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RESEARCH ARTICLE

Strategic systematic for software development in industry 4.0

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Abstract

Industry 4.0 is a relevant subject both in academia and practice. Organizations need systems for managing technologies and to understand how they can be essential for business strategy. The requirements of software development include points that must be discussed at a strategic level to create institutional value. Systematics that integrate technology, and theory will influence the organization's strategic decisions.
Keywords: industry 4.0, software development, systematic proposal, technology roadmapping

KEYWORDS

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1 | INTRODUCTION

Smart industry and industry 4.0 are crucial keywords for the developments in manufacturing systems (Longo, Nicoletti, & Padovano, 2017). The capabilities of digital solutions/tools have opened new opportunities and created ambitious challenges for manufacturing systems. In recent years, these technological advances have motivated the industries, companies, and even governments to seek an improved alignment between strategic objectives and technology management through the application of structured and flexible approaches using techniques such as technology road-mapping (TRM) (Carvalho, Fleury, & Lopes, 2013).

The basic principle of industry 4.0 is the core of the so-called Internet of things and manufacturing interfaces (R. Lopez, 2014): Products in progress and production machines that will collect and share data in real-time. This technology leads to a shift from centralized plant control systems to intelligent decentralization (Shrouf, Ordieres, & Miragliotta, 2014). According to the same author, this approach allows the machines to adapt to changes and behavior, auto reconfiguring, showing the ability of systems to perceive information and obtain results, besides storing knowledge gained from experience. That is intelligent production at systems and processes level, with adequate engineering and quick installations in the future (Kagermann, Wahlster, & Helbig, 2013).

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Industry 4.0 offers new and innovative ways for organizations to manage and monitor their operations intelligently and seamlessly using the maximum of embedded technology, sensors, and connections. Based on research found in Weyer, Schmitt, Ohmer, and Gorecky (2015) and Stock and Selinger (2016), but as highlighted in Qin, Liu, and Grosvenor (2016), the technology roadmap for the realization of Industry 4.0 is still unclear and the gap analysis between current manufacturing systems and industry requirements 4.0 shows that there is still a long way to go.

TRM is intended to help understand how technology and business knowledge combine to provide strategic support, innovation, and hence the operational process in the enterprise in the context of the external and internal environment (Blismas, Wakefield, & Hauser, 2010; Kim et al., 2009). Roadmapping is a long-term planning instrument that allows establishing strategic goals and estimating the potential of new technologies, products, and services (Vishnevskiy, Karasev, & Meissner, 2016). It is concerned with identifying technological trends as well as the most important (key) technologies (Phaal, Farrukh, & Probert, 2001, 2004). TRM is a growing technique widely used for strategic planning and alignment of technology with general business objectives. TRM's are widely used in several diverse fields in products, technology, industry, enterprises, and national levels (P. Bloem, Schlichtkrull, et al., 2018; S. L. Bloem, Vasconcellos, Guedes, Guedes, & Costa, 2018). An increasing number of published articles on the subject indicate that there is more considerable attention to TRM among academics, industry, and government researchers (Amer & Daim, 2010). However, there is a growing need for new models and innovations. With the use of these new approaches and tools in conjunction with the TRM, one can increase its impact on the company, develop new capabilities, and better prepare the organization for the changes imposed by innovation, technology, and globalization (Zhang et al., 2016). The research question: How would a TRM system for software development in industry 4.0 be?

The study seeks to propose a TRM for the development of software in the industry 4.0. The methodological approach adopted was the bibliographic review and the case study. The approach of the study will be guided by the term "systematic" for the descriptions of how the general requirements should be addressed, which are described in the literature as a model, structure (NBR ISO 31000, 2009), systematic or process (Goldberg & Weber, 1998) and strategy for techniques or tools that support the analysis, being judged more appropriate for the context researched. The research will also use the term technology road-mapping or TRM because according to Willyard and McClees (1987) the term technology was used by the name of TRM in its broader context in which it means the application of science to problem-solving of capacity development, market, competition, and performance. The research adopts the terms TRM to mention the method, road-mapping for its application process and roadmap to the result in the form of a map. The article is structured as follows: The first section presents the research, its objectives, and its justifications; section two is dedicated to the literature review on industry 4.0, software development and TRM; section three contemplates materials and methods; section four presents the analysis of results and, finally, section five presents the conclusions and direction for future research.

