Business models in the context of Industry 4.0 as support in generating value and strategic alignment

Modelos de negócio no contexto da Indústria 4.0 como apoio na geração de valor e alinhamento estratégico

Modelos de negocio en el contexto de Industria 4.0 como soporte en la generación de valor y alineamiento estratégico

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Abstract
The production models created by the industry throughout the twentieth century are now put in check in the face of technological developments and the new digital transformation of manufacturing, known as Industry 4.0 (I4.0). Although many advantages and possibilities are still perceived from this transition, there is little discussion about the business models that will best adapt to this context, making it opportune to review the business models that emerge or are adapted to this new paradigm. This study aims to study the business models related to I4.0, in order to understand how these models support the value creation and how the alignment takes place with the strategy, in addition to identifying gaps for future studies. The methodology used was a systematic literature review, using bibliometrics and network and content analysis. This research had a descriptive purpose, making use of secondary sources through bibliographic survey, with consultation of SCOPUS and Web of Science databases. The sample of 149 publications was analyzed, allowing the discussion of business models in the context of Industry 4.0. Likewise, the analysis of the selected articles made evident the wide scope for future research. It is concluded from the research, that business models in the context of Industry 4.0 point to sustainable industrial value creation and tend to be directed to consumers, with a flexible and customized demand offer, passing by the lot size one, mass customization, when companies will shift their focus from marketing their products to providing solutions to specific customer desires.
Keywords: Industry 4.0; Business model; Strategy; Value creation; Bibliometry.

Resumo
Os modelos de produção criados pela indústria ao longo do século XX passam a ser questionados diante da evolução tecnológica, e da nova transformação digital da manufatura, conhecida como Indústria 4.0 (I4.0). Embora muitas vantagens e possibilidades sejam percebidas a partir desta transição, ainda existe pouca discussão acerca dos modelos de negócio que melhor se adaptarão a este contexto, tornando-se oportuna uma revisão dos modelos de negócio que surgem ou são adaptados a este novo paradigma. Este estudo visa a estudar os modelos de negócios relacionados ao

I4.0, a fim de entender como esses modelos suportam a criação de valor e como ocorre o alinhamento com a estratégia, além de identificar lacunas para estudos futuros. Como metodologia foi utilizada a revisão sistemática da literatura, por meio de bibliometria e análise de redes e conteúdo. Esta pesquisa fez uso de fontes secundárias por meio de levantamento bibliográfico, com consulta as bases de dados Scopus e Web of Science. A amostra de 149 publicações foi analisada, permitindo a discussão de modelos de negócio no contexto da Indústria 4.0. A análise dos artigos selecionados tornou evidente o largo espaço para pesquisas futuras. Conclui-se que os modelos de negócio no contexto da Indústria 4.0 visam a criação sustentável de valor industrial e tendem a ser direcionados aos consumidores, com uma oferta de demanda flexível e customizada, passando pelo lote tamanho um, customização em massa, quando as empresas mudarão seu foco da venda de seus produtos para o fornecimento de soluções para os desejos específicos dos clientes.
Palavras-chave: Indústria 4.0; Modelo de negócio; Estratégia; Criação de valor; Bibliometria.

Resumen

Los modelos productivos creados por la industria a lo largo del siglo XX comenzaron a ser cuestionados ante la evolución tecnológica conocida como Industria 4.0 (I4.0). Aunque se perciben muchas ventajas y posibilidades de esta transición, todavía hay poca discusión sobre los modelos de negocio que mejor se adaptarán a este contexto, por lo que es oportuno revisar los modelos de negocio que surgen o se adaptan a este nuevo paradigma. Este estudio tiene como objetivo estudiar los modelos de negocio relacionados con I4.0, con el fin de comprender cómo estos modelos apoyan la creación de valor y cómo se produce la alineación con la estrategia, además de identificar brechas para futuros estudios. Como metodología se utilizó una revisión sistemática de la literatura, a través de bibliometría y análisis de redes y contenido. Esta investigación hizo uso de levantamiento bibliográfico, con consulta de las bases de datos Scopus y Web of Science. Se analizó la muestra de 149 publicaciones, lo que permitió la discusión de modelos de negocios en el contexto de la Industria 4.0. El análisis de los artículos seleccionados evidenció el amplio espacio para futuras investigaciones. Se concluye que los modelos de negocio en el contexto de la Industria 4.0 apuntan a la creación sostenible de valor industrial y tienden a estar dirigidos a los consumidores, con una oferta de demanda flexible y personalizada, pasando por el lote tamaño un, la personalización masiva, cuando las empresas cambien su enfoque de comercializar sus productos a brindar soluciones a los deseos específicos de los clientes.
Palabras clave: Industria 4.0; Modelo de negocio; Estrategia; Creación de valor; Bibliometria.

1. Introduction

In a world without frontiers, facing technological advances and considering the increasing competition in the market, many countries are channeling efforts towards advanced manufacturing technologies, as a pillar for economic growth (Chen 2017). In this sense, governments are developing and launching different initiatives and programs related to the "fourth industrial revolution", such as *Industrie* 4.0 in Germany, Industrial Internet and Advanced Manufacturing in the USA, Made in China 2025 and Internet Plus in China, Super Intelligent Society in Japan and *La Nouvelle France Industrielle* in France.

Global manufacturing is going through the fourth industrial revolution with the introduction and improvement of new technologies, especially the Internet of Things (IoT) and servitization concepts, resulting in vertically and horizontally integrated production systems. The physical and virtual worlds grow together, and the most distinct objects, including machines, are equipped with sensors and actuators (Klocke et al., 2011). The result is smart factories that, with increased integration between humans and machines, begin to meet the increasingly customized demands of customers, with high variability and in small batches. (Thoben et al., 2017).

According to Stock and Seliger (2016), this new perspective is based on the creation of smart factories through networked devices as a way to simplify and streamline production. The fourth industrial revolution is described as a model in which new modes of production and consumption will dramatically transform all major industrial systems, becoming a constant target of many government plans as a goal for a sustainable future (Bertola & Teunissen, 2018).

In this sense, considering technological trends related to Industry 4.0 (I4.0), consumers are witnessing a rigid global competition, which requires companies from many sectors to constantly innovate (Bolesnikov et al., 2019). The central issue in such Economy 4.0 is to understand the impact of digital transformation, the creation of connection networks and adapt business models to increasingly demanding customers (Stverkova & Pohludka, 2018).

This new phenomenon, represented by digitalization, are bring positive impacts on different segments, creating new jobs and modifying current ones, also providing improvement in industrial productivity, development of new products, processes and new business models (Cezarino, Liboni, Stefanelli, Oliveira, & Stocco, 2019).

One of the biggest obstacles to this transition may be in the mindset of those used to existing standards, when moving to the new platform. But this must be seen as an opportunity, since it is about a transformation of organizations and their processes. (Hansen & Sia, 2015). In this way, as a reflection of the technological development driven by the I4.0 paradigm, companies need to adapt their business models as a way to promote opportunities and face the challenges that arise in this context (Saebi et al., 2017). Business models create value for stakeholders (Galegale et al., 2020; Jerman et al., 2019; Lima & Acuña, 2020; Marzzoni & Pereira, 2020; Silva, 2020; Wibowo, 2020), in addition to highlighting the main elements contained therein (Bolesnikov et al., 2019). These new business models make it easier for customers to access services (Cezarino et al., 2019).

Understanding this transformation in manufacturing and service provision by companies, and all the potential that can be generated, is of great relevance as customers are increasingly demanding in terms of product customization, price and service level (Stverkova & Pohludka, 2018). Furthermore, Ren et al. (2017) argue that I4.0 constitutes an intelligent production system capable of structuring global value creation networks by combining different industrial production factors. From a practical point of view, innovation in business models needs to be aligned with the company's strategy and its competitive landscape (Weking et al., 2019). In this sense, the understanding of how these business models are aligned with the strategy and their collaboration to generate value in organizations deserves attention from practitioners and academics.

