (BMI) (Madhavan *et al.*, 2022) has also been studied. For example, Garzella *et al.* (2021) highlighted the fact that the digital era and the I4.0 paradigm "*open unforeseen possibilities and offer the potential not only to create radically new products and services and to share knowledge between different actors of the technology ecosystem … but also to generate innovative BMs*" (p.35). In the specific case of SMEs, which often face resource scarcity, focusing on BMI as a source of future value is a crucial element (Dutot *et al.*, 2023; Amit and Zott, 2012). Additional research has pointed out the fact that such firms are often reluctant to develop new business models in the context of I4.0 (Kiel *et al.*, 2017). Understanding why or how they could benefit from I4.0 is important, as their economic positioning is crucial for most countries.

Going back to the work of Muller and Daschle (2018), we agree with the authors when they say that a variety of frameworks and definitions of business models have emerged over the past decades. However, academics tend to agree on the fact that BM focuses on (1) adding value to customers, (2) levels of interaction with their stakeholders, and (3) the compensation from their customers. BMI through I4.0 thus represents both an opportunity and a challenge for companies. On the one hand, they can solve customer problems even more effectively, create new revenue models, and address entirely new customer

segments (Müller *et al.*, 2018). On the other hand, a growing number of companies are also expressing concern about the threat to their existing business models. Müller (2019) reinforced the idea that companies can only derive value from new technologies through appropriate business models (Chesbrough, 2010). He sees technological innovation as a key driver of BMI (Baden-Fuller and Haefliger, 2013). In response to changes in the environment, companies need to adapt their business models to external threats and opportunities (Saebi *et al.*, 2016). More specifically, by introducing I4.0, manufacturers are able to develop new customer value (Ehret and Wirtz, 2017; Müller *et al.*, 2018) through new services and product-service systems.

Avenue 2. I4.0 success

This research avenue, which is related to the organizational impact thematic area (Sidorova *et al.*, 2008), is currently being explored to some extent in the literature. For example, Ghobakhloo *et al.* (2021) identify thirteen determinants of I4.0 success, including the availability of capital. The study by Sony & Naik (2020) also identifies ten I4.0 success factors, including alignment between I4.0 initiatives and organizational strategy, top management support, employee reskilling, and cybersecurity management. With respect to SMEs, Moeuf *et al.* (2020) also emphasize employee training and strong support from the owner or top management as critical success factors for I4.0. However insightful these studies may be, they do not shed light on the process (how, why) that can lead to I4.0 success, i.e., the "*activities and events that occur over time to generate*" the success of I4.0 initiatives in SMEs (Jewer & Compeau, 2022, p.577). In other words, beyond just presenting a long list of potential success factors, we need to understand how SMEs can achieve success for their I4.0 initiatives, i.e., how they can realize the net benefits expected from I4.0 projects undertaken. DeLone & McLean's (1992) IS success framework, probably the most influential in the IS field (Mehta *et al.*, 2022), provides to some extent, such a process perspective. Their framework presents "*both temporal and causal influences*" that can lead to the realization of the expected net benefits (DeLone & McLean, 1992, p.83). However, as the phenomenon of I4.0 in SMEs is emerging and complex, we recommend following the theorizing strategies suggested by Burton-Jones *et al.* (2021). For example, future studies can *extend* or *replace* DeLone & McLean's (1992) success framework to improve our understanding of how SMEs can achieve the expected benefits of I4.0. On the other hand, Metha *et al.* (2022, p.617) have pointed out that the current IS success literature has not conclusively demonstrated technology success at the organizational level. In this regard, we encourage scholars to explore how SMEs are able to realize I4.0 benefits at the organizational level. Regarding individual-level success, some contributions (Cecez-Kecmanovic *et al.*, 2014; Metha *et al.*, 2022) emphasize that perceived or experienced benefits may vary depending on the position in the organization. Therefore, the perceptions or expectations of owners, top managers, middle managers, and front-line employees may be quite different, and potentially conflicting. How, then, can SMEs reconcile the expectations of their various internal stakeholders in realizing I4.0 benefits at the individual level?