2 | LITERATURE REVIEW

2.1 | Industry 4.0

Industry 4.0 is an additional stage of development in the organization and management of the entire value chain process involved in the manufacturing industry. It may be called the fourth industrial revolution (Schlick, Stephan, Loskyll, & Lappe, 2012). Industry 4.0 is widely used in Europe, particularly in the manufacturing sector of Germany. In general, other related terms are also used to refer to it, such as Internet of things, Internet of everything or industrial Internet (Mahidhar & Schatsky, 2013). These terms will be used in the search for articles. All these terms and concepts have in common the recognition that the traditional methods of manufacture and production are in full digital transformation (Openshaw et al., 2014). Industrial processes have increasingly adopted modern information technology (IT), but recent trends go beyond the simple automation of production that, since the early 1970s, was driven by developments in electronics and IT (Longo et al., 2017).

The widespread adoption by the manufacturing industry and the traditional operations of information and communication technology are increasingly intertwined in the boundaries between the real world and the virtual world in the well-known Cyber Physical Production Systems, which are the nucleus of new distributed control and automation systems, or the production system of the near future (Keeley, 2013). CPPSs are online networks of social machines that are organized in a similar way to social networks. They connect IT with mechanical and electronic components that communicate with each other over a network. Radio-frequency identification technology, which has been used since 1999, was a very early form of this technology (Shrouf et al., 2014).

Intelligent machines continuously share information about current inventory levels, problems or failures, and changes in orders or levels of demand (Mahidhar & Schatsky, 2013). Processes and deadlines are coordinated to increase efficiency and optimizing production times, capacity utilization, and quality in development, production, marketing, and procurement (Schlick et al., 2012). CPPSs are not only network machines among themselves, but they also create an intelligent network of machines, properties, systems, intelligent products, and the complete product lifecycle (Keeley, 2013). Sensors and control elements allow machines to be linked to plants, fleets, networks, and humans. Intelligent networks of this type are the basis of intelligent factories, and they support industry 4.0 (Cotteleer, Holdowsky, & Mahto, 2013). Qin et al. (2016) propose a categorical and hierarchical framework, where Industry 4.0 is achievable through a continuous and incremental process of evolution, whose main dimensions are automation and intelligence.

Central to industry 4.0 is its interface with other intelligent infrastructures, such as smart mobility, smart networking, intelligent logistics, and intelligent houses and buildings (Openshaw et al., 2014). Links to commercial and social networks—the business web and the social web—also play an increasingly important role in digital transformation for the industry 4.0 (Mahidhar & Schatsky, 2013). All these new networks and interfaces offered by the industry 4.0 within an internet of things, services, data, and people mean that manufacturing is subject to enormous changes in the future (Cotteleer et al., 2013). This trend is still in its infancy in some industrial enterprises and industrial sectors, but in others, the transformation to industry 4.0 is already underway. The traditional industrial economies hope that this fourth industrial revolution will bring many advantages, such as improved global competitiveness (Openshaw et al., 2014).

Moore's law (Déchamps & Niels, 2018; Moore, 1965) states that the capacity of microchips, bandwidth, and computers doubles every 18 months, representing exponential growth—also applies to other technological developments. 3D printing, sensor technology, artificial intelligence, robotics, drones, and nanotechnology are just a few examples of exponentially increasing technologies that are radically changing industrial processes, accelerating them and making them more flexible (Longo et al., 2017). These technologies are not new. However, the massive increase in computing power and cost reduction, coupled with miniaturization, make them suitable for industrial use (Hall, Gu, & Guo, 2018).