Charro and Schaefer (2018) present a study and reveal that there is a growing need for new business models in the context of I4.0 in different areas. Therefore, other studies show that this scenario, involving I4.0, attracts great interest from governments, industries and academic communities around the world (Fang, 2016), and it is opportune to move forward in order to verify business models in the context of I4. 0, and understand how these models support value creation, as well as their alignment with the organization's strategy. To this end, the methodology of systematic literature review was used, mixing bibliometrics, cluster analysis and content analysis.

In this sense, this research presents contributions to organizational theory and practice, with the identification of a set of business models verified in the context of I4.0, in order to understand how these models support the value creation and how the alignment takes place with the strategy. There is a clear direction of business models towards the theme of innovation and value creation, sustainability and circular economy, smart factories and decision making and knowledge. Finally, the gaps identified in the study are proposed to enable the advancement of scientific research.

2. Methodology

Systematic literature review was used as research methodology, (Alcantara and Martens, 2019), mixing bibliometrics, cluster analysis and content analysis. To this end, this research deals with a theoretical study aiming to understanding concepts and contextualization inherent to business models related to I4.0. This research has a descriptive purpose. For Vergara (2013), descriptive research is about showing the idiosyncrasies of a certain population or a certain phenomenon. The research has a qualitative approach, as it focuses on understanding the meanings perceived in the phenomenon in focus (Creswell, 2014).

The research was guided by a bibliographic survey, with data collection taking place through secondary sources as a way of composing the theoretical framework. Thus, with the purpose of promoting discussion on the subject, and proceeding with a literature review, the scientific databases Scopus, Web of Science and Scielo were consulted, limiting to papers published in indexed journals, in English and Portuguese languages. Scopus and Web of Science were selected due to their broad coverage of engineering and management journals, and Scielo considered as a way to increase the spectrum of study collection.

The articles that fit the search terms were selected, without considering any temporality criteria. To identify the articles, a structured search was carried out in the databases using keywords, where different terms used to characterize I4.0 globally were listed, combined with terms referring to business models and added to the terms Strategy and Value Creation, that is, focusing on articles that address strategy and value creation (Weking et al., 2019).

Thus, the searches concentrated terms used to refer to **Industry 4.0**, including "Industr* 4.0", "Advanced Manufacturing", "Made in China 2025", "Manufacturing 2025", "Internet Plus", "4th Industrial Revolution", "Fourth Industrial Revolution", "Smart Manufacturing", "Digital Manufacturing", "Society 5.0", "Smart Factor*", "Smart Industr*", "Industrial Internet of Things", "La Nouvelle France Industrielle" and "Industrial Internet"; added to terms related to **Business Model**, "Business Mode*", "Business Plan*", "Business Project*", "Business Design*", "Business Strateg*", "Business Proposal*", "Business Program*" , combined with the terms associated with **Strategy and Value Creation**, "Strateg*", "Value Creat*" or "Creat* Value". The selection took place considering the totality of articles that fit the search terms, without considering any temporality criteria.

Based on this search, 264 articles were found in the Scopus database, 236 articles in the Web of Science database, and no article in the Scielo database. Subsequently, using the R Bilbliometrix tool (Aria & Cuccurullo, 2017), the 500 documents from both databases were compared, and those common to both platforms (duplicates) were removed, reaching the amount of 370 articles. Once such documents were identified, they were read and analyzed. After reading the abstracts and keywords of the articles, those aligned with the objectives of the study were identified. From the searches into the bases, 26 articles were considered adherent for a more detailed analysis, with another 10 obtained through the references from the selected articles, totaling 36 articles. A summary of the path taken can be seen in Figure 1.

Figure 1 - Flowchart of the article search and selection process.

Source: Elaborated by the authors (2022).

For cluster analysis, the R Bilbliometrix tool was used, combined with VOSviewer v.1.6.18 software (Van Eck & Waltman, 2010), to give greater credibility to the data processing, which enabled the identification of clusters. For the content analysis, the MS Excel tool was used, with cells aligned in columns, suitable for the insertion of specific information to carry out the literature review.

3. Results and Discussion

3.1 A background on I4.0 and business models

In a world without frontiers, facing technological advances and considering the growing competition in the market, countless countries are channeling efforts towards advanced manufacturing technologies, as a strong pillar for economic growth (Chen, 2017). In 2011, the term I4.0 emerged in Germany, which encompasses cloud computing, Internet of Things (IoT), big data, 3D printing, virtual reality and cyber-physical systems, among other technologies, presenting a growing number of applications in several areas (Vu, 2018). Officially, the I4.0 was presented in Germany in 2012 at the Hannover Fair (Pfeiffer et al., 2016).

To support the manufacturing industry in this conversion process and increase global competitiveness, policymakers in several countries have established different modes for research and technology transfer. In addition to Germany, which enacted its Industrie 4.0 program, which had an influential effect on European technology policy, the United States focused on advanced manufacturing – Advanced Manufacturing. Other industrial nations have also created their own smart manufacturing programs, such as Korea and Japan (Thoben et al., 2017).

Therefore, I4.0 is a concept that integrates the main technological innovations in the areas of automation, control and information technology, applied to manufacturing processes, creating an environment where various equipment and machines are connected in networks and provide information in a unique way, where production processes tend to gradually become more efficient (Lee et al., 2015). According to Ren et al. (2017), I4.0 creates value by combining different industrial production factors, such as production facilities, storage systems and logistics systems.

This transformation means changing the current manufacturing model to smart factories, which are much more flexible and capable to meet today's production challenges, such as lean production, rigid global competition and shorter product life cycles, which tend to have a degree of higher level of customization (Upasani et al., 2017).

Thus, Industries 4.0 is expected to have a major effect on the global economy in a short period of time (Fraga-Lamas et al.,), meaning a new period in the context of the great industrial revolutions (Lee et al., 2015). For this market, some projections consider investments of US$ 60 trillion over the next 15 years, estimating more than 50 billion equipment connected to the network in the medium term (Chen, 2017).

Industrial managers need to face the vast complexity that I4.0 represents (Jansen, 2016), and how it is characterized by being an environment where all participants are interconnected and share information (Schlechtendahl et al., 2015), therefore it is necessary that all those involved understand its dynamics, so that its principles can be applied efficiently (Ford, 2015).

The fourth industrial revolution is characterized by the introduction of the concepts of Internet of Things (IoT) and Internet of Services (IoS) in manufacturing, which enables smart factories with vertically and horizontally integrated production systems (Thoben et al., 2017). This integration, combined with the enabling technologies of I4.0, represents a major transformation, with a considerable increase in the complexity of manufacturing processes, which creates a scenario where the search for new business models becomes essential.

Within this architecture, complete virtual transparency of the service or product lifecycle allows unprecedented benefits in terms of efficiency, flexibility, response speed, consistency between individual customer needs and service and product capabilities. It is thus understood that the 4.0 concept tends to overcome the manufacturing-centric view to embrace a combination of smart factories, smart grids and smart products (Geissbauer et al., 2016).

This globally verified complexity needs to be managed by appropriate methods and tools, since the interaction between humans and machines requires efficient and secure interfaces. The new service offer needs to be based on new innovative business models, which are profitable (Baines et al., 2007).

Thus, it is worth noting that history has shown that the technological revolution without the proper evolution of business models represents a great risk for many companies (Rayna & Striukova, 2016). In this line that represents the need for new business models, the alignment with I4.0 encompasses the creation of a new architecture of the company's ecosystem, so that all data and information are collected and exchanged at any level of the organization (vertical hierarchy), and at different stages of the process throughout the value chain (horizontal network) (Schwab, 2017).

The I4.0 bases on smart production, smart logistics, smart grids, smart products and the growing use of the Internet of Things, involving planning and actions that transform value chains and lead to the emergence of new business models (Kagermann et al., 2013). In this global scenario, considering technological advances and increasingly customized customer demands, it is essential that innovative business models emerge as a way for companies to meet consumer demands, whether from consumers or in relationships with other companies.

A business model refers to the way companies create value, for whom they create value, and how they capture such value (Andries et al., 2013). Zott and Amit (2007) describe a business model as the structural pattern of the focal company, which negotiates with customers, suppliers and other partners, and thus, horizontally or vertically, establishes relationships with different stakeholders.