Avenue 3. Vulnerabilities associated with I4.0

While I4.0 has the potential to bring benefits to organizations (and society) as discussed above, it may also introduce new vulnerabilities or exacerbate some of the existing ones (Kim *et al.* 2022;

Ransbotham *et al.*, 2016; Tarafdar *et al.*, 2015; Venkatraman *et al.*, 2018). Therefore, this line of research, which is related to the technology applications thematic area (Baiyere *et al.*, 2020), seems important to explore further.

Vulnerabilities refer to the risk of harm resulting from adopting and using I4.0 digital technologies (Ransbotham *et al.*, 2016, p.834). Vulnerabilities also refer to the 'dark side' of the concept, that is, the negative phenomena related to the use of digital technologies of I4.0 that could harm personal, organizational, and societal well-being (Tarafdar *et al.*, 2015, p.161). Several contributions in the IS literature (Califf *et al.*, 2020; Ransbotham *et al.*, 2016; Tarafdar *et al.*, 2015; Venkatraman *et al.*, 2018) suggest that vulnerabilities can arise from the mere presence (adoption and use) of digital technologies (e.g., techno-distress, information overload), unintentional or unconscious negative use of these technologies (e.g., inadvertent confidentiality breach), or intentional, conscious deviant use (e.g., unethical use). Various vulnerabilities associated with the adoption and use of digital technologies have also been investigated in the IS literature, as summarized by Tarafdar *et al.* (2015, p.161). Examples include control of individuals in the work context, workflow rigidity, reduced interpersonal interaction and social support, technological anxiety, automation-induced unemployment, identity theft, loss of privacy, intellectual piracy, and software-related accidents.

With respect to particularly ubiquitous digital technologies, such as those often referred to in I4.0, the contribution of Ransbotham *et al.* (2016) identifies several mechanisms that lead to the manifestation of vulnerabilities associated with their adoption and use. As one mechanism, the *increased visibility* afforded by the adoption and use of I4.0 can lead to identity and intellectual property theft, loss of trade secrets, and privacy concerns (Kim *et al.* 2022; Ransbotham *et al.*, 2016). As another mechanism, the *increased interconnectedness* provided by digital technologies that are often associated with I4.0 can increase techno-distress and facilitate security breaches and cyber fraud (Baiyere *et al.*, 2020; Ransbotham *et al.*, 2016). Another mechanism, *cost reductions* driven by I4.0, can create new competitive threats (from new entrants) to incumbents (Ransbotham *et al.*, 2016). For example, additive manufacturing makes it possible to produce physical artifacts easily and cost-effectively.

However, the vulnerabilities mentioned above and the plausible mechanisms that can lead to their manifestation seem to be less considered in the current I4.0 literature. For example, as shown in the paper by Lemstra & de Mesquita (2023), the vulnerabilities most often mentioned in the I4.0 literature are related to security issues. However, there may be over types of vulnerabilities. Therefore, we invite researchers to take a closer look at I4.0-related vulnerabilities beyond security issues.

On the other hand, there is a lack of studies investigating the vulnerabilities associated with adopting and using I4.0 in SMEs. The contribution of Son *et al.* (2020), one of the rare studies exploring the dark side of digitalization from the perspective of SMEs, focused on the digitalization of the supply chain. Although this topic of interest could be related to the overarching phenomena of I4.0, it was not explicitly the focus of the study. Nevertheless, this contribution interestingly demonstrated that supply chain digitalization can increase SMEs' dependence on their larger customers

in the value networks. In such a configuration, SMEs are more exposed to the opportunism of larger customers (Son *et al.*, 2020). In other words, in addition to exposing SMEs to new competitive threats from the supply side (see cost reduction mechanism), the I4.0 may also increase their vulnerability to opportunistic behavior from the demand side. Such issues merit further investigation.