2.2 | Software development and industry 4.0

The software industry is directly linked to industry 4.0 because it derives all the techniques and solutions that the technological organization needs (Mineo et al., 2016). Industry solutions techniques 4.0 (Keeley, 2013; Mahidhar & Schatsky, 2013; Openshaw et al., 2014): Vertical network: IT integration, data analysis and management, cloud-based applications, and operational efficiency 2.0. Horizontal integration: business model optimization, intelligent supply chain, intelligent logistics, IT security management, new taxation models, and the new management of the intellectual property. Engineering across the value chain: the "ten kinds of innovation," efficient management of innovation, efficient management of the life cycle. Exponential Technologies: corporate business and organizational learning. Industry 4.0 is well conceptualized and transparent in its foundations, it is a complicated process due to the diversity of systems and given the multiplicity of available/conceivable solutions (Longo et al., 2017). In this context of intelligent data management, software, which is all the documentation and configuration data required for the application/program to run error-free, is an innovative industry tool. Software engineers are involved in the development of software products, such as database, word processors, project management tools, also covering complex areas such as air-traffic control systems, systems, websites, e-commerce (Sommerville, 2011).

Software development should be a set of organized activities used to define, develop, test, and maintain software (Lamounier, 2014). These activities result in a product that reflects the way the whole process was conducted. Each software has a development cycle, no matter its size and how many people are working on it, all applications go through the same steps (Bezerra, 2015). A process must be appropriate to the application domain and the specific project. Processes must be defined on a case-by-case basis, taking into account the specifications of the application, the technology to be adopted in its construction, the organization in which the product will be deployed, and who will develop (Coser, Carvalho, & Kovaleski, 2006). According to the literature of Wazlawick (2013) and Pressman, Maxim, and Bruce (2016) the software development process can be divided into seven phases: design, requirements gathering, requirements analysis, design, implementation, testing, and deployment. For software development, other related terms such as cloud application, IT security, and data management can be found in theory (Keeley, 2013; Openshaw et al., 2014). These terms will also be used in the search for articles search.

The risks/challenges of software integration and new technologies identified are (Blanco-Novoa, Fernández-Caramés, Fraga-Lamas, & Vilar-Montesinos, 2018; Bologa et al., 2017; Giorgio, Romero, Onori, & Wang, 2017; Martinez et al., 2017; Penas, Plateaux, Patalano, & Hammadia, 2017; Teles, Vianna Jr., & Le Roux, 2018; Wang, Zhang, Liu, Li, & Tang, 2017): lack of systems compatibility, labor replacement, the impact of consumer relations, the structure of big data, security and robustness of information systems (legislation), expansion of Internet services and communication, and diffusion of the new technological scenario for students and researchers. With innovations allied to new market needs, new tools and models are needed, especially when the business is connected to technology/software (Shmuelli & Ronen, 2017). One approach that makes this connection is the TRM.

2.3 | Technology roadmapping

A TRM connects technologies with the strategic objectives of a company and, therefore, supports the acquisition of necessary technologies before the needs. It is a powerful tool for strategic planning and technology management. As technology is changing rapidly and competition in the market is fierce, the role of a TRM is becoming increasingly important (Choi, Kim, Yoon, Kim, & Lee, 2013). According to Phaal et al. (2001, 2004), TRM assists the development and implementation of integrated business strategies, products, and technology plans, providing companies with the information, processes, and tools needed to understand these strategies. Roadmaps and the roadmapping process can broaden the horizons of planning, identify possible threats and opportunities in the business environment. There is a wide variety of maps. This fact occurs due to the absence of a standard process for its elaboration (Phaal et al., 2001, 2004). Kappel (2001) developed a taxonomy as a proposal to characterize and understand map variations. In it, there are four significant areas of application for the map: science-technology, industry, product-technology, and product. According to Albright and Kappel (2003), the TRM of products is used by companies to define their evolution plan, linking the business strategy, evolution of characteristics, and costs of the product with the technologies necessary to reach the strategic objectives. TRMs, for product planning, is the most common type and are related to the insertion of technology into manufactured products (Phaal et al., 2001).