On the same line, there are different approaches in the literature. Reymen, Berends, Oudehand and Stultiëns (2017) define a business model as the way a company creates, captures and delivers value to its stakeholders. Similarly, a business model explains how organizations operate and create value (Jerman et al., 2019), that is, it demonstrates how the company creates, delivers and perceives value, showing the main business elements that are taking place in it (Bolesnikov et al., 2019).

Business models are not easy to define, as they can serve as scale models, functional models and ideal models at the same time (Rayna & Striukova, 2016). Therefore, a business model defines the essential mechanisms that explain how the company works without going into operational details (Abdelkafi et al., 2013).

In the manufacturing industry, business models traditionally focus on manufacturing or assembling more or less customized (physical) products and generating revenue from their sales. However, these traditional business models have come under pressure with the global harmonization of technological standards and the reduction of trade barriers (Thoben et al., 2017), with new emerging models emerging that change these traditional models (Liboni et al., 2018).

For Iansiti & Lakhani (2014), two things define a business model: the way the organization creates value for its customers (customer value proposition), and how it captures this value (how it makes money). However, there are other contributions in the literature, which were consolidated by Rayna and Striukova (2016), evidencing creation, capture, communication, proposition and value delivery.

Stock and Seliger (2016) provided an overview of the main trends and the expected development for different factors of value creation, relating equipment, people, structure, processes and products. Thus, due to the implementation of I4.0, many new innovative business models are viable and practically possible to be implemented in the market to add value to the customer and also create a competitive advantage. (Ivanov et al., 2016). In this sense, the enabling technologies of I4.0 are beginning to show the forms of service and product business models that are emerging. Such business models can be classified as product-oriented, use-oriented, or result-oriented (Ford & Despeisse, 2016).

I4.0 brings the possibility of designing new digital business models and will provide customers with greater access to services (Cezarino et al., 2019). It becomes increasingly evident that products will be manufactured in “batch one” size according to individual customer needs. This mass customization of products integrates the customer early into the value chain. For this, the physical product will be combined with new services, offering functionality and access, rather than just ownership of the product to the customer, as part of new business models (Stock & Seliger, 2016).

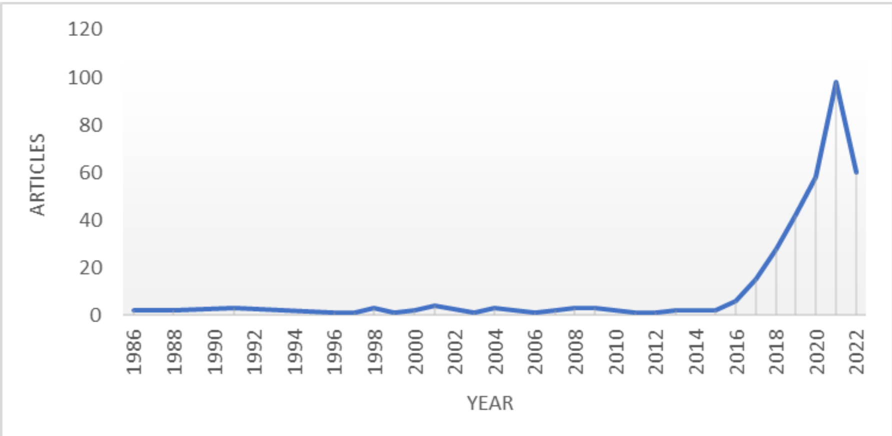
For instance, on assembly lines systems are characterized by an increasing ability to offer different products to each customer, more suited to their needs and preferences. These assembly systems will be increasingly influenced by the advent of I4.0 technologies, making it possible to propose business models that allow for late customization of products. In other words, customers will be able to modify the attributes of their product after their production (Rossit et al., 2019).

In this way, I4.0 is expected to transform industrial value creation significantly (Müller, 2019), since the new business models that emerge in such context are highly motivated by the use of smart data to offer new services, with attention to the development of sustainable business models able to create positive impacts – or reduce negative ones – for the environment and society (Stock & Seliger, 2016). Thus, considering horizontal, vertical and end-to-end integration, the authors highlight a vision based on the product life cycle in an interconnected way, as a central element of value creation networks in I4.0.

3.2 Bibliometric analysis

A total of 370 articles were identified from 228 different sources. The first bibliometric indicator (Figure 2) refers to the number of articles published along the timeline, being possible to perceive an increase of publications from 2016 onwards. Studies correlating I4.0 and business models begin to emerge. Although the term I4.0 emerged from 2011, other related terms may bring articles from previous periods. As an example, the term advanced manufacturing technology has been used for decades in the context of manufacturing, and which was included when adding the term advanced manufacturing, which is designed to refer to I4.0 in the USA.

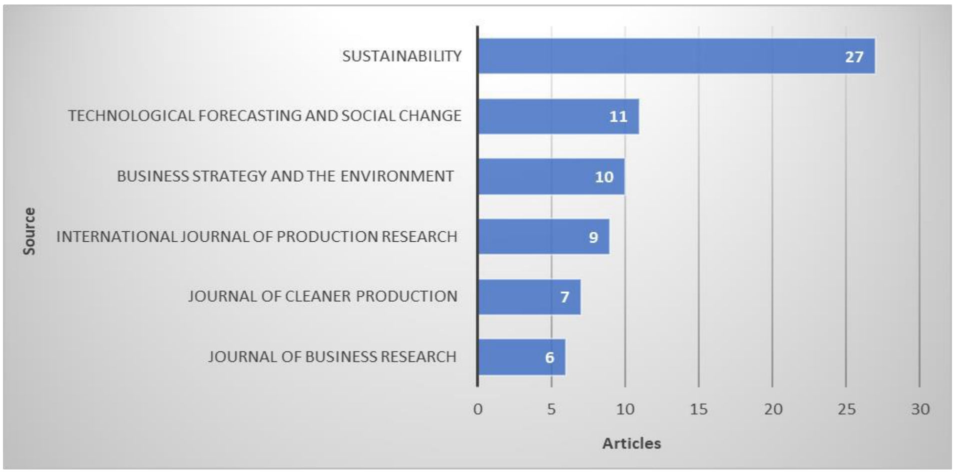
Figure 2 - Annual scientific production.



Source: Elaborated by the authors (2022).

Regarding the authors who research the topic, the number still does not seem to be significant, and the number of publications per author tends to be small. Only eight authors published more than three articles, and K.I. Voigt stands out with 7 publications. Regarding the sources, 228 were identified, with five most relevant being shown in Figure 3.

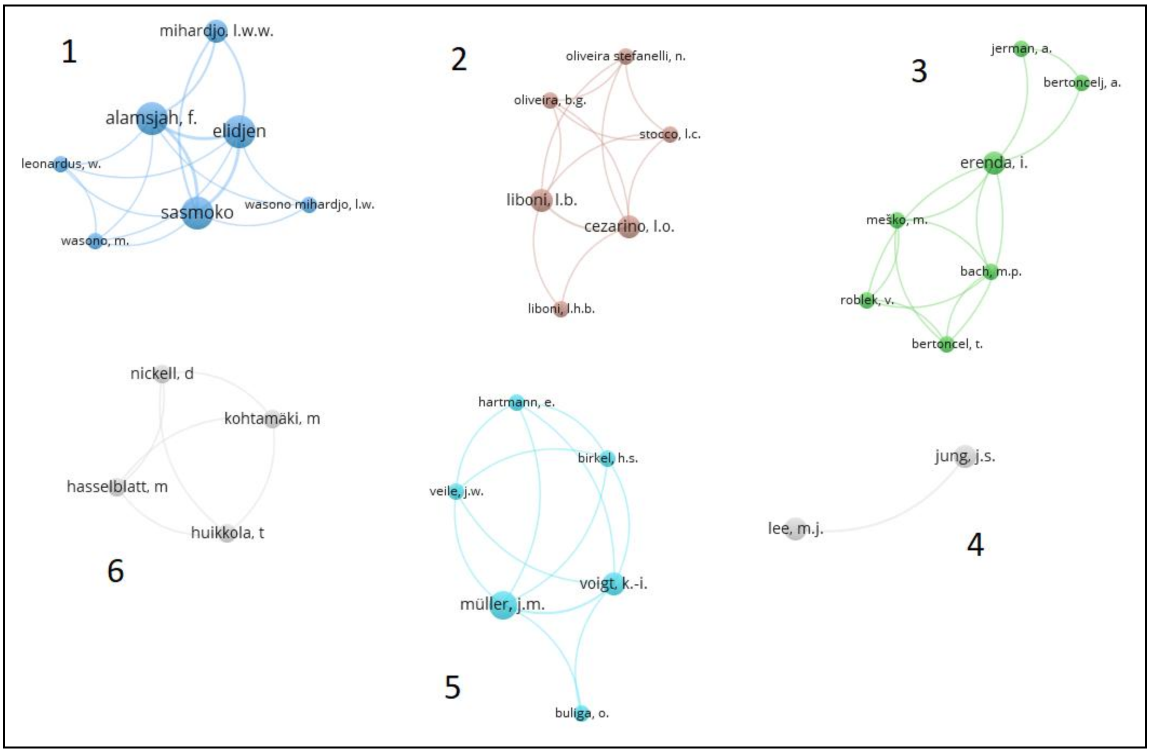
Figure 3 - Most relevant sources.



Source: Elaborated by the authors (2022).

A total of 981 authors involved in the production of the articles were identified, and Figure 4 shows the clusters formed by them, where the different themes addressed can be verified. The authors with more publications among the selected articles are perceived through the searches in the databases and snowball. J.M Müller. and K. I. Voigt stand out with a greater number of publications, as already mentioned. In the bibliometric analysis, it is worth checking the clusters formed through the interrelationship between authors, which highlights the theme addressed by the groups.

Figure 4 - Author's clusters.



Source: Authors, based on VOSviewer software (Van Eck & Waltman, 2010).

In Cluster 1, the authors are involved with innovation in business models related to I4.0, highlighting its significant impact as a facilitator in accelerating company performance in all sectors. In this sense, Mihardjo et al., (2018) understand that digital transformation, which is a combination of business models and innovation, is necessary for companies to sustain their business, and understand the measurement of implementation success of such transformation. as one of the main success factors. Collaboration is also highlighted, evidenced through co-creation, which is seen as a form of economic strategy that provides innovations in business models. Authors show that partnerships, which provide co-creation, are key factors to boost the company's performance and constitute an integrated strategy to act in the market, in the digital transformation and in the disruptive era, generating new business models (Mihardjo et al., 2019).

In Cluster 2, the authors with the most publications are Cezarino and Liboni (2019), and the theme is focused on studying issues connected with sustainability and circular economy. The authors highlight that new emerging models are changing traditional models. According to Cezarino and Liboni. (2019), the phenomenon represented by digitalization will bring positive impacts by improving industrial productivity, developing new products, processes and new business models, providing greater customer access to services. Faced with mass customization, driven by I4.0, Liboni et al. (2018) analyze the electrical systems industry in Brazil, and focus on environmental protection and process safety, with attention to detailing organizational resources.

In Cluster 3, the articles have a greater focus on smart factories and decision making. In this case, the authors see there are fundamental factors influencing business models (understood as how organizations operate and create value for stakeholders) in a smart factory. Such factors refer to top management and leadership orientations, employee motivation, collective wisdom, creativity and innovations (Jerman et al., 2019).

Like in Cluster 1, Cluster 4 also focuses on business model innovation. But here, the authors Lee & Jung (2018) analyze that the Fourth Industrial Revolution requires companies to radically rethink existing business models and innovate in business models through detailed and consistent strategies, suggesting business models guided by smart connectivity and predictability, based on ICT (Information and Communication Technologies). The authors also analyze and suggest new business model structures and strategies for the cultural content industry, which has been the object of efforts by governments and companies to discover new business models (Jung & Lee, 2019).

In Cluster 5, Müller, Voigt, and Buliga (2018), focus on the importance of business model innovation as the main source of strategic differentiation in highly competitive markets, especially regarding SME and the risks related to the adoption, or not, of the new technologies that enable I4.0. The authors give emphasis on the Internet of Things (IoT) and Industrial Internet of Things (IIoT), also making a link with the Triple Bottom Line (TBL), or Sustainability Tripod, which refers to the results achieved by an organization when measured in social, environmental and economic terms.

Müller (2019) understands that I4.0 will significantly transform industrial value creation, retrofitting traditional business models can also be a new way to generate attractive new business models with the potential to generate good profits (Kiel, Müller, Arnold & Voigt, 2017).

Finally, in Cluster 6, the authors understand that it is essential to have the adequate knowledge in order to identify the relevant and necessary data to add value to all parties that especially use the IoT solution. In this sense, Kohtamäki et al., (2019) investigate digital servitization business models, highlighting the degree of autonomy and customization of each model, based on the theory of the Firm. Hasselblatt et al. (2018), identify the skills of a manufacturer to develop, create, sell and provide Internet of Things (IoT) services, highlighting that the development of digital business models refers to the manufacturer's ability to build a new and feasible business model that, through IoT solutions, can identify the interests of its customers, suppliers and other interested parties, as a way to better meet the needs of its stakeholders.

In this context, investigations are conducted in order to analyze sustainable value creation in small and medium-sized companies, including analyzes carried out in Europe and Asia, with great emphasis on the influence of IIoT on business models, respecting the idiosyncrasies concerning to different sectors of industry. Müller et al., (2018) highlight that new business models emerge where products and services are data-oriented, with greater customer orientation. However, they claim that the implementation of these new concepts will bring many challenges to current companies, involving high costs and threats to existing business models, as well as the fear that employees will be replaced.

Thus, some business models, identified in the context of I4.0, are presented and discussed in the sequence.

3.3 Business Models in the context of Industry 4.0

The progress of digital technologies combined with other enabling technologies is transforming the way we design, produce, market and generate value from products and services. Advances in technologies such as the Internet of Things (IoT), 5G, cloud computing, data analytics and robotics are transforming products, processes and business models across all industries, creating new industry standards as global value chains unfold transform (Sung, 2018).

According to Kagermann et. al. (2013), with the I4.0, new business models emerge, which provide increases in flexibility and productivity, and intensify the ecological and social potential. In the context of I4.0, the availability of all relevant information in real time will enable manufacturing systems to meet customer requirements without waste due to reconfiguration of assembly lines or setup times through dynamic business and engineering processes (Thoben et al., 2017). Considering the possibilities of a cyber-physical system, I4.0 can allow new business models based on data, and more sophisticated forms of collaboration between companies in the value creation (Schneider, 2018).

In this way, companies must be aware of the I4.0 paradigm as they develop their activities and plan their strategies, since traditional manufacturing business models no longer fit the emerging technologies of I4.0, and new models are emerging (Sung, 2018). As for technologies, there is a growing consensus that additive manufacturing (3D printing) will be one of the next great technological revolutions (Rayna & Striukova, 2016). Likewise, according to Hasselblatt (2018), IoT has improved the ability of manufacturers to provide services, given the rapid improvement of connectivity and sensing technologies, which allow manufacturers to develop new business models.

According to Jerman et al. (2019), top management and leadership orientations, employee motivation, collective wisdom, creativity and innovations are the main factors that influence business models in a smart factory. Müller et al. (2018) state that new business models are beginning to emerge through data-driven products and services, with greater customer orientation, as well as service-based business models, made possible by data transparency. As demonstrated by Geissbauer, Vedso and Schrauf (2016), the enabling technologies of I4.0 will guide all the company's actions, based on its business model.

In this context, through the fragmentation of the value chain, business models will make it possible for small participants to become “global” players (Maslarić et al., 2016). According to Iansiti and Lakhani (2014), the scientific literature suggests that I4.0 business models are designed around new value propositions, characterized by highly individualized products, and by combinations of integrated, synchronized products and services that present innovative digital service solutions.

According to Birkel et al., (2019), many companies are still focused on marketing their products, but in the future, the focus will be on providing solutions and solving customer problems. Thus, there are different ways to monetize a business, with an intensification in the offer of different personalized services. Stock and Seliger (2016) state that in many cases customer may not pay only for the tangible asset, but for its functionality, accessibility and associated value-added services.

Wu, Rosen, Wang and Schaefer (2015) highlighted Cloud-based Design Manufacturing (CBDM), or cloud-based manufacturing design, as a decentralized and networked model supported by many enabling technologies such as cloud computing, 3D printing, media social, Internet of Things (IoT) and service-oriented architecture (SOA), informing about the possibility of a pay-per-use business model, as a form of monetization, depending on its deployment (private, public or hybrid cloud).

Thus, this model contains at least three roles: cloud service provider (known as service provider), cloud service consumer (known as user), and cloud platform provider (referred to as cloud provider). Users contract Manufacturing Services (MSs) provided by the cloud service provider to develop manufacturing related steps. The service provider, in turn, hosts their (MSs) in the cloud, leased from a cloud provider.

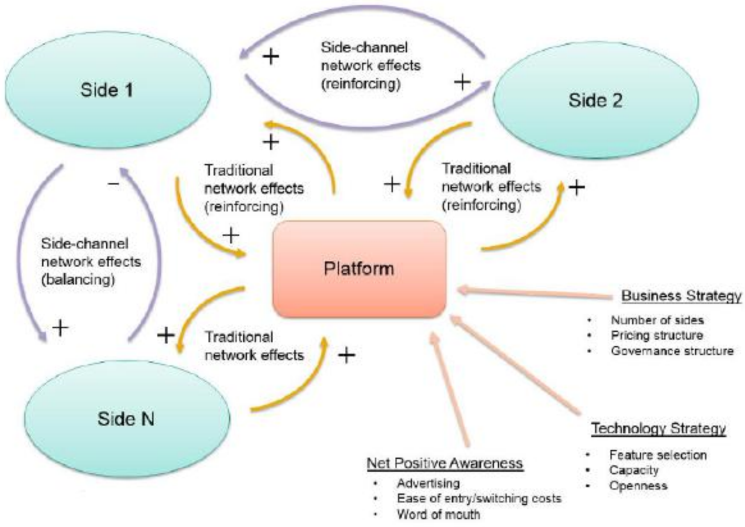
In the same vein, Charro and Schaefer (2018) address the possibility of new opportunities for business models based on the idea of providing Cloud Manufacturing (CMfg) as a new type of product and service system, or Product-Service Systems (PSS). According to the authors, from the moment of ideation passing through conception and production, there are several possibilities with Cloud-based Design Manufacturing (CBDM), with services through the cloud, including hardware-as-a-service (HaaS), when hardware is leased through a CBDM environment; software-as-service (SaaS), using software without purchasing a license; platform-as-a-service (PaaS), which provides product development tools used in a CBDM environment; and Infrastructure-as-a-service (IaaS), when computing resources are made available to consumers without the need to purchase.

Based on such models, there are some pricing strategies involved, such as offering discounts for large orders, except for 3D printing, as increased production does not generate scale economies, and aggregating orders shipped to manufacturers to reduce costs. Thus, a CMfg-PSS can vary its prices to stimulate (or even out) production and demand, as Uber does. Usage is charged per unit of time, and there may be a prior installation fee, and many companies provide additional services, such as consultations, question and answer blogs, educational support materials, articles, videos and tutorials, among others, with no fees subscription for platforms, when they operate strictly on commission (Charro & Schaefer, 2018).

According to Beckmann, et al. (2016), considering the difficulty of developing projects that find application in the market, the Digital Manufacturing Commons (DMC) was created in the United States, which is an open source platform involving the Massachusetts Institute of Technology (MIT), the Defense Advanced Research Projects Agency (DARPA), and General Electric (GE) with the purpose of democratizing the development and access to tools for manufacturing innovation in small and large companies, universities, different institutes and entrepreneurs, to collaborate in manufacturing and accelerate technologies that integrate the digital space from design to manufacturing and service.

In this context, the authors presented a business model based on a multilateral platform, called Multi-Sided Platform (MSP) business model, developed by Barkley (2016), as shown in Figure 5, as a Cloud-based Design and Manufacturing (CBDM), stating that it is a new manufacturing paradigm that allows the rapid development of products at low cost through internet-based services such as social networks and trading platforms. As examples of the use of similar platforms, Uber, Facebook and Groupon can be cited, which bring together two or more groups of customers that have interdependencies (Beckmann et al., 2016).

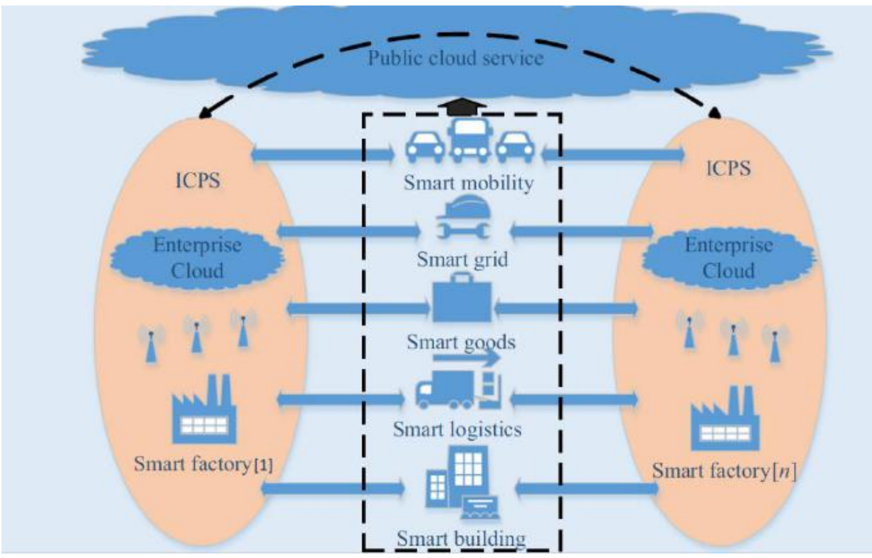
Figure 5 - Multi-Sided Platform (MSP) business model.



Source: Barkley (2016, p15).

Yue et al., (2015) address the cloud-assisted industrial Cyber-physical Systems ICPS (Cloud-assisted CPS), which refer to a service-oriented technology, as demonstrated in Figure 6. The Cyber-physical System (CPS) aims to link anything to the internet, while the cloud will allow working with data after this step. The authors also highlight the service-oriented ICPS model, supported by the cloud, as an infrastructure platform and application of services that will promote manufacturing efficiency, increase production quality, and further contribute to the development of a sustainable industrial system and the emergence of ecologically correct businesses, which is a trend in the I4.0 paradigm according to Stock and Seliger (2016), who see a direction in relation to the creation of sustainable industrial value.

Figure 6 - Cloud-assisted Industrial Cyber-physical System framework (ICPS).

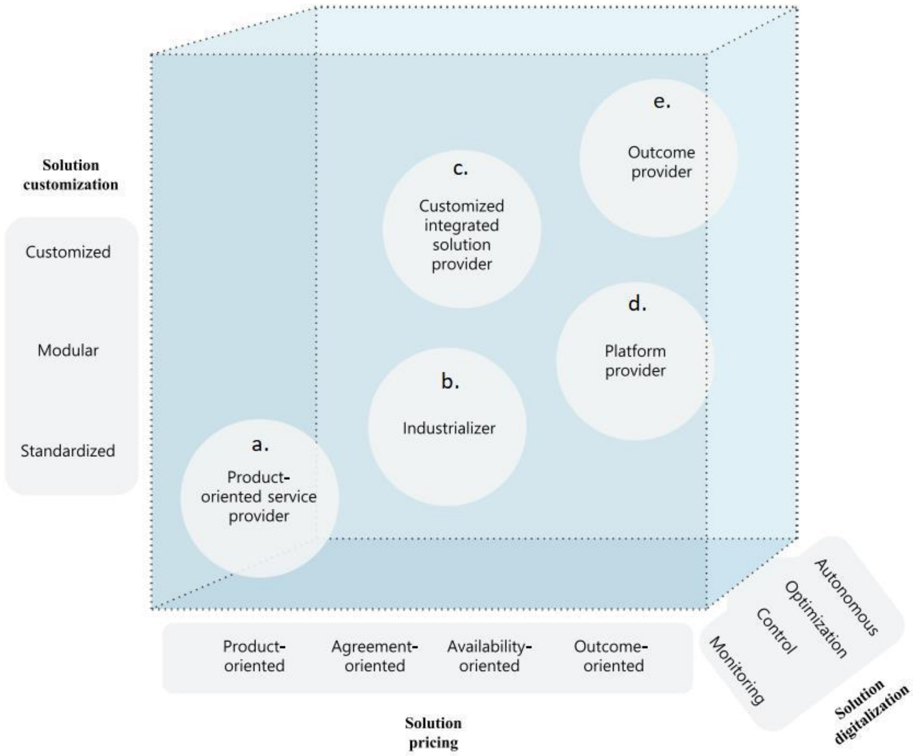


Source: Yue et al. (2015, p. 1263).

Following the models presented, Chen et al., (2016) propose the CMFAS (Cloud Manufacturing Framework (CMF) with Auto-Scaling Capability in a very technical way, with automatic scaling capability for the industry machining, based on a pay-per-use business model, being a cloud-based architecture that aims to transform a single user's manufacturing functions into cloud services that can be accessed by different users simultaneously, with a scaling algorithm for automatically perform the expansion or reduction of the number of virtual machines. The authors also develop an Ontology Inference Cloud Service (OICS) for machine tools based on CMFAS. Thus, users can utilize the Manufacturing Services (MSs) available in the cloud, and provided by the service provider to complete manufacturing-related tasks, and this service provider leases the cloud computing resources from the cloud provider to deploy and host their MSs.

On the other hand, as shown in Figure 7, Kohtamäki et al. (2019) investigate digital servitization business models and use firm theories to understand the configurations of five specific business models, evidencing the degree of autonomy and customization of each model, for a better understanding of the characteristics of the offers solutions in the digital servitization business models, namely: a) product-oriented service provider, b) industrializer, c) customized integrated solutions provider model, d) the business model as a platform provider, and e) the business model as an outcome provider.

Figure 7 - Digital servitization business models.

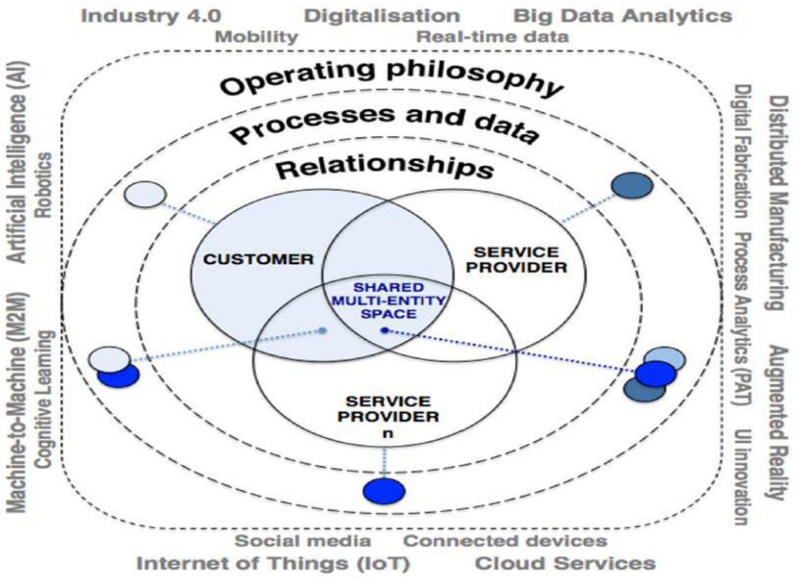


Source: Kohtamäki et al. (2019, p 384).

Regarding additive manufacturing, Ford and Despeisse (2016) investigated the implications of this technology for organizations and industries, analyzing advantages and challenges, focused on sustainability, as sources of innovation, configuration of value chains and business models, addressing the oriented model product-oriented, use-oriented, and results-oriented, as well as a pay-per-use product/service business model. According to the authors, outsourcing services are another type of results-oriented service-product business model.

Harrington and Srai (2016) introduce the idea of a Concept of Operations (ConOps), stating that it can be effective given increasing complexity (greater dispersion of service activities, geographically) and interdependence (increasing dispersion of activities across organizational boundaries), and then examine attributes to consider when developing a ConOps protocol. Figure 8 shows the three-tier approach to designing Multi-Organizational Service Networks (MOSNs), with relationships, processes and data, and operational philosophy highlighting the importance of transformative technologies in the design and operational philosophy of MOSNs. Provides an overview as well as a strategic objective of an operation or series of operations, based on defining the roles and responsibilities of all relevant stakeholders in an organization or network.

Figure 8 - Multi-organizational service networks – MOSNs.



Source: Harrington and Srai (2016, p.4).

In the future, supply chain-oriented companies can organize around more agile business processes and better tailor their Key Performance Indicators (KPIs) as well as their supply chain incentives to a specific business model that involves a number of partners (Harrington & Srai, 2016).

Thoben et al. (2017) highlighted some technologies that should influence business models more intensely, thus emphasizing Cyber-Physical Systems (CPS); Internet of Things (IoT); Industrial Internet of Things (IIoT); Cyber-Physical Production Systems (CPPS); Intelligent Manufacturing Systems (IMS); Cyber-Physical Logistics System (CPLS); Product-Service System (PSS); Cyber-Physical Product-Service System (CPSS) and Data Analytics. The influence of these technologies, according to these authors, represents means for the development of new business models. In a separate analysis, Stverkova and Pohludka (2018) focused on the reorganization and optimization of the organizational structure of global companies, which characterizes a territorial business model, which predicts a long-term return.

In the clothing and fashion industry, Bertola and Teunissen (2018) understand that there are good opportunities when connecting factories, networks and product projects, as shown in Figure 9. In this new scenario, the project can become a mechanism for creating power, interacting in real-time with the entire value chain and driving innovation processes collectively negotiated between end customers and other stakeholders, enabling the creation of new business models, where local production facilities are networked with various distributed services to provide new service and product concepts, based on key values that drive contemporary customers in the age of social media, such as democratization, personalization, sharing, co-creation and sustainability. The co-creation strategy has a significant effect on business model innovation (Mihardjo et al., 2019).

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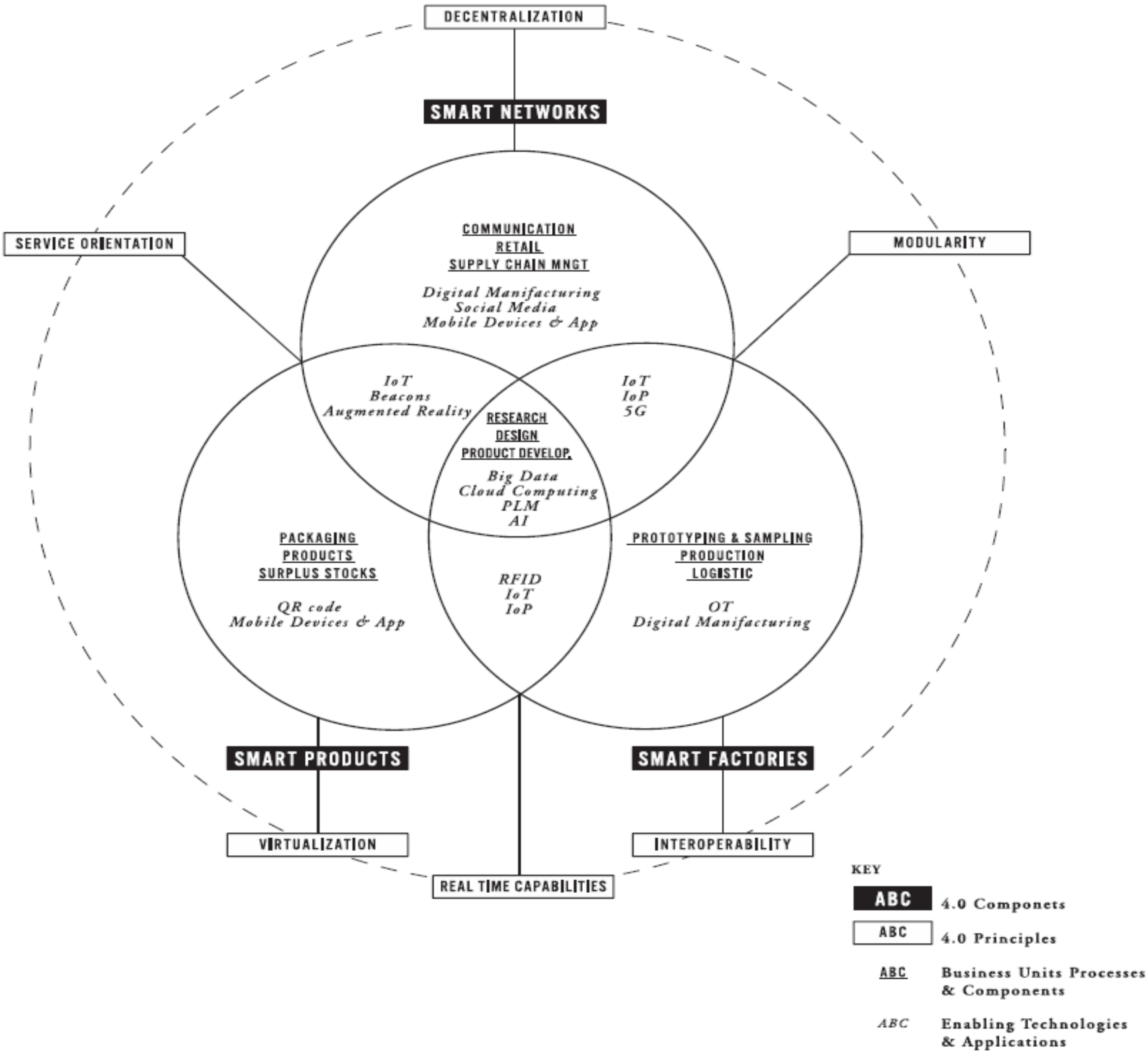
Figure 9 - I4.0 components and principles within the fashion business.



Source: Bertola and Teunissen (2018, p. 357).

When analyzing the cultural content industry, Jung and Lee (2019) state that traditional business models are based on physical resources, while the business models of the fourth industrial revolution are guided by hyperconnectivity (an axis that places all heterogeneous networks, including people and objects, on a common platform), hyperintelligence (refers to the axis that optimizes a company's structure and production system, combining existing products and services with IoT, artificial intelligence and sensors, as well as big data and utilization cloud computing), based on increased computing power and the large amount of data that can be analyzed, and hyperconvergence (an axis that allows the creation of new values, recombining areas that were separated due to hyperconnectivity and hyperintelligence, as a way of optimizing reality in a virtual world), allowing for a revolution in existing business models and structures, with possibilities for and creating competitive advantages and increasing added value.

Bressanelli, Adrodegari, Perona and Saccani (2018) addressed business models focused on servitization and directed towards the Circular Economy, verifying the role of digital technologies as a facilitator, with emphasis on the IoT and Big Data. Such models, according to the authors, can be product-focused, when customers own the product; or usage-focused, when customers pay a fee to gain access to a product; or even result-focused, when clients pay a variable fee depending on the achievement of the agreed results.

An interesting contribution was recently made by Weking et. al. (2019), when verifying some patterns of business models related to I4.0, with emphasis on: integration, referring to the focus on processes; servitization through the combination of products and services; and expertise, related to the focus on process and products in a hybrid way. Integration, servitization and expertise are thus defined by the authors as super patterns, by means of which other patterns are derived, such as mass customization and use of platforms, which perfectly align with this study.

Table 1 presents a summary of the approaches to the business models of the sample of this study and sets of factors that enable new business models in the context of I4.0, considering the support in value creation, as well as its alignment with the organizational strategy.

Table 1 - Different approaches regarding business models.

Author	Year	Approach to business models	Support in value creation	Alignment with strategy	I4.0 Key Technologies
Beckmann et al.	2016	Business models based on Multi-Sided Platform (MSP), similar to Cloud-based Design Manufacturing (CBDM).	It allows innovating through different ways which can add value to all actors in the service chain.	It systemically brings together two or more groups of clients with interdependencies.	Cloud Computing
Bertola e Teunissen	2018	Business models by connecting factories, networks and product designs.	Enables real-time interaction with the entire value chain.	Redesigns the fashion industry into a more sustainable and truly customer-centric business.	3D printing and the Internet of Things (IoT)
Bressanelli et al.	2018	Business models focused on the product (product-focused), focused on use (usage-focused), and focused on results (result-focused), in the Circular Economy paradigm.	Contributes to increasing resource efficiency, extending shelf life and closing the product life cycle.	It uses digital technologies to support implementation of the Circular Economy paradigm in business.	IoT and Big Data
Charro e Schaefer	2018	Cloud-based Design Manufacturing (CBDM), with the possibility of new business model opportunities through the cloud, including hardware-as-a-service (HaaS); software-as-service (SaaS); platform-as-a-service (PaaS); and infrastructure-as-a-service (IaaS).	It allows to reduce costs, create new revenue streams, and enable instant manufacturing scalability.	Increases sustainable competitive advantage.	Cloud Computing
Chen et al.	2016	Cloud Manufacturing Framework (CMF) with Automatic Scaling Capability (CMFAS), and an Ontology Inference Cloud Service (OICS) for machine tools to facilitate the development of Cloud Manufacturing Systems (CMS), with a pay-per-use business model.	Enables faster turnaround time and lower cost of leasing cloud resources.	It serves as an approach to the systematic and rapid construction of CMSs for the machining industry.	Cloud Computing
Ford e Despeisse	2016	Product-oriented, use-oriented, and results-oriented business model, as well as a pay-per-use product-services business model.	It allows for improvements in resource efficiency, as well as new production models.	It creates, through 3D printing, opportunities for manufacturing to become decentralized (creating sustainable consumption).	3D printing
Harrington e Srai	2016	Multi-organizational service networks (MOSNs), with relationships, processes, data and operational philosophy, with emphasis on processes.	It allows equipment and service providers to cooperate in a shared environment, aiming at a win-win relationship.	Provides an overview as well as a strategic objective of an operation or series of operations.	Several, as shown in Figure 8
Hasselblatt et al.	2018	IoT as a way to improve the ability of manufacturers to provide services, given the rapid improvement in connectivity and sensing technologies.	Identifies the interests of customers, suppliers and other interested parties to provide customized solutions.	It allows manufacturers to develop digital business models, creating value for the customer.	IoT
Iansiti e Lakhani	2014	Business models characterized by highly individualized products, and by combinations of integrated and synchronized products and services.	It provides benefits beyond industrial equipment, through analysis based on data generated by such equipment.	Understands digital transformation as a way to sell solutions in addition to products.	IoT and Cloud Computing
Jung e Lee	2019	Combination of business in the virtual world with business in the physical world related to cultural content, through cyber-physical systems (CPS), highlighting the characteristics of “hyperconnectivity”, “hyperintelligence” and “hyperconvergence”, and platform connection	Improves efficiency in production and communication, with more autonomy and interaction online/offline and real/virtual.	Allows the integration of cultural content (production and consumption).	CPS, IoT, AI, Big Data, Augmented Reality and Cloud Computing

Author	Year	Approach to business models	Support in value creation	Alignment with strategy	I4.0 Key Technologies
Kohtamäki et al.	2019	Analyzes five distinct business models: product-oriented service provider, industrializer, customized integrated solutions provider, platform provider and outcome provider.	It grants more efficiency in solutions customization, through monitoring, control, optimization and autonomous functions.	Allows different configurations of competitive advantage sources.	IoT
Mihardjo et al.	2019	Collaboration based business models.	Creates value in the market, with contributions from customers, suppliers, partners and other stakeholders, driving the company's performance.	It focuses on co-creation, which provides innovations in business models.	Cloud Computing, IoT and Big Data
Müller, Buliga e Voigt	2018	Business models in I4.0 through data-driven products and services, with greater customer orientation, as well as service-based business models, enabled by data transparency and pay-per-use models.	It enables benefits such as: increased productivity, quick access to manufacturing data, monitored and increased production, and lower inventories.	It helps companies strengthen their interaction with customers and reach new customers through personalized value offerings.	CPS and IoT
Rayna e Striukova	2016	3D printing enabling mobile and fully adaptable business models.	Allows to offer services that further develop crowdsourcing and mass personalization, with cost savings.	It enables modular and adaptable business models, according to demand variation.	3D printing
Rossit, Tohmé e Frutos	2019	Business models to support late product customization.	Allows to rebalance the workflow.	Allows late products customization, where the customer can modify the attributes of their product after production has started.	CPS
Stock e Seliger	2016	Business models driven by the use of intelligent data to offer new services, with attention to the development of sustainable business models. Tendency to pay for functionality, accessibility and associated value-added services.	Focuses on horizontal, vertical and end-to-end integration, with the interaction of different factors such as equipment, personnel, organization, process and product.	It guides the creation of industrial value focused on sustainability.	Cloud Computing, CPS and IoT
Stverkova e Pohludka	2018	Territorial business model, based on the reorganization and optimization of the organizational structure of global companies, aiming the long term.	Increases productivity and sales volumes.	Responds to market trends, diversification and customization, increasing sales.	n/a
Thoben, Wiesner e Wuest	2017	Manufacturing systems that meet customer requirements without waste due to reconfiguration of assembly lines or setup times through dynamic business and engineering processes.	Creates relationships with other systems and their environments, allowing access to product lifecycle data, for instance.	It integrates new value propositions and collaborative arrangements associated with new business models.	CPS
Wu et al.	2015	Cloud-based Design Manufacturing (CBDM), with pay-per-use business model.	It defines how design and manufacturing services can be provided, how they can be implemented and how they can be paid for.	Characterizes a potential shift to the next generation of collaborative design.	Cloud Computing, 3D Printing, IoT and Service Oriented Architectures (SOA).
Yue et al.	2015	Cloud-assisted industrial CPS with service-oriented technology as a way to link anything to the internet.	It promotes production efficiencies by enabling open collaboration between manufacturing resources and services.	Contributes to the development of a sustainable industrial system (green business).	CPS, Cloud Computing, Big Data and SOA.

Source: Authors (2022).

3.4 Implications for practice and future research

The I4 will enable solutions for new business models, such as platforms, with the focus being on customer solutions (Birkel et al., 2019). It is possible to verify that cloud computing has a strong prominence among the authors, which addresses strategy and value creation, as this technology enables the feasibility of new business models through platforms. It is an accessible way of aggregating services to traditional products, through partnerships and data processing, combined with big data and artificial intelligence. Another highlight refers to the IoT, which makes possible a series of possibilities for new business models, and its use is also understood as strategic for the value creation.

While the current and potential advantages of digital manufacturing are notable, in terms of greater efficiency, sustainability, customization and flexibility, only a limited number of companies have already developed necessary ad hoc strategies to achieve superior performance, best suited to the I4.0 context. (Savastano, Amendola, Bellini, & D'Ascenzo et al., 2019).

In addition, there are some issues that must be addressed, including IT security, reliability and stability required for critical machine-to-machine (M2M) communication, including the need to maintain the integrity of production processes and avoid any IT issues (Sung, 2018).

It is understood that I4.0 is relevant and influential in creating value for companies, opening space for new business models, which lead to new opportunities to design and redesign new business models. The literature demonstrates that the transformations will affect different segments of production and services, through new business models, involving the whole society in a new form of consumption, more directed to specific needs, tending to strong customization and lot size one. Thus, new services guided by mass customization can replace traditional business models based solely on product sales.

In general, the enabling technologies of I4.0 are enabling the emergence of new business models, as there is a strong trend towards the emergence of platforms in which products, services and information can be exchanged and shared through predefined flows, generating services based on payment of subscriptions or licensing of intellectual property, for example. Among different business models, companies are increasingly monetizing data.

Cyber-physical systems, internet of things, big data, cloud computing and additive manufacturing (3D printing) stand out in the perception of the authors studied as enabling technologies that play a more present role in the creation of new business models in the field of I4.0. Additive manufacturing combined with cloud computing, for instance, has changed business models for some companies that also become co-creators of products, when they introduce a certain degree of personalization at delivery points. Modularity was also understood as key to business models, whether intra-company or with different partners, regionally or globally

Finally, digitization is having a major impact on society, as it is making everything more dynamic. Production tends to be leaner, more dynamic and flexible, in the face of rigid global competition, shorter product life cycles and quick consumer reaction, tending towards a higher degree of customization in order to satisfy the specific desires of customers with costs similar to those of mass production industries. In this way, business models in the context of the fourth industrial revolution will be guided by the increasingly intense use of the enabling technologies of I 4.0 in defining the proposition, aligning with the organizational strategy, capturing and creating value for the business, with a focus on pursuit of competitive advantage.

The context of I4.0 provides new ways to create value and new business models, as well as addressing and solving some of the challenges the world faces today, such as resource and energy efficiency, urban production and demographic changes (Kagermann et al., 2013). In this sense, the analyzed sample on business models in the context of I4.0 made it possible to highlight gaps in the study on the subject, in order to encourage future research.

Thoben et al. (2017), state that it is necessary to develop mechanisms to ensure data; Vukanović (2018) show the understanding of the broader use of smart products; Müller (2019) proposes to investigate the implementation of business model adaptations over time, analyzing the interaction with partners, suppliers and customers; Charro and Schaefer (2018) highlighted a clear research gap regarding the creation of new business models for Cloud Manufacturing from the perspective of new and emerging products-services in the context of I4.0 (PSS); based on the Firm Theory, Kohtamäki et al. (2019) identify research gaps around the interaction between servitization, IoT and different theories of the enterprise, focusing on how IoT applications can shape future business models and how IoT affects the role of services in the future; Bresanelli et al. (2018) suggest future studies on business models focused on the product and results; Jung and Lee (2019) suggest further studies in the digital content industry, highlighting that more features can be found; Savastano et al. (2019) proposed to verify the innovation of business models and activities in the value chain, and the multidimensional assessment of sustainability and digital transformation, and Müller et al. (2018) state that future research can analyze how I4.0 affects cooperation between companies from different sectors.

It is important to highlight expectations of theoretical and especially applied advances. To this end, Beckmann, et al. (2016), when addressing the Digital Manufacturing Commons (DMC), reported that academic communities represent a constant and essential source of new research, and highlighted the difficulty for projects to find application in the market. In this sense, an analysis of the relationships between the aforementioned stakeholders, such as small and large companies, universities, and different institutes, is considered opportune, as a way of aligning an approach with the purpose that projects and research easily provide applied results to the market, considering the scenario of an increasingly digital world driven by I4.0. In this sense, Cezarino et al. (2019) state that in emerging countries there is a growing interest in the role of institutions and industry-related policies amid the phenomenon of digitization, with much to be explored on institutional issues related to governance.

4. Conclusion

This article addressed I4.0 and discussed different business models that arise with it, considering an increasingly technological and unpredictable scenario that will require managers' sensitivity in addition to knowledge about the enabling technologies of I4.0. In addition to the objective of identifying and analyzing business models in the context of I4.0, a network analysis was carried out to identify trends in business models in topics related to innovation and value creation, sustainability and circular economy, smart factories, decision and knowledge. This analysis in particular is given as an important contribution to practice, in the sense of directing business models to specific strategies and organizational practical application. Furthermore, evidenced research gaps are considered an important contribution to the advancement of scientific and practical research.

In this sense, as a theoretical contribution, different business models were analyzed in the context of I4.0, customer-oriented, based on innovative hybrid solutions of products and services, with a focus on customization, while the wide space for future research was evidenced. From the results, it is understood that managers need to be increasingly aware of the preferences of their consumers, and understand their desires, instead of pushing products and services to their customers. Likewise, keeping up with digitization and servitization trends, as a way of identifying different technologies and new business partners, as a way of capturing more value for customer delivery, as digitization not only affects the business models of individual companies, but it requires alignment with one's own organizational strategies, as well as with the business models of other companies in the ecosystem.

Although the study uses two highly relevant databases in the academic environment, and the searches correlate several terms related to I4.0, the research was guided by articles involving business models, focusing on alignment with the strategy and value creation, which may denote a limitation of this study. A broader analysis, disregarding this direction, would bring a new perspective to the study. Another limitation considered is the fact that there was no deepening of innovation in business models or in business models guided by sustainability issues. For future studies, it is proposed to study the opportunities and barriers for the implementation of these the business models related to I4.0, their degree of innovativeness, and how they impact sustainability.

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