Avenue 4. Greater focus on work-related well-being

While the current literature is highly interested in the potential benefits of I4.0 for organizations and society, the resulting impact on people has been underexplored (Melville *et al.*, 2023; Neumann *et al.*, 2021). However, the use of I4.0 digital technologies in organizational settings is leading to the emergence of what some contributions have called 'augmented employees' or 'operators 4.0' to illustrate the resulting evolution of the job characteristics of front-line organizational members for example (Fantini *et al.*, 2020; Neumann *et al.*, 2021; Romero *et al.*, 2020). In this line, it has been shown that the use of I4.0 technologies often requires additional competencies while at the same time leading to job breadth, expanded responsibilities, increased autonomy and problem-solving demands, and decentralized decision-making for front-line employees (Affogbolo, 2022; Cagliano *et al.*, 2019). In other words, the use of I4.0 affects the work design of different employees (Wang *et al.*, 2020). These evolutions can have both positive (e.g., opportunities for growth and development, opportunities to learn and develop new competencies, sources of motivation, etc.) and negative (e.g., fatigue, anxiety, strain, etc.) consequences for the well-being of these workers (Guest, 2017; Huo & Boxal, 2018). These evolving work characteristics therefore require a greater focus on well-being (Guest, 2017, p.21;), and, broadly, the humanistic dimension of I4.0 (Melville *et al.*, 2023; Neumann *et al.*, 2021) as mentioned above.

Work-related well-being corresponds to the "*overall quality of an employee's experience and functioning at work*" (Grant *et al.*, 2007, p.52). This synthetic view of well-being seems to be the most accepted in the current literature (Guest, 2017; Ho & Kuvaas, 2020). It can be related to the concept of human sustainability, which refers to "*an employee's ongoing ability to maintain health (psychological, social, and physical) without subverting growth (the investment of resources into expanding the self beyond its current state) or generativity (the investment of resources into expansion outside or beyond the self)*" Barnes *et al.* (2023, p.1966). In other words, well-being is an overarching concept that emphasizes the importance of also considering the benefits to employees (in addition to organizational benefits), or at least not undermining their health and professional growth. In the literature, scholars (Barnes, *et al.*, 2023; Guest, 2017; Grant *et al.*, 2007; Ho & Kuvaas, 2020) often conceptualize well-being around three dimensions: psychological, physical, and social.

Psychological well-being refers to employees' subjective experiences at work (Grant *et al.*, 2007). It reflects the extent to which employees are engaged, satisfied, and happy at work (Guest, 2017; Ho & Kuvaas, 2020). These aspects are important to consider as Neumann *et al.*, (2021) argue that the use of I4.0 technologies may have an impact on psychological job demands (cognition, emotion). For example, Bednar & Welch (2020, p.293-294)

note that I4.0 can enable employees "*to realise their full creative potential … and find greater meaning in their work roles*". This may suggest that I4.0 can, to some extent, lead employees to be more aligned with their calling or to experience their job as a calling, i.e., a job that is meaningful and allows for self-expression while being aligned with a purpose beyond self-interest and that addresses needs in the world (Duffy & Dik, 2013; Thompson & Bunderson, 2019). As noted by Melville *et al.* (2023), such a potential positive evolution of work enabled by I4.0 is likely to make employees more satisfied and happier. On the other hand, I4.0 digital technologies can make employees feel trapped in a digital cage (Wang *et al.*, 2020). In fact, the constant and end-to-end digital monitoring enabled by I4.0 (Calabrese *et al.*, 2021) can eventually intrude into employees' personal lives and cause emotional and psychological exhaustion. For example, digital monitoring of autonomous manufacturing processes can push notifications or emails to employees (operators and/or managers) anytime and anywhere regarding various events (process completion, unplanned interruption, etc.). Depending on the type of notification, the employee is expected to take action, even after regular working hours. Such situations of 'digital obligations' can cause psychological exhaustion if they occur frequently outside regular working hours. Melville *et al.* (2023) also point to employees' fear (albeit potentially exaggerated; see Fleming (2019) on the likely limited impact of I.40 digital technologies such as AI on job destruction) of being replaced by I4.0 technologies that can emulate human cognition and communication. This sense of fear can make them less happy and undermine their job satisfaction and engagement at work.

Physical well-being refers to the health of employees in an occupational context, whether physiological and/or mental (Grant *et al.*, 2007; Guest, 2017; Ho & Kuvaas, 2020). In this context, it is often explored whether the work environment causes injuries, illnesses, distress (the dark side of stress), anxiety, or burnout in employees, or whether the work environment leads to positive feelings such as a sense of challenge (Guest, 2017; Ho & Kuvaas, 2020). Returning to I4.0 digital technologies, they support employees and allow them to save cognitive and mental resources in the work environment (Romero *et al.*, 2020; Wang *et al.*, 2020) which in turn can lead to reduced distress and anxiety. In the same line, I4.0 can reduce physical workload and related physiological injuries by automating certain physical tasks (Affogbolo, 2022). In addition, several contributions explain that the use of digital technologies, as often mentioned in I4.0, can lead to a positive feeling of eustress (bright side of stress), i.e., the challenge of successfully managing these technologies for greater personal effectiveness at work (Califf *et al.*, 2020; Tarafadar *et al.*, 2019). On the negative side, however, the use of I4.0 digital technologies and the associated increased job demands can generate information overload, learning requirements, and hassles (Wang *et al.*, 2020), which in turn can lead to increased anxiety and distress (e.g., fear of unsuccessfully managing such increased demands, which can lead to unchanged or, in the worst case, decreased personal performance at work).

Social well-being refers to the quality of employees' interpersonal relationships in their work environment (Grant *et al.*, 2007; Guest, 2017). It is often reflected in the level of support from the hierarchy as well as peers, trust, and fairness (Grant *et al.*, 2007; Guest, 2017; Ho & Kuvaas, 2020). The contribution of Wang *et al.* (2020) recalls that two types of social support are often

developed in a work context. The first one, referred to as *instrumental support*, is more formal and related to the tasks and roles. It is usually a channel to provide employees with the necessary resources, advice, information, training, etc. The second, referred to as *expressive support*, is more informal and takes the form of friendship and empathy from peers and supervisors. As Wang *et al.* (2020) further explain, digital technologies more often promote instrumental support. For example, the I4.0-enabled digital monitoring discussed above allows supervisors to monitor the work of employees and provide feedback, advice, or help when needed (Mantello *et al.*, 2023). Similarly, an I4.0 digital technology such as Augmented Reality (AR) allows maintenance specialists to remotely assist operators to perform minor machine repairs more quickly in order to reduce unplanned downtime (Affogbolo, 2022). At the same time, however, I4.0 may make employees uncomfortable with instrumental support because it implies constant digital monitoring and managerial control. As Mantello *et al.* (2023, p.98) point out, digital surveillance "*can erode employer-employee relations, leading to lower trust levels and stalled productivity*". Wang *et al.* (2020) added that (constant) digital monitoring can lead to employees feeling less autonomous and more distressed. In addition to these potential negative sides of instrumental support, it is also worth noting that I4.0 digital technologies may undermine expressive support. In this regard, the contribution of Wang *et al.* (2020) points to the feelings of loneliness or isolation among employees caused by digital technologies. For example, as I4.0 makes it possible to increasingly automate manufacturing processes, only one operator may be responsible for managing entire manufacturing production lines (one or more, depending on the organization), often including several automated machines. Such a work situation can potentially lead to increased social undermining of employees, as their interactions (especially face-to-face, which are the most prone to emotional support) with peers and superiors are reduced.

To summarize our discussion in this section concerning the thematic area of I4.0's impact on individuals, we argue that the use of I4.0 digital technologies can both enhance and undermine the well-being of organizational members. Indeed, the I4.0 can help employees experience their work as a calling, reduce work-related injuries, and increase the instrumental support from the hierarchy. At the same time, however, it can lead to psychological exhaustion, distress, and even loneliness. Unfortunately, these important human-related effects of I4.0 have been poorly explored in the IS and broader management literature. This lack is particularly acute with respect to SMEs. Therefore, more research is needed to explore what effects I4.0 has on the well-being of individuals, and how they occur, especially with respect to SMEs. We expect these issues to attract more academic interest in the future.

Avenue 5. I4.0 effects on sustainability

Sustainability is one of the hottest topics in academia. Special issues in almost all fields integrate this concept. I4.0 has been mainly addressed in the current literature from a technological perspective, overlooking the sustainability challenges related to this recent paradigm. Ejsmont *et al.* (2020) identified almost fifteen literature reviews about the impact or link between I4.0 and sustainability. However, as Jamwal *et al.* (2022) pointed out recently, very few studies discussed the relationship between I4.0 and sustainability from a managerial perspective.

They suggested that additional factors, such as policy implications or risks, should be discussed by academics and included in subsequent research.

Following this recommendation, academics (Zizic *et al.*, 2022) have focused on business model changes (or BMI) as a driver of sustainability. Indeed, by designing better business models – i.e., balancing profits with social and environmental benefits, reconfiguring resources and processes for new business models, integrating technologies with the business model "*as a multidimensional and complex task, and usage of the existing business modeling methods and tools*" (p.10) – firms could respond to the United Nations' call and align their structure with the Sustainable Development Goals.

In line with these contributions, we believe that many research opportunities lie ahead and urge academics to answer the following questions: How can applications of I4.0 contribute to sustainable development and help managers develop sustainable practices? What are the main frameworks that should be considered to integrate I4.0 with sustainable development? How can such integration lead to improved performance?

Having outlined the research avenues that we believe are important to explore in relation to SMEs' journey to I4.0, we will now introduce the two papers in this issue and conclude the editorial essay.

PRESENTATION OF PAPERS IN THE ISSUE AND CONCLUSION

The two papers in the special issue are related to the thematic area of organizational implications of I4.0. They both examine, albeit differently, the impact of I4.0 at the organizational level in SMEs.

The first paper, by Tezenas Du Montcel and Rayna, entitled *Digitization and Suppliers Disruption: The Impact of Digital Manufacturing in the Dental Care Industry,* focuses on the impact of I4.0 on the value chain. Their paper can be linked to some extent to the first research avenue discussed above, in particular, the change in the value network (and then the business model) resulting from I4.0. Especially, the authors examined the case of the dental industry which is quite interesting to study because it is undergoing major shifts as a result of the adoption and use of a variety of I4.0 digital technologies, such as Computer-Aided Design and Additive Manufacturing, to name a few. In their study, the authors showed that dentists, who operate at the bottom of the value chain can disrupt their suppliers, the prosthetists (who operate at an upper position in the value chain), by adopting and using I4.0 digital technologies. In doing so, dentists are reshaping the value network in this industry and improving their value proposition (Affogbolo *et al.*, 2020). Indeed, in profiting from I4.0 digital technologies, dentists can now provide a complete treatment in just one appointment (as opposed to at least two appointments previously). In addition, the paper shows that dentists can overcome their small size and related resource constraints by joining together in a larger practice in order to reduce entry costs for each member.

The second paper, by Penin, Guichardaz and Schenk, entitled *Blockchain and open innovation for SMEs: Analytical framework and decision model*, analyzes the potential impact of blockchain technology on SMEs in the context of open innovation (OI). Through a theoretical analysis, the authors establish that blockchain has a positive

impact on market-based OI processes and in collaborative OI, involving well-defined sets of tasks and codified knowledge. Their analysis highlights the relevant roles of trust and intermediaries. Finally, the authors develop and propose a decision model for SMEs that consider the implementation of Blockchain in an OI setting, offering an important contribution to academia.

The papers in this special issue, as well as the discussion proposed in this editorial, lead us, the guest editors, to advocate for three future research directions. First, we strongly believe that the focus of I4.0 should no longer be limited to manufacturing industries. Focusing on other industries will not only help academics in their understanding of I4.0, but also help more managers in their implementation of related technologies. Second, we propose that I4.0 encompasses both digitization and digitalization. And third, IS scholarship is well-positioned to be interested in this phenomenon and should therefore be more engaged with it. Further contributions to address this phenomenon are more than welcome.

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