The TRM tends to have its areas of the application linked to companies with technological capacity and a member of large networks of chains, such as the automobile industry (Andrade, Monti, & Silva, 2009), energy industry (Amer & Daim, 2010; Hillegas-Elting, Yu, Oliver, Daim, & Estep, 2016), wind energy (Amer, Daim, & Jetter, 2016), pharmacy (Tierney, Hermina, & Walsh, 2013), among others. Studies (Garcia & Bray, 2007) suggest that the roadmap can be represented on two levels: industrial or corporate. Some organizations use TRM internally as an aspect of their technology planning (corporate TRM) (Vishnevskiy, Karasev, & Meissner, 2015). However, at the industrial level, the TRM involves multiple organizations, either individually or in a consortium (industrial TRM) (Loureiro, 2010). Little is found in the literature on the use of the tool in smaller companies, even having an inventive and technological character, such as software companies. Trends are already being observed in these sectors, as can be seen in innovation support research by Ho and O'Sullivan (2017) and in developing countries by Ghazinoory, Dastranj, Saghafi, Kulshreshtha, and Hasanzadeh (2017). Phaal et al. (2001) present the main model of TRM, T-plan, the approach is developed to support managers who are committed to developing and communicating their product and business technology planning. The conventional T-plan encompasses four seminars. The first three focus on the three key layers of the map (market/business, product/service, and technology). The fourth seminar joins these three tiers on a time basis to construct the chart/data table: (a) Seminar 1: identification of the market and business drivers and the performance dimensions of the product; (b) Seminar 2: the creation of product characteristics conceptions; (c) Seminar 3: identification of options for technological solutions; (d) Seminar 4: mapping of milestones, product, and evolution of technology, among other approaches and adaptations.

TRM is a useful tool because it links innovation and technology to organizational strategy (Ghazinoory et al., 2017). The combination of other management techniques with TRM can reduce knowledge gaps and further improve management decisions (Zhang et al., 2016). As pointed out by Carvalho et al. (2013), there are only limited research papers on hybrid procedures. The tools that can be integrated with the TRM include SWOT analysis, Delphi method, five competition forces, value proposition, competitive characteristics matrix, perceptual map, hierarchical process analysis (AHP), technology development envelope (Fenwick, Daim, & Gerdsri, 2009), (QFD) (Lee, Phaal, & Lee, 2013), portfolio management (Phaal, Farrukh, & Probert, 2006) and technology management tools (Probert & Radnor, 2003). Regardless of how it is used, TRM has been adapting to new global trends and becoming more complex (Vishnevskiy et al., 2015).

3 | MATERIALS AND METHODS

In order to propose a systematic mapping technology for the development of software in industry 4.0, descriptive research was carried out systematically (Gressler, 2004). Regarding the nature of the research, the qualitative approach was used. In the present study, a bibliographic review was performed to find the general requirements that will compose the systematic and then a case study, employing a novelist, for validation of the same. The bibliometric research data was acquired from articles between 2013 and 2020. The articles were collected through databases: ISI Web of Science, Science Direct, and SCOPUS. It is justified the choices to be considered the best mechanisms of academic search to facilitate the searches by scientific content, considering the criteria of specificity by area, scientific language, credibility, reliability, and responsibility (Buchinger, Cavalcanti, & Hounsell, 2014). The data collection period was March of 2018. The keywords of the survey are industry 4.0 and software development. In order to maintain the comprehensiveness and legitimacy of the research, other related terms or derivations, already explained in the literature review, concerning keywords were also used. They were, for industry 4.0, the Internet of things, the Internet of everything and industrial Internet, and for software development, cloud application, IT security, and data management.

The collected data was examined through the technique of content analysis, where systematic procedures and objectives are used to describe the messages, aiming at the inference of knowledge regarding the conditions of production. Three steps were performed: pre-analysis, the analytical description, and the interpretation of the data (Bardin, 2011). Finally, a case study was carried out to adapt the proposed systemic approach. Industry experts 4.0 in the academic and/or practical areas were interviewed, from the considerations about the systematic, one can determine and adapt its stages. The case study was chosen because it is a qualitative method that consists of a way to deepen an individual unit. It serves to answer questions that the researcher does not have much control over the phenomenon studied. It is a tool used to understand the form and motives that led to a decision. According to Yin (2015), the case study is a research strategy that comprises a method that covers everything in specific approaches of data collection and analysis. This study may help in the search for new theories and questions that will serve as the basis for future investigations. It has as one of the most important sources of information, interviews. Through them, the interviewee will express their opinion on a specific subject, using their interpretations (Yin, 2015).

4 | ANALYSIS OF THE RESULTS

The TRM directs future actions and relates to the company as a whole. Innovations and technologies need to be managed to gain strategic learning and development (Ghazinoory et al., 2017). With the use of new approaches and tools in conjunction with the TRM, one can expand its impact to the company, develop new capabilities, and better prepare the organization for the changes imposed by innovation, technology, and globalization. The construction of systematics will be done by combining the general requirements of software development within industry 4.0, which are necessary for the full development and creation of the value of the organization that will use this new system. The basis of this new system comes from the alignment that both TRM and industry 4.0 have with strategic planning, future development approaches, and intelligence networks. With the bibliometric and bibliographic studies on the subject, one can make this relation of the TRM with methodologies linked to high technology, cutting-edge innovation, and connection tools. A bibliographic review was carried out between the years 2013 and 2018, with 43 articles identified, referring to industry 4.0 and software development. From the analysis, the general industry requirements 4.0 adapted to the context of software development are (Keeley, 2013; Mahidhar & Schatsky, 2013; Openshaw et al., 2014) found in Tables 1–5.

Regarding the general requirements, it is essential to comment on current risk thinking, which includes the possibility of opportunity risk, which could have a beneficial effect in achieving the long-term organizational goals, that is, in future planning. The risks as opportunities are linked to technological opportunities, innovation, and strategy since management involves the identification and management of all sources of uncertainty that originate and shape perceptions of threats and opportunities within organizations. These influence decision making and the company's future.

The embedded software in the context of the modularity related to the development of systems is discussed. Parnas (1972) mentions that it brings modularity by dividing a system into independent parts known as modules, which can be modified individually without additional information from others. The modules are indeed independent, the modification or addition of new modules does not interfere in the system (or language) as a whole, contributing to agility and practicality in the development or maintenance processes (Oliveira, 2017). P. Bloem, Schlichtkrull, et al. (2018) and S. L. Bloem, Vasconcellos, et al. (2018) stress the importance of learning and management of innovation and the new and integrated methodologies, such as big data, augmented and virtual reality, and clouds, which are considered as the pillars of the new industrial revolution. The tools that make technology management are essential because they can anticipate technological

TABLE 1 Strategic requirements—opportunities analysis

Opportunities analysis		
Thematic	Operation efficiency 2.0	Business' model optimization
Objective	The efficient analysis, evaluation and application of the data collected through machines and sensors.	Developing new skills, at the individual employee level and in the organization as a whole.
Challenges	Using the new opportunities that digital transformation for the 4.0 industry offers to drive operational efficiencies that create long-term competitive advantages in both reliability and price.	A top-down approach will create resistance in the organization, while the introduction of innovation in traditional business will provoke a reaction from less engaged employees.
Risks	Systems' incompatibility and labor replacement	
Gaps	Integration with other organizational environments, industrial applicability and exploitation of techniques.	New tools, approaches, industrial perspectives, recommendations and mechanisms in flexible industrial approaches.
Advantages and tendencies	Operational efficiency shapes the new industrial vision that is emerging, directly related to the changes.	Business models geared toward industry 4.0 feature a new way of perceiving and dealing with the industry clearly and technologically, aiming at its growth, but in a conscious and lean way.
Literature	(Parida, Choudhury, Chatterjee, & Chatterjee, 2016; Penas et al., 2017; Rauch, Rojas, Dallasega, & Matt, 2018; Tang & Yang, 2016)	(Chen, Tai, & Chen, 2017; Fricke, 2015; Guerrero & Holgado-Terriza, 2017; Hortelano, Olivares, Ruiz, Garrido-Hidalgo, & López, 2017; Jovanović, Lalić, Mas, & Mesquida, 2015; Kho, 2013; Mueller, Chen, & Riedel, 2017; Schuh, Potente, Wesch-Potente, Weber, & Prote, 2014)

trends, contributing to decision making, resource allocation, risk analysis, and the definition of technologies and skills to be developed.

Software development allied to industry 4.0 come across the problems of integration, or even losses from software development in an unstable and transforming environment. The modern industrialization goes through some significant challenges that are explained in the systematics. Industry 4.0 will substantially increase the technological complexity of value-adding processes (F. Lopez et al., 2017). Mastering this degree of complexity requires adequate software tools to design and build the proper installations and systems, and of course, also to operate them (Prause & Weigand, 2016). It can be seen that industry 4.0 in several areas, such as software development, has been gaining prominence in the organizational environment and is growing in studies and research. As one of the top priorities of industrial development, industry 4.0 is described as the pursuit of academic and business practice (Mueller et al., 2017). However, much still can be explained in the fields of technology, allied to strategy. One of the tools that can help acquisition of knowledge and innovation is the TRM. Aligned with the T plan model, there are the steps of the systematics:

TABLE 2 Strategic requirements—information technology

Information technology		
Thematic	IT integration.	IT management and security.
Objective	Development of solutions from a variety of components, from sensor suppliers, modules, control systems, communications networks, business applications and customer-facing applications.	Improve operational security and protection against attacks across the value chain.
Challenges	Existing IT infrastructures are very fragmented and result in poor quality networks.	Increased demands made on data security.
Risks	Security and robustness of information systems (legislation) as well as expansion of internet and communication services.	
Gaps	Implementation of other areas of research.	Technological difficulties that IT security imposes on organizations.
Advantages and tendencies	Research advantage is related to the subject of new industry characteristics.	Studies imply a necessary development for science that expands rapidly and needs security.
Literature	(Keeley, 2013; Mahidhar & Schatsky, 2013; Openshaw et al., 2014; Patelay, 2013)	(Dieber et al., 2018; Sha, Xiao, & Chen, 2018)

TABLE 3 Strategic requirements—new interfaces and data

New interfaces and data			
Thematic	**New IP (intellectual property) management**	**Data analysis and management**	**Cloud-based applications**
Objective	New and individual solutions to the problem of IP	Develop new specialized skills in the areas of analysis and efficient data management.	Provide universal access at any time to all data across the value chain network.
Challenges	Intellectual property issues related to systems and plans.	Gather, analyze and process new generated data.	Hosting and making efficient use of large industry-generated data 4.0.
Risks	Big data structure		
Gaps	Discussion of the technology paradigms and integration, besides the applicability in the different domains.		Treatment of ideas, creation of prototypes, allying techniques with software tools, among other system improvements.
Advantages and tendencies	Performance and approach of the industrial integration.		The discussion is current and frequent in the daily routine of those who use technologies and can be considered part of a new engineering of data processing
Literature	(Goguelin, Colaco, Dhokia, & Schaefer, 2017; Harpham, Cleverley, & Kelly, 2014; Peters, 2017; Wang et al., 2017)		(Erol & Sihn, 2017; Thames & Schaefer, 2016; Wu, Terpenny, & Schaefer, 2017)

TABLE 4 Strategic requirements—integrated management

Integrated and intelligent management			
Thematic	**Smart supply chain**	**Smart logistics**	**Life cycle management**
Objective	The creation of a single database, making supply chains smarter, more transparent and more efficient at every stage, from customer needs to delivery.	Make logistics processes smarter. This applies to inbound logistics, internal logistics and outbound logistics.	Ability to provide data relevant to life cycle management anytime, anywhere.
Challenges	The particular focus on new models that are tailored to individual customer needs and enable new cooperative models with business partners, places new demands on the supply chain.	Integration of autonomous technologies, flexible logistics systems, new services, new storage and distribution models and the interconnection between internal production, pre-assembly and external service providers.	Understand and better meet customer needs, as well as customize product cycles.
Risks	Impact of consumer relations.		
Gaps	Discussion beyond the theoretical simulation, integration with other design processes, concepts and difficulties of small and medium enterprises.		
Advantages and tendencies	Relevant topics are related to the development of current technology on a large scale, without forgetting small and medium technology companies, which contribute to the growth of this organizational scenario of software development by working together.		
Literature	(Bauerdick, Helfert, Menz, & Abele, 2017; Lopez et al., 2017; Lorenz et al., 2016; Müller, Gust, Feller, & Schiffmann, 2015; Pfeiffer, Hellmers, & