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PROJECT CAPABILITIES IN INDUSTRY 4.0: FUTURE RESEARCH OPPORTUNITIES IN PROJECT MANAGEMENT

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ABSTRACT

Purpose: Industry 4.0 is transforming companies around the world through business integration, implemented by disruptive technologies, and accompanied by the transformation of data into information and intelligence. This research aims to explore literature about capabilities and project management, in the context of industry 4.0 manufactures, to identify research opportunities in project management.

Methodology / Approach: A Systematic Literature Review (SLR) analyzed 55 articles discussing project capabilities developed by industry 4.0 manufactures.

Originality / Value: This study fills a research gap, as no literature review has reported state of the art knowledge about project capabilities in the context of industry 4.0.

Findings: Project capabilities were summarized in six perspectives: project management, business models, innovation, skills of project professionals, technologies, and data management. Project management surfaces as a structural capability to implement industry 4.0. Besides, collaboration among parties amalgamates companies in new business models, as well as project professionals and teams while they implement new processes, products, and technologies.

Theoretical implications: This study uncovers opportunities for future research related to customer and data-centered business transformations of industry 4.0, including how to manage projects in collaborative business networks and implement fast-paced innovation.

Keywords: Industry 4.0. Innovation. Capabilities. Collaboration. Project management.

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CAPACIDADES DE PROJETOS NA INDÚSTRIA 4.0: OPORTUNIDADES DE PESQUISAS FUTURAS EM GERENCIAMENTO DE PROJETOS

RESUMO

Objetivo: A indústria 4.0 está transformando empresas ao redor do mundo por meio da integração de negócios, implementada por tecnologias disruptivas e acompanhada pela transformação de dados em informação e inteligência. Esta pesquisa tem como objetivo explorar a literatura sobre capacidades e gerenciamento de projetos, no contexto das manufaturas da indústria 4.0, para identificar oportunidades de pesquisa em gerenciamento de projetos.

Método / Abordagem: Uma Revisão Sistemática da Literatura (RSL) analisou 55 artigos que discutem capacidades de projetos desenvolvidas por manufaturas da indústria 4.0.

Originalidade / Relevância: Este estudo preenche uma lacuna de pesquisa, uma vez que nenhuma revisão da literatura descreveu o estado da arte do conhecimento sobre gerenciamento de projetos no contexto da indústria 4.0.

Resultados: As capacidades de projetos foram sumarizadas em seis perspectivas: gerenciamento de projetos, modelos de negócios, inovação, habilidades dos profissionais de projetos, tecnologias e gerenciamento de dados. O gerenciamento de projetos emerge como uma capacidade estrutural para implementar a indústria 4.0. Além disso, a colaboração entre os envolvidos combina empresas em novos modelos de negócios, assim como profissionais de projetos e times enquanto eles implementam novos processos, produtos e tecnologias.

Contribuições teóricas: Este estudo aponta oportunidades para pesquisas futuras relacionadas com a centralidade nos consumidores e nos dados das transformações de negócios na indústria 4.0, incluindo como gerenciar projetos em redes de negócios colaborativos e implementar inovação de maneira rápida.

Palavras-chave: Indústria 4.0. Inovação. Capacidades. Colaboração. Gerenciamento de Projetos.

1. INTRODUCTION

Industry 4.0, also named Fourth Industrial Revolution (4IR), initiated in Germany as "industrie 4.0". A long-term strategic initiative in which technologies, professionals and businesses would undergo an evolutionary process (Kagermann et al., 2013). Crossing German borders, industry 4.0 initiatives were recognized relevant worldwide by The World Economic Forum (2017). Recently, The Forum and McKinsey & Company (2019) reported 4IR leaders transformed businesses and empowered professionals, to capitalize on the full potential of technology. Although, they also announced the extensive benefits of transformations at scale are yet to be reached.

Despite industry 4.0 is commonly known by its technologies, 4IR transformations are more than implementation of new technologies. Rather, transformations are guided by two forces: pushed by technologies and pulled by business needs (Lasi et al., 2014). Impelling its implementation, ten technologies are commonly referred: (1) big data and analytics, (2) simulation of interconnected machines, (3) Internet of Things (IoT), (4) cyber-physical systems, (5) cloud computing, (6) virtual reality, (7) cyber security, (8) collaborative robots (Moeuf et al., 2018), (9) additive manufacturing (de Sousa Jabbour et al., 2018), and (10) artificial intelligence (Kuo & Smith, 2018).

Heaving industry 4.0, business transformations call for shortened innovation lifecycle, product customization, process modularization, decision-making decentralization, sustainable resource efficiency (Lasi et al., 2014), and integration of manufacturing networks (Ferreira et al., 2017; Hasselblatt et al., 2018). Summarizing, Rashid et al. (2018) explain smart factories are characterized by fully integrated and interoperable systems, different from "islands of scattered automated machines".

Considering these transformations, manufactures must develop capabilities and competences to support implementation and operation of industry 4.0. The concepts of capabilities and competences are not new, and could be studied from different paradigms (Le Boterf, 2006; Leonard-Barton, 1992; Prahalad & Hamel, 1990; Stalk et al., 1992). Nevertheless, they are recognized as building blocks of competitive advantage (Prahalad & Hamel, 1990; Stalk et al., 1992).

While Prahalad and Hamel (1990) identify core competences as the collective learning of an organization, which is hard to imitate and integrates individual technologies and production skills. Stalk et al. (1992) understand capabilities as a set of business processes, managed to deliver value to customers. Despite not completely dissimilar, core competences appear to focus on a production expertise, whereas capabilities are broader distributed along the value chain (Stalk et al., 1992). Given this study reviews industry 4.0 capabilities from a wider project management perspective, we adopt the definition by Stalk et al (1992).

As temporary organizations, responsible for delivering unique products, services and results (PMI, 2017), industry 4.0 projects implement new technologies (Hasselblatt et al., 2018), and transform business models (Lerch & Gotsch, 2015). Likewise, industry 4.0 projects carry out process innovation, in which multiskilled teams collaborate and solve problems together (Sjödin, 2019).

In this context, authors highlight manufactures willing to implement industry 4.0 must commit to long-term innovation (Parviainen et al., 2017; Rashid et al., 2018). They are able to analyze large amounts of data (Lerch & Gotsch, 2015), to extract business value (Moeuf et al., 2019; Raptis et al., 2019). Therefore, industry 4.0 projects also implement infrastructure to acquire and store industrial data, targeting its analysis (Raptis et al., 2019).

In industry 4.0 context, project management is a structural capability (de Sousa Jabbour et al., 2018; Holtgrewe, 2014; Rashid et al., 2018). *But which further research opportunities would enrich knowledge about project management in industry 4.0 manufactures?*

This research aims to explore literature about capabilities and project management, in the context of industry 4.0 manufactures, to identify research opportunities in project management. A Systematic Review of Literature (SRL) synthesizes industry 4.0 projects in six perspectives. Centered in project management, five other perspectives arise - business models, innovation, skills of project professionals, technologies, and data management.

Following, this study is organized in four more sections. Methodology describes steps taken on to assure transparency and replicability to the SRL, while Results details capabilities perspectives of industry 4.0 projects. Discussion highlights research opportunities for project management in industry 4.0, whereas Conclusion emphasizes this study main findings.

2. METHODOLOGY

Detailed review of literature about capabilities and project management, regarding 4IR manufactures, identified six perspectives of capabilities in industry 4.0 projects. In accordance, past studies were accessed and analyzed through an SRL to identify knowledge gaps (Tranfield et al., 2003). Procedures are systematically described (Figure 1) to render transparency to the research method (Costa et al., 2015).

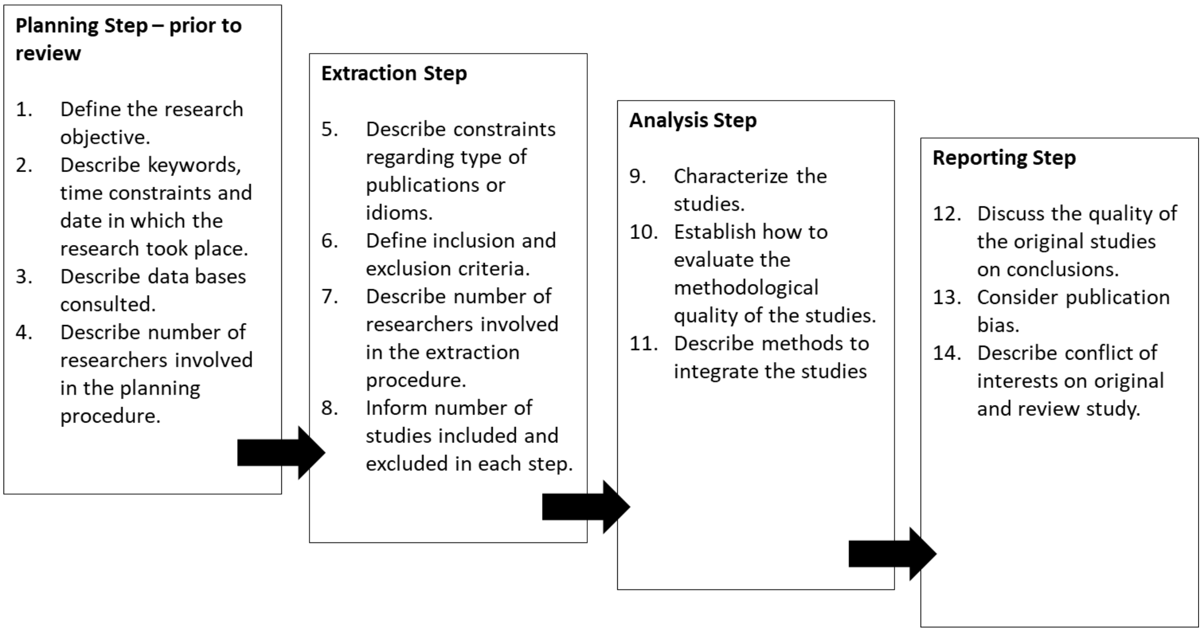

Figure 1: SRL Protocol (elaborated by authors, based on Costa et al. (2015))

During planning, a Boolean search was elaborated, based on research objective. It combined keywords related to industry 4.0, project management and capabilities (Costa et al., 2015). Extra care was taken to determine industry 4.0 relevant synonyms. Specifically, preliminary search for industry 4.0 adopted the expression (“four* indust* revol*” OR “4* indust* revol*” OR “Indust* 4*”). Although, analysis of preliminary results using the R-studio application ‘biblioshiny’, included two more keywords to initial string.

Following, the expression (("four* indust* revol*" OR "smart factor*" OR "smart manufact*" OR "industr* 4*" OR "4* indust* revol*") AND ("project* manag*" OR "manag* of project") AND (capabil* OR compet* OR skill*)) was validated by a project management specialist. Hence, used to acquire the studies for this review.

In September 2019, Scopus and Web of Science databases were consulted, not restricted to subjects, title and keywords, returning 435 and 3 documents, respectively (Costa et al., 2015). On extraction, no time constraint was established, as the extract only included documents published after 2014. However, documents were limited to peer-reviewed articles for reliability purposes. Hence, quantities of studies were reduced to 203 articles from Scopus and 1 article from Web of Science, this last comprised within Scopus extract.

The database with 203 articles was downloaded to Excel, and abstracts were read to establish inclusion and exclusion criteria (Costa et al., 2015). To focalize the research body, articles on civil construction, cities, government, and country policy were excluded from the main extract. Besides, articles not available in Portuguese or English, as well as detailed studies on supply chain management, were also excluded. Again, exclusion criteria definition was overseen by a PhD researcher (Costa et al., 2015). Thus, it ensured reviewed studies discussed capabilities and project management in industry 4.0 manufactures.

Into analysis step, 89 articles, from three areas of knowledge - management, engineering, and computer science, composed the research body. They were carefully read, and those only briefly debating the subjects, with deficient methodology or not contributing to the research objective were further excluded. As a result, 34 other articles were excluded, and the final research corpus comprised 55 peer-reviewed studies.

They were further analyzed through coding on ATLAS.ti. Six capabilities perspectives emerged to synthesize industry 4.0 projects: project management, business models, innovation, skills of project professionals, technologies, and data management. Therefore, Frame 1 shows each article highlighting capabilities perspectives discussed on industry 4.0 projects (Costa et al., 2015).

Reviewed article	**Project Management (PM)**	**Business Models (BM)**	**Innovation (IN)**	**Skills of Project Professional (SPP)**	**Technologies (TE)**	**Data Management (DM)**
(Moeuf et al., 2018)		BM			TE	
(de Sousa Jabbour et al., 2018)	PM	BM		SPP		
(Ooi et al., 2018)		BM	IN		TE	
(Kuo & Smith, 2018)		BM			TE	
(Roßmann et al., 2018)		BM		SPP		DM
(Wang et al., 2018)					TE	
(Yadegaridehkordi et al., 2018)	PM				TE	DM
(Hasselblatt et al., 2018)	PM	BM		SPP		DM
(Rashid et al., 2018)	PM	BM		SPP		
(Ho & O’Sullivan, 2017)		BM	IN			DM
(Caruso, 2018)	PM			SPP		
(Ferreira et al., 2017)		BM				
(Bibby & Dehe, 2018)	PM			SPP	TE	

(Walker & Lloyd-Walker, 2019)	PM					
(Sjödin, 2019)	PM		IN	SPP		
(Bertoncel, Erenda, Bach, et al., 2018)		BM	IN	SPP		
(Ratzmann et al., 2018)	PM		IN	SPP		
(Qu et al., 2019)		BM				DM
(Parida & Wincent, 2019)		BM				DM
(Shivajee et al., 2019)						DM
(Li et al., 2019)		BM		SPP		DM
(Nikitina & Lapiņa, 2019)			IN	SPP		
(Pejic-Bach et al., 2019)	PM					
(Agostini & Nosella, 2019)		BM		SPP		
(Moeuf et al., 2019)	PM	BM		SPP		
(Raptis et al., 2019)						DM
(Singh et al., 2019)	PM	BM		SPP		
(Briones-Peñalver et al., 2019)	PM	BM	IN	SPP		
(Goh et al., 2019)					TE	
(Chehbi-Gamoura et al., 2019)		BM				DM
(Villalba-Diez et al., 2018)		BM				
(Lerch & Gotsch, 2015)		BM	IN			DM
(Holtgrewe, 2014)	PM			SPP		
(Parviainen et al., 2017)		BM				
(Park & Huh, 2018)	PM					
(Campatelli et al., 2016)			IN	SPP		
(Fettermann et al., 2018)					TE	
(Bernstein et al., 2018)						DM

(Gunckel et al., 2018)						DM
(Rejeb et al., 2019)		BM			TE	
(Keskin, 2019)	PM					
(Synnes & Welo, 2016)		BM	IN	SPP		
(Roblek et al., 2016)		BM				DM
(Bressanelli et al., 2018)		BM				DM
(Olszak & Mach-Król, 2018)						DM
(Bertoncel, Erenda, & Mesko, 2018)	PM	BM		SPP		
(Yun & Liu, 2019)		BM	IN			
(Müller & Voigt, 2018)						DM
(Salehi, 2020)	PM		IN			
(Garcia-Muiña et al., 2019)		BM				DM
(Tarifa-Fernández et al., 2019)		BM				
(Siddoo et al., 2019)				SPP		
(Dewa et al., 2018)		BM				
(Bag, 2018)		BM				
(Hannola et al., 2018)			IN			

Frame 1: Project capabilities in industry 4.0 (elaborated by authors)

At last, reporting step involves discussing quality and bias of reviewed studies (Costa et al., 2015). In this context, Scopus 2018 citations ranking was employed to rate the journals of original articles. As a result, we determined 95% of original articles were published on journals rated on the 1st and 2nd quartiles of Scopus 2018 citation ranking.

3. RESULTS

Results will be presented in seven subsections. First subsection analyzes bibliographic data, while other six presents different capabilities perspectives of industry 4.0 projects: project management, business models, innovation, skills of project professionals, technologies, and data management.

3.1. Bibliographic data

Studies about capabilities and project management in industry 4.0 are distributed in four distinct areas of knowledge (Table 1). When a journal was simultaneously classified under Business and Management and another area, the managerial view was prioritized. As 80% of original articles discuss Business and Management paradigm, it indicates research corpus is suitable to explore research opportunities in project management in industry 4.0.

Areas of knowledge	Quantity of journals	%
Business and Management	32	80%
Engineering	4	10%
Computer Sciences	3	8%
Multidisciplinary	1	2%
Total	40	100%

Table 1: Journals per area of knowledge (elaborated by authors)

Table 1 also demonstrates 40 different journals published studies under review from 2014 onwards (Figure 1). Following a steep increase from 2017 to 2018, the ascendant trend continues, reaching almost the same number of articles in September 2019 as published in the year before.

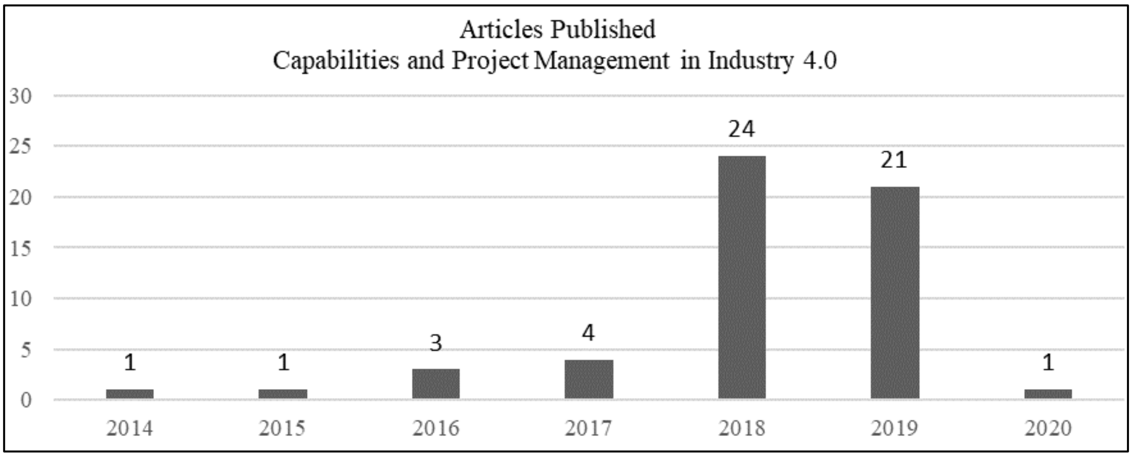

Figure 1: Articles published yearly (elaborated by the authors)

Concluding this brief bibliographic analysis, reviewed articles were classified in terms of their research approach (Table 2). Exploratory studies, such as qualitative studies, literature reviews and conceptual articles represent 83% of research corpus. High concentration of exploratory studies could be explained because knowledge about organizational phenomena is still incipient (Creswell, 2010).

Research approach	Number of articles	%	Accumulated %
Qualitative	27	48%	
Conceptual	10	14%	62%
Literature review	9	21%	83%
Quantitative	6	12%	95%
Mixed methods	3	5%	100%
Total	55	100%	

Table 2: Articles per research approach (elaborated by authors)

Therefore, based on information from Figure 1 and Table 2, this study establishes research about capabilities and project management, in the context of industry 4.0 manufactures, is in its infancy, having gained interest in the last years.

3.2. Project management

The term industry 4.0 was coined in Germany, to define a strategic governmental initiative that would promote industrial innovation (Kagermann et al., 2013). In specialized literature, it is referred as a synonym for the Fourth Industrial Revolution (4IR) (Caruso, 2018; Schumacher et al., 2016). However, others argue 4IR affects more than manufactures. Schwab (2017, p. 7), for example, establishes 4IR is actually "changing the way we live, work and relate to one another", due to convergence of technology breakthroughs which facilitates knowledge access and boosts connectivity between people and machines.

Despite acknowledging Schwab's broader point of view, this study concentrates on transformations in manufactures. Restricted to industrial outlook, still many definitions surface. De Sousa Jabbour et al. (2018), characterize industry 4.0 as a vigorous industrial wave, service-centered and driven by digital technologies. While Schumacher et al. (2016), explain disruptive technologies facilitate horizontal and vertical integration of production and enterprises, requiring a new set of capabilities. Companies' borders are surpassed, reaching suppliers and consumers on collaborative business models (Ferreira et al., 2017; Hasselblatt et al., 2018; Lerch & Gotsch, 2015).

Given industry 4.0 is an evolutionary process transforming technologies, professionals, and organizations (Kagermann et al., 2013), projects are single temporary initiatives delivering defined objectives (PMI, 2017). To guide industry 4.0, a roadmap (Bibby & Dehe, 2018), could be discussed within portfolio management, as project portfolio is regarded instrumental to implement organization strategy (Bredillet et al., 2018).

In portfolio context, initiatives are selected to compose it, given they compete for scarce organization resources (Archer & Ghasemzadeh, 1999). One of the reviewed articles proposes a fuzzy approach to assist on portfolio selection (Keskin, 2019), given uncertainties and project interdependences in industry 4.0. However, Keskin (2019) focalizes on mathematical calculations of portfolio selection, leaving unexplored other singularities of portfolio management in industry 4.0.

Project management is a structural capability leading manufactures towards industry 4.0 strategic goals (de Sousa Jabbour et al., 2018; Holtgrewe, 2014), as it contributes for project successful implementation (Ratzmann et al., 2018). Nevertheless, top management must commit to the change process (Agostini & Nosella, 2019; Yadegaridehkordi et al., 2018). Studying the future of project management, Walker and Lloyd-Walker (2019) foresee project professionals must evaluate project and organization at hand to adequate its management. This corroborates project professionals shall think strategically (Walker & Lloyd-Walker, 2019), to occupy executive positions (Pejic-Bach et al., 2019).

On single project implementation, Hasselblatt et al. (2018) argue IoT suppliers must deliver value as an asset, putting together turnkey solutions to satisfy customers' needs. They combine technical knowledge on Information and Communication Technologies (ICT) and on physical devices. When a collaborative business network is established among equipment suppliers and manufacturing consumers, industry 4.0 benefits and value co-creation are deepened (Agostini & Nosella, 2019).

Studying project success, Rashid et al. (2018) define critical factors for projects implementing fully integrated systems, among them, steering committees, project sponsors and multiskilled teams. While experienced steering committees guide projects towards strategic organizational goals, project sponsors negotiate resources and intervene to manage resistances (PMI, 2017; Rashid et al., 2018). Complementarily, multiskilled teams challenge and refine innovative ideas (Ratzmann et al., 2018; Walker & Lloyd-Walker, 2019).

While Salehi (2020), and Park and Huh (2018), defend agile project management to improve project efficiency. Walker and Lloyd-Walker (2019) claim projects, either waterfall or agile, will be managed more collaboratively, with team interactions still greased by trust (Ratzmann et al., 2018). In this context, Figure 2 summarizes project management capabilities in industry 4.0 literature.

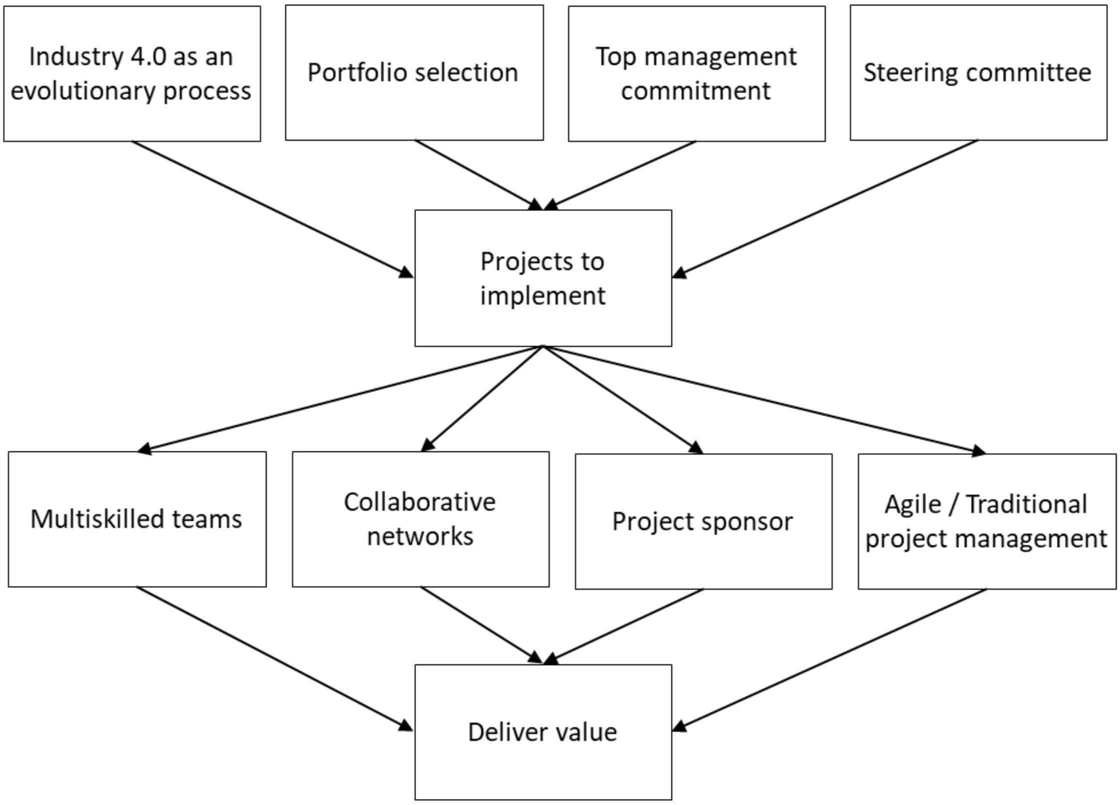

Figure 2: Project management in industry 4.0 (elaborated by authors)

As industry 4.0 is an evolutionary long-term program, implementation of industry 4.0 projects must be guided by portfolio management to become instrument of company strategy. Top management support, steering committee, project sponsors and multiskilled teams are seen as key success factors for industry 4.0 projects. Through agile or traditional approaches, project professional must collaborate to supplement their abilities and deliver value.

3.3. Business models

Manufactures interested on industry 4.0 projects must align their strategy, to ensure investments are structured to be capitalized (Li et al., 2019; Moeuf et al., 2019; Parida & Wincent, 2019; Parviainen et al., 2017; Villalba-Diez et al., 2018). Studying industry 4.0 strategy, Parida and Wincent (2019), argue business models can be radically changed when supported by digitalization. Besides, early adopters of digitalization may reach more business value (Tarifa-Fernández et al., 2019).

Projects integrate different companies, as well as different departments, with four business models deepening industry 4.0 benefits and value co-creation. Servitization (Hasselblatt et al., 2018; Lerch & Gotsch, 2015), sustainable circular economy (Garcia-Muiña et al., 2019; Kuo & Smith, 2018; Parida & Wincent, 2019), collaborative business networks among manufactures (Agostini & Nosella, 2019; Bag, 2018; Rejeb et al., 2019; Yun & Liu, 2019), and intracompany integration (Qu et al., 2019), will be further detailed.

Servitization offers a combination of a product and a service, named a product-service (Lerch & Gotsch, 2015). Authors explain product-service data enables manufactures to 1) foresee maintenance requirements, 2) improve product capacity, and 3) enhance product-service design. Moreover, servitization data allows assessment of customer needs, which facilitates customization of the product-service (Roblek et al., 2016), and sharing of the product among various users (Bressanelli et al., 2018).

When retrofit data improves the product-service, it promotes consumer-centered innovation that may leverage market acquisition (Lerch & Gotsch, 2015). However, Parida and Wincent (2019) critically highlight companies embarking on servitization must develop capabilities to extract its full potential: how to develop network partners, analyze large amounts of data and upgrade towards sustainable co-creation of value.

Turning to circular economy, Parida and Wincent (2019) argue companies adopting it could reach new competitive advantages. In circular economy, products and processes are designed to enhance resource efficiency and reuse, while reducing waste generation (Kristensen & Mosgaard, 2020). In industry 4.0, improvements to resource efficiency were reported as project outcome, enabling analysis of real time production data (Garcia-Muiña et al., 2019).

In a wider sense, industry 4.0 projects implement collaborative networks that integrate businesses (Agostini & Nosella, 2019). Two types of webs are exemplified: operation networks to produce goods collaboratively (Chehbi-Gamoura et al., 2019; Ferreira et al., 2017), and supplying networks to install and customize equipment (Hasselblatt et al., 2018; Rashid et al., 2018). These networks increase geographical coverage and facilitate identification of emergent strategies (Bertoncel, Erenda, Bach, et al., 2018). However, lack of collaboration would prevent full use of network data (Chehbi-Gamoura et al., 2019).

Emphasizing internal strengths, industry 4.0 projects may integrate intracompany systems (Qu et al., 2019; Rashid et al., 2018), connecting supply chain management, enterprise resource planning, product lifecycle management and manufacturing execution systems (Li et al., 2019; Rashid et al., 2018). In this context, Figure 3 summarizes business models capabilities in industry 4.0 projects.

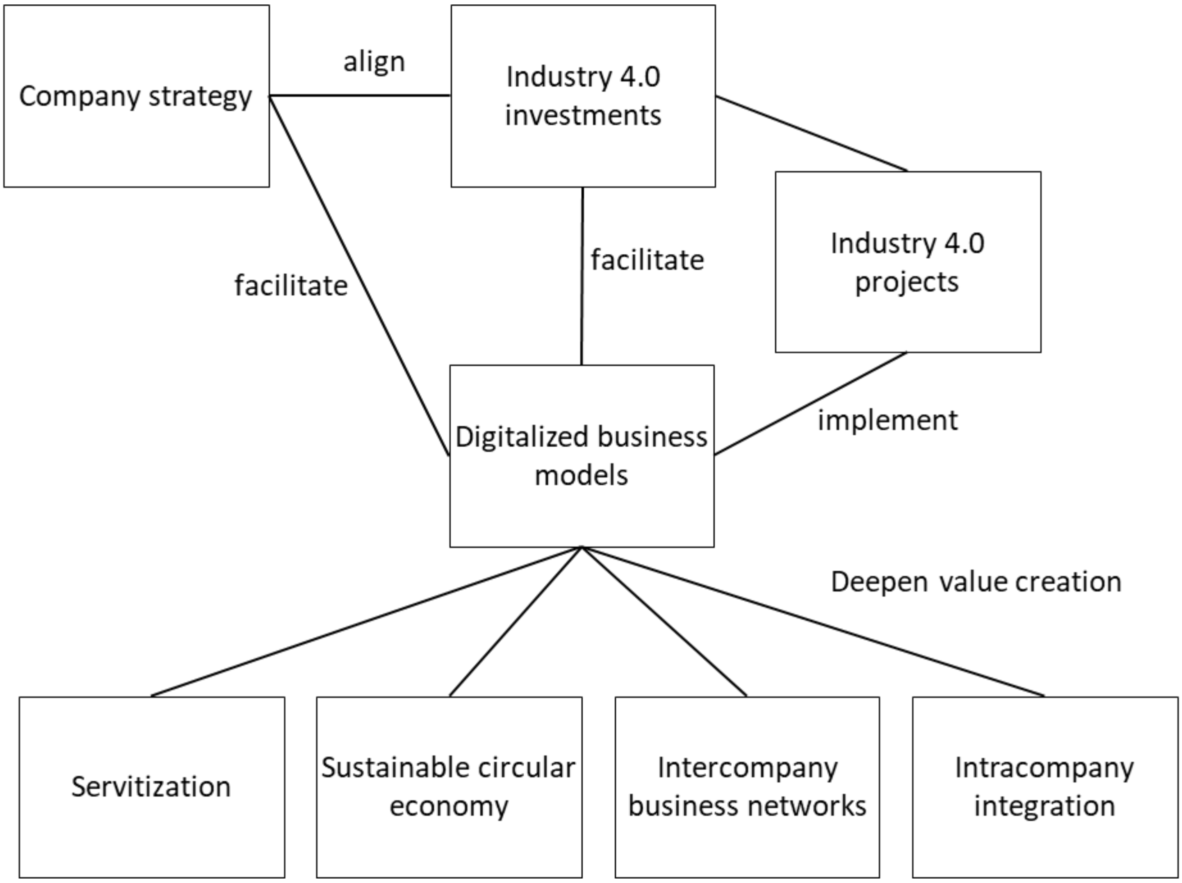

Figure 3: Business models and industry 4.0 projects (elaborated by authors)

Corroborating the value of networks, Agostini and Nosella (2019) found companies investing in internal and external integration are more likely to implement industry 4.0 innovation. They balance a variety of stakeholders needs, in the context of the company itself or within business alliances.

3.4. Innovation

According to Damanpour (1991), new processes and technologies are forms of innovation, generally targeting better performance. In 4IR manufactures, innovation is also connected to performance and value co-creation (Bertoncel, Erenda, Bach, et al., 2018; Briones-Peñalver et al., 2019; Lerch & Gotsch, 2015; Ooi et al., 2018; Sjödin, 2019; Synnes & Welo, 2016), prominently favoring intracompany (Qu et al., 2019), and interorganizational integration (Lerch & Gotsch, 2015; Yun & Liu, 2019). To supplement their capabilities, companies rely on partners (Briones-Peñalver et al., 2019; Synnes & Welo, 2016), and customers (Lerch & Gotsch, 2015).

Collaboration supports innovation in multidisciplinary industry 4.0 projects. While some discuss collaboration among manufactures (Bertoncel, Erenda, Bach, et al., 2018; Briones-Peñalver et al., 2019; Lerch & Gotsch, 2015), their relationship with other economy sectors to support innovation (Ho & O'Sullivan, 2017; Yun & Liu, 2019), others debate the collaborative dynamics of innovation teams and the role of manufacturing workers in industry 4.0 innovation (Hannola et al., 2018; Nikitina & Lapiņa, 2019; Ratzmann et al., 2018; Sjödin, 2019). Following, these three trends will be further discussed.

Studying how manufactures and other sectors collaborate, Yun and Liu (2019) highlight industrial firms increasingly adopt open innovation. Facilitated by government, open innovation reunite manufactures, universities and customers, to commercialize goods and share knowledge (Yun & Liu, 2019). Another research on intersectoral collaboration debates standards for ICT innovation, which would accelerate interoperability across devices (Ho & O'Sullivan, 2017). They argue adequate standards must consider different perspectives to identify common goals (Ho & O'Sullivan, 2017).

To implement innovative projects, manufactures collaborate. Companies networks facilitate detection of business threats and opportunities (Bertoncel, Erenda, Bach, et al., 2018), while on implementation front, collaboration with equipment providers promotes process innovation (Briones-Peñalver et al., 2019; Sjödin, 2019). As industrial processes are interdependent, foreseeing undesired effects is difficult (Sjödin, 2019), and introduction of new technology often requires customization (Hasselblatt et al., 2018; Sjödin, 2019). Thus, Sjödin (2019) argues joint problem solving, open communication and early involvement of end-users are instrumental to recombine knowledge into innovation.

Studying the dynamics of innovation teams, authors highlight the power of collective problem solving to challenge and refine ideas (Campatelli et al., 2016; Ratzmann et al., 2018; Salehi, 2020; Sjödin, 2019). Feasibility tests (Ratzmann et al., 2018), and process simulation (Synnes & Welo, 2016), allow team discussions, and deals with difficulties as they arise (Salehi, 2020; Synnes & Welo, 2016). Hence, authors bet on social and trust relationships to improve joint problem solving (Nikitina & Lapiņa, 2019; Ratzmann et al., 2018; Sjödin, 2019).

Debating the role of production workers in industry 4.0 innovation, studies highlight end-users involvement and knowledge sharing are relevant (Campatelli et al., 2016; Dewa et al., 2018; Hannola et al., 2018; Salehi, 2020; Sjödin, 2019). As senior workers from maintenance and operations have unique understandings about requirements, they must be early involved in industry 4.0 projects (Sjödin, 2019). On the other hand, industry 4.0 innovation increases opportunities to empower production workers, facilitating self-learning and interaction with other teams (Hannola et al., 2018).

Knowledge management and learning accompany innovation (Briones-Peñalver et al., 2019; Hannola et al., 2018; Nikitina & Lapiņa, 2019), while business networks accelerate technology transference among partners (Briones-Peñalver et al., 2019). Committed to continuous learning, industry 4.0 professionals must be curious, to turn insights into innovation (Nikitina & Lapiņa, 2019). In this context, Figure 4 summarizes innovation capabilities in industry 4.0 projects.

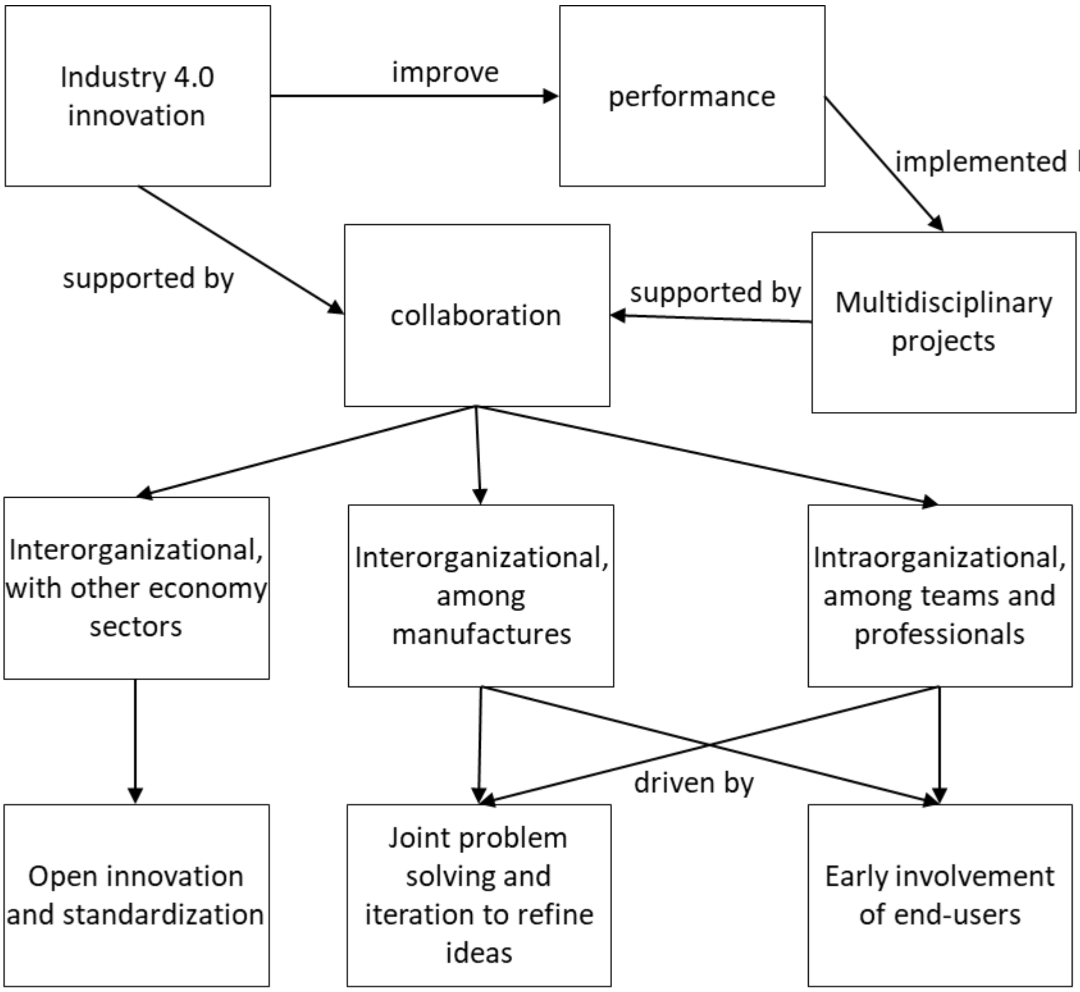

Figure 4: Innovation and industry 4.0 projects (elaborated by authors)

Industry 4.0 innovative projects improve company performance, supported by collaboration in multidisciplinary teams. These projects might take place among manufactures and other economy sectors, among manufactures in interorganizational partnerships and inside organizations, amid teams and professionals. They are driven by joint problem solving and early involvement of end-users.

3.5. Skills of project professionals

Industry 4.0 projects require professionals that are ICT skilled (Caruso, 2018; Holtgrewe, 2014; Moeuf et al., 2019; Synnes & Welo, 2016), and understand manufacturing processes (Singh et al., 2019). Additionally, they build relationships and communicate effectively (Caruso, 2018; Hasselblatt et al., 2018). To supplement their own capabilities, manufactures rely on consultants, academic and business partners (Li et al., 2019; Moeuf et al., 2019). As such, industry 4.0 projects are developed by multiskilled (Bertoncel & Meško, 2019), cross functional and collaborative project teams (Rashid et al., 2018).

Various authors highlight teamwork as an essential skill for industry 4.0 professionals (Agostini & Nosella, 2019; Bertoncel & Meško, 2019; Holtgrewe, 2014; Nikitina & Lapiņa, 2019; Siddoo et al., 2019). Their projects integrate organizations (Synnes & Welo, 2016), while introducing new technologies to manufacturing processes (Sjödin, 2019). For effective teamwork, industry 4.0 project professionals must share knowledge (Nikitina & Lapiņa, 2019; Singh et al., 2019), and collaborate (Bibby & Dehe, 2018; Rashid et al., 2018; Sjödin, 2019; Synnes & Welo, 2016).

Industry 4.0 project professionals critically assess problems (Siddoo et al., 2019), with open mind and curiosity (Bibby & Dehe, 2018; Moeuf et al., 2019), to find collaborative solutions (Agostini & Nosella, 2019; Siddoo et al., 2019). They combine knowledge from manufacturing, business, and IT departments (Agostini & Nosella, 2019), in organizational cultures that value continuous improvement (Rashid et al., 2018; Singh et al., 2019), lifelong learning (Siddoo et al., 2019), and business agility (Bibby & Dehe, 2018; Moeuf et al., 2019).

Industry 4.0 project professionals must be skilled communicators (de Sousa Jabbour et al., 2018; Hasselblatt et al., 2018; Rashid et al., 2018; Siddoo et al., 2019). They must consider various interdepartmental perspectives (Rashid et al., 2018; Sjödin, 2019), to reduce employees resistance towards industry 4.0 projects (Li et al., 2019), and to grasp end-users' needs (Campatelli et al., 2016; Hasselblatt et al., 2018). Specifically, end-users involvement from initial stages is claimed to reduce project rework (Singh et al., 2019). However, it increases the number of perspectives accommodated into a solution (Sjödin, 2019).

Considered industry 4.0 rely on project teams working together, many studies underline trust relationships are relevant (Agostini & Nosella, 2019; de Sousa Jabbour et al., 2018; Rashid et al., 2018; Roßmann et al., 2018). They improve information exchange (Briones-Peñalver et al., 2019; Ratzmann et al., 2018; Sjödin, 2019), and reduce friction among professionals, steering them towards value co-creation (Sjödin, 2019). Experts foresee trust relationships will support supply chain management, with artificial intelligence assisting professional skills (Roßmann et al., 2018).

To improve skills, manufactures must train their professionals (de Sousa Jabbour et al., 2018; Moeuf et al., 2019; Ooi et al., 2018; Singh et al., 2019), and foster experimentation (Sjödin, 2019). Despite paving a longer road towards industry 4.0 readiness, training facilitates knowledge integration (Moeuf et al., 2019), and lowers employees resistance (Li et al., 2019). In this context, Figure 5 summarizes skills of project professionals in industry 4.0 projects.

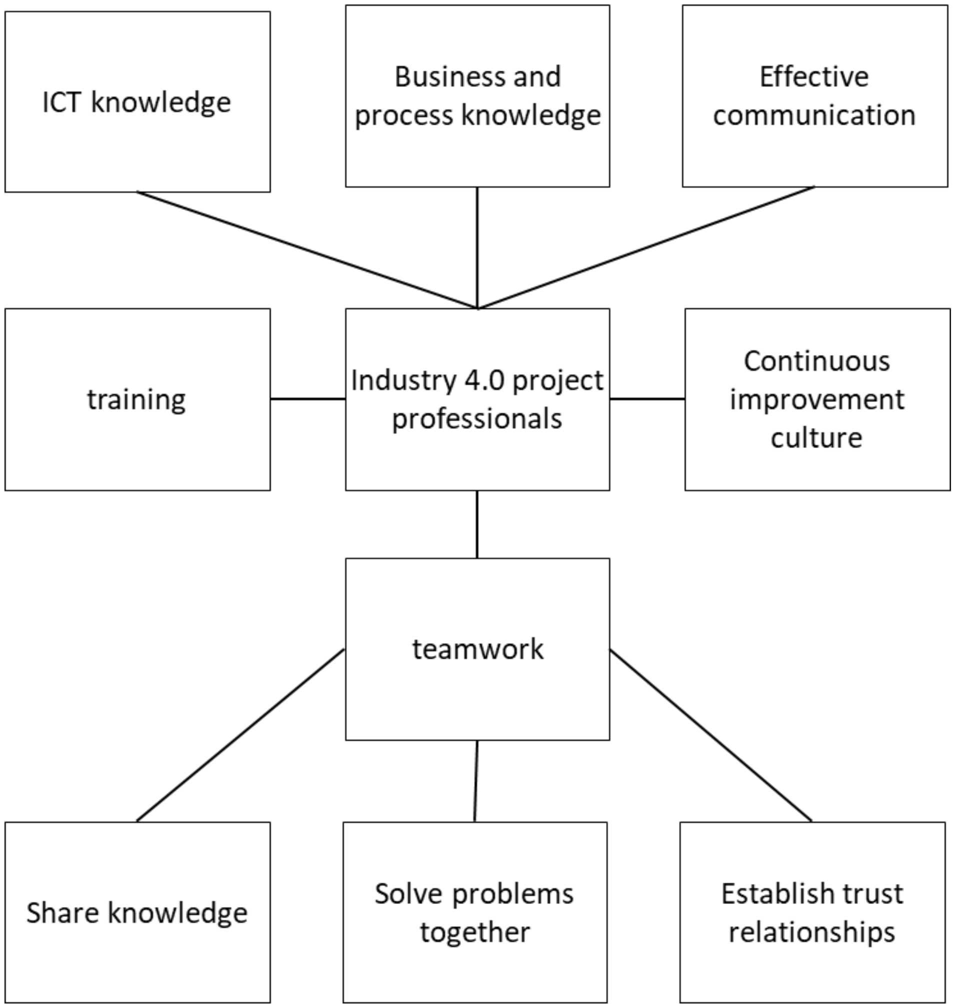

Figure 5: Skills of project professionals in industry 4.0 projects (elaborated by authors)

Project professionals must navigate the array of technologies supporting industry 4.0 innovation, while understanding business processes and needs. They compose multidisciplinary teams to supplement their knowledge and experiences. Hence, it is relevant they establish trust relationships, solve problems together and share knowledge.

3.6. Technologies

Industry 4.0 projects implement ten new technologies: 1) big data analytics, 2) simulation of interconnected machines, 3) IoT, 4) cyber-physical systems, 5) cloud computing, 6) virtual reality, 7) cyber security, 8) collaborative robots (Moeuf et al., 2018), 9), additive manufacturing (de Sousa Jabbour et al., 2018), and 10) artificial intelligence (Kuo & Smith, 2018). Following, each of them will be briefly discussed.

Big data are data sets with different formats continually generated in large amounts (Babiceanu & Seker, 2016). Authors explain data analytics evaluates these data sets to return business value. Besides, experts predict effective analysis of data will enhance order forecasts and reduce storage, improving supply chain management (Roßmann et al., 2018). However, big data adoption by manufactures is challenged by complexity, quality and integration issues (Yadegaridehkordi et al., 2018).

Simulation of interconnected machines provides virtualization of processes and products, employed on scenario validation and optimization (Moeuf et al., 2018). For example, a simulation model facilitated scenario evaluation when an existing manufacturing unit was automated (Caggiano & Teti, 2018). Diversely, IoTs are information networks connecting sensors and physical objects, called ‘things’, which range from pallets of goods to industrial machines and household appliances (Rejeb et al., 2019). IoT promises performance improvements for products supplied by intertwined companies, while the conjugation of blockchain technology and IoT is believed to protect data availability (Rejeb et al., 2019).

Cyber-physical systems are composed by collaborating computational units, which closely connect to physical machines, to consume and provide data to the internet (Monostori et al., 2016). For example, they compare real time with historical data to indicate maintenance requirements (Monostori et al., 2016). Differently, cloud computing allows companies to access software applications and data from anywhere in the world, because they are supplied on demand as a service (Buyya et al., 2009).

Virtual reality reconstructs real life in a computing scenario, adding high-tech elements to evaluate changes to manufacturing processes, for example, facilitating layout planning (Lee et al., 2011). Cyber security, diversely, protects manufacturing companies from cyberattacks which target digital interconnected components (Wells et al., 2014). Experts believe threats to security will continue to exist, even though improvements are made, because hackers accompany system evolution (Roßmann et al., 2018).

Collaborative robots work with humans, improving industrial process while adapting to changes (Djuric et al., 2016). For example, collaborative robots automated a deburring unit, replacing production workers on tasks with high injury risk (Caggiano & Teti, 2018). Differently, additive manufacturing allows components and goods to be produced without specialized machines, using 3D printing, thus facilitating product prototyping and customization (Holmström et al., 2016).

At last, artificial intelligence are systems that perform typical human functions, like learning with feedbacks (Ellen MacArthur Foundation & Google, 2019). Authors argue artificial intelligence may boost circular economy businesses, making data analysis available to users and providers. Besides, another application involves supporting human decision in supply chain management (Roßmann et al., 2018).

These technologies target different capacities in industry 4.0 manufactures: monitoring, controlling, optimization and autonomy (Moeuf et al., 2018; Porter & Heppelmann, 2014), listed from low to high maturity (Porter & Heppelmann, 2014). However, only monitoring applications were observed in small manufacturing enterprises, focused on cost reduction and lacking business models innovation (Moeuf et al., 2018). Likewise, Fetterman et al (2018) also reported only monitoring applications, restricted to tracking and reporting. Nevertheless, manufactures search professionals who could aid them build and improve intelligent machines and devices (Pejic-Bach et al., 2019).

On the road towards integration, tasks are still carried out by skilled operators due to process variability (Goh et al., 2019). However, Rashid et al. (2018) explain smart factories comprise machines fully integrated and interoperable, different from 'islands of scattered automated machines'. Thus, industry 4.0 manufactures must be committed to long-term innovation (Rashid et al., 2018). In this context, Figure 6 summarizes technologies capabilities of industry 4.0 projects.

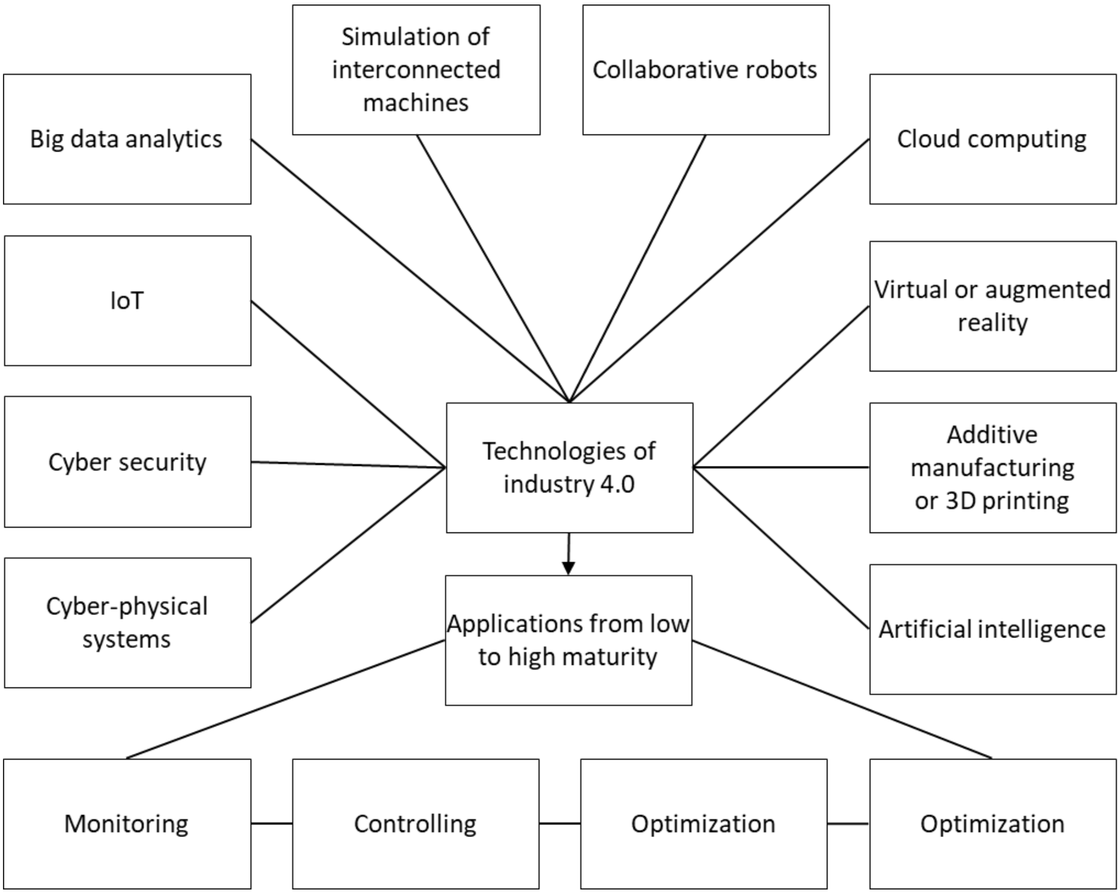

Figure 6: Technologies of industry 4.0 projects (elaborated by authors)

Industry 4.0 projects are supported by a set of technologies to implement monitoring, control, optimization, and autonomy capacities. In this context, technologies and capacities are combined to meet business requirements. Thus, manufactures must consider their current maturity on industry 4.0 projects to select appropriate technology.

3.7. Data management

Innovative business models rely on data to foresee potential faults, improve product capacity and retrofit design lifecycle (Hasselblatt et al., 2018; Lerch & Gotsch, 2015). For example, IoT and data analysis facilitate product end-of-life collection, improving resource efficiency (Bressanelli et al., 2018). Since business main intention is to extract value from data (Moeuf et al., 2019; Raptis et al., 2019), industry 4.0 projects must account for data management (Li et al., 2019; Wang et al., 2018), targeting to support managerial decisions (Olszak & Mach-Król, 2018).

Manufactures must acquire and direct data to a repository where information will be produced (Raptis et al., 2019). On a more technical perspective, authors explain industrial data is typically stored in centralized cloud networks, however, risks may arise regarding data ownership and cloud network capacity. To mitigate such risks, a multi-layered cloud infrastructure is suggested, combining local and global networks (Raptis et al., 2019). Nevertheless, data related to recent events shall remain available locally, to dispense transferring them back and forth among devices.

Data standardization is also key to integrate heterogeneous systems (Bernstein et al., 2018; Ho & O'Sullivan, 2017; Wang et al., 2018). Bernstein et al. (2018) report information from production and maintenance systems were used to retrofit product lifecycle. However, data from different subsystems had to be manually matched, because no standardization existed (Bernstein et al., 2018). Thus, system interoperability will be facilitated when standardization allows correlation between machine, systems and parts information (Wang et al., 2018).

Regarding data visualization, graphic panels assist monitoring, control and analysis of performance indicators (Gunckel et al., 2018). Graphic visualization (Gunckel et al., 2018), and digitalization of real time data (Shivajee et al., 2019), facilitate information reading, supporting decision-making, fault detection, and identification of improvement opportunities. On the other hand, there are still developments to be made on data security (Raptis et al., 2019). Authors recommend distributing security solutions, to improve deviation detection and quick mitigation of potential damage. In this context, Figure 7 summarizes data management capabilities in industry 4.0.

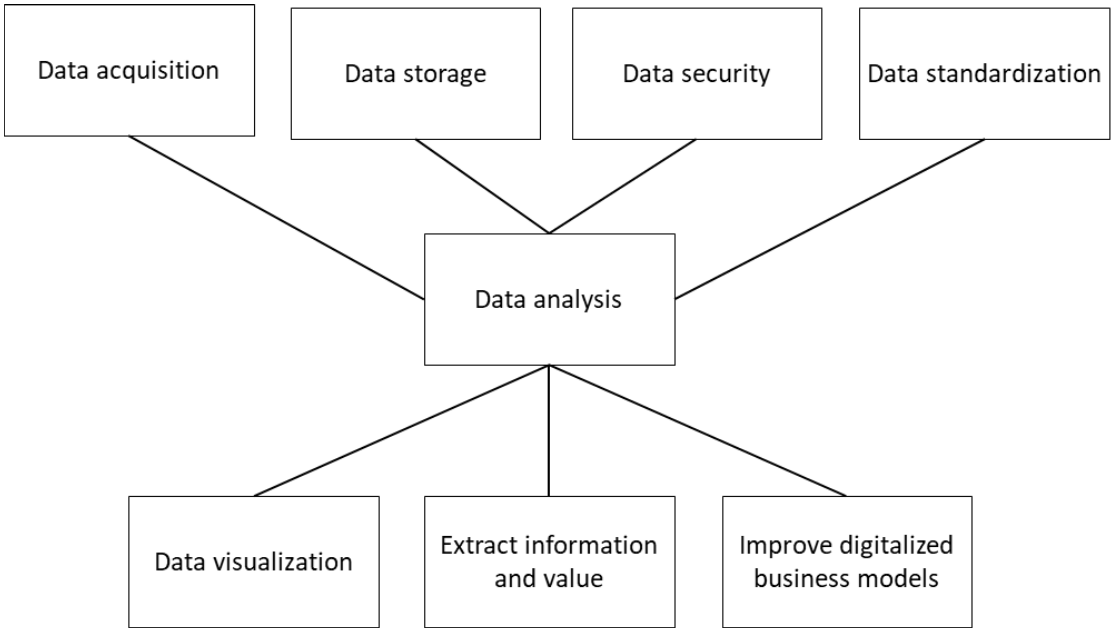

Figure 7: Data management in industry 4.0 projects (elaborated by authors)

Data analysis and visualization are backbones of industry 4.0 projects, to generate information and business value. However, they are supported by data acquisition, storage, security, and standardization. All these functions aim to improve business models and manufacturing processes.

4. DISCUSSION

Research about capabilities and project management in industry 4.0 manufactures is in its infancy, with crescent interest since 2014. Most reviewed studies have chosen a qualitative epistemology, which corroborates there is still much knowledge to be explored. Despite project management being considered structural for the 4IR, few articles have deepened its understanding, which points to opportunities for further research about the subject.

To compose its definition for industry 4.0, this study builds on concepts established by Schumacher et al. (2016), Porter and Heppelmann (2014), and De Sousa Jabbour et al. (2018). Thus, we understand industry 4.0 projects comprise business integration implemented by disruptive technologies and accompanied by transformation of data into information and intelligence. Besides, collaboration among professionals, teams, and organizations facilitates industry 4.0 implementation.

Considering industry 4.0 projects contribute to successful implementation and development of the 4IR, this study attempts to make sense of different capabilities perspectives of these projects. Centered on the perspective of project management, five other perspectives synthesize industry 4.0 projects: business models, innovation, skills of project professional, technologies, and data management. Therefore, research opportunities are identified following these perspectives (Frame 2).

Industry 4.0 perspective	**Research opportunities in project management to understand**
Project management	- how collaborative projects are implemented and their interaction with interorganizational Project Management Offices (PMO) and portfolio.
Business models	- how shared strategic goals are compromised among business partners into project portfolio.
Innovation	- which factors facilitate collaboration among intra and interorganizational project stakeholders.
Skills of project professionals	- which hard and soft skills are relevant for industry 4.0 project professionals.
Technologies	- how new technologies are employed to implement project outcomes and throughout project lifecycle management.
Data management	- how industry 4.0 projects equip manufactures with capabilities for data analysis.

Frame 2: Research opportunities in project management (elaborated by authors)

Given digitalized business models are boosted by industry 4.0, the way strategic objectives are defined might change, as different manufactures must align goals towards common strategic objectives. Hence, manufactures must develop capabilities to balance drivers from more than one organization into their portfolio. Besides, data management may transform the way project portfolios functions are executed - selection, prioritization, execution, and monitoring -, turning them more data and customer driven.

Once portfolio management is settled, business alliances must discuss how to handle collaborative industry 4.0 projects, for example, by an autonomous project manager or one employed by one of the companies. Therefore, manufactures must develop capabilities to handle collaborative and data-driven projects which interact with each organization portfolio, PMO and different landscapes of stakeholders. On a different perspective, research on agile project management claims it would be more applicable to changing industry 4.0 context than waterfall project management. Nevertheless, studies comparing strengths and weakness of waterfall and agile project management, in the context of industry 4.0, still lack.

Innovation perspective in industry 4.0 projects emphasizes manufactures must collaborate to develop projects. As such, they work together with universities and government to discuss standards that would improve technology interoperability. Besides, inter and intraorganizational teams must collaborate to share experiences, combine knowledge, and solve problems together. Always centered on end-users needs, be them costumers using industrial products or production workers operating innovative equipment.

Industry 4.0 project professionals must develop technical and project management skills to implement disruptive technologies applied to business needs. Nevertheless, they must also develop soft skills to share knowledge and solve problems together in multiskilled teams. As such, effective communication and establishment of trust relationships facilitate project implementation amidst a changing environment.

From a more technical perspective, a set of technologies enable monitoring, controlling, optimization, and autonomy of industrial processes. Thus, identifying how these technologies are employed to implement industry 4.0 projects could point to benchmark solutions. Referring to project lifecycle management, industrial projects could be inspired by construction virtual models (e.g., Building Information Modelling - BIM) to design and manage manufacturing projects, facilitating scope, and earned value tracking.

Industry 4.0 projects must account for data analysis to generate information and business value. Hence, manufactures must develop capabilities to analyze large amounts of production and customer data while seeking business opportunities. Nevertheless, investments to support data acquisition, storage, security, and standardization must precede. Besides, data analytics and artificial intelligence might also change the way projects are managed and controlled.

5. CONCLUSION

This study explored literature about capabilities and project management, in the context of industry 4.0 manufactures, to identify research opportunities in project management. Ensuring replicability and transparency (Tranfield et al., 2003), a Systematic Literature Review analyzed 55 peer-reviewed articles and established only few articles focused on project management. Among reviewed articles, six capabilities perspectives summarize industry 4.0 projects: project management, business model, innovation, skills of project professional, technologies, and data management.

Building on previous research (de Sousa Jabbour et al., 2018; Schumacher et al., 2016), we consider industry 4.0 projects comprise business integration implemented by disruptive technologies and accompanied by transformation of data into information and intelligence. Besides, collaboration among professionals, teams, and organizations facilitates industry 4.0 implementation. As research about industry 4.0 capabilities and project management is at initial stages, much knowledge is yet to be explored.

Industry 4.0 is an evolutionary program implemented by single projects, which must be guided by strategic portfolio management. As industry 4.0 projects deepens inter and intraorganizational integration through digitalized business models - servitization, sustainable circular economy, intercompany business networks and intracompany integration - different manufactures must align goals towards shared strategic objectives. Thus, changes to project portfolio management are expected.

Business networks must ensure project professional collaborate and iterate to supplement their abilities and deliver value, through agile or waterfall approaches to project management. The agile approach was proposed to emphasize projects must essentially deliver value, while managing scope, time and cost. Perhaps, because through the decades too many projects may have forgotten that predictive management of time and cost does not assure value creation, if project delivery is detached from stakeholders needs.

Nevertheless, this research argues waterfall and agile approaches could be seen as similar when value creation is central to project management. Therefore, scope definition would be accomplished through collaboration and iteration among project professionals and stakeholders, with scope changes processed swiftly when they reflect positively on value delivery.

Business networks must also discuss how to handle industry 4.0 collaborative and data-driven projects, as well as develop capabilities to interact with each organization portfolio, PMO and different landscapes of stakeholders, given multidisciplinary project teams collaborate to support industry 4.0 innovation. Collaboration might take place among manufactures and other economy sectors, among manufactures in interorganizational partnerships and inside organizations, amid teams and professionals, driven by key success factors yet to be researched.

Project professionals must understand business processes and needs while they navigate the array of technologies of industry 4.0, as part of multidisciplinary teams. It is relevant they develop soft skills and establish trust relationships to share knowledge and solve problems together, however specific research would confirm it.

A set of technologies supports industry 4.0 projects to monitor, control, optimize, and provide autonomy to manufacturing process, indicating industry 4.0 projects come in different maturities, to achieve business needs. Regarding project lifecycle management, manufactures could be inspired by construction virtual models to manage manufacturing projects, facilitating collaborative project implementation. Understanding how industry 4.0 technologies digitalize industrial process and project management would uncover benchmark solutions.

Data analysis generates information and business value for industry 4.0 manufactures, preceded by projects to structure data acquisition, storage, security, and standardization. Thus, manufactures must develop capabilities to analyze large amounts of production and customer data. Besides, data analytics and artificial intelligence applied to project lifecycle might also change the way projects are managed.

As theoretical contribution, research opportunities for project management in the context of industry 4.0 are uncovered. On the other hand, this research contributes for practitioners interested on industry 4.0 investments by clarifying which perspectives they encompass - project management, business models, innovation, skills of project professional, technologies and data management - to maximize business value.

This study is not free from limitations, as it relies on previous literature to portray an interpretation of projects capabilities in industry 4.0 manufactures. Hence, future empirical research would acknowledge and complement these findings. Besides, original studies were limited to peer-reviewed articles, to prioritize their quality and integrity, leading to knowledge still discussed in conference papers been unreviewed.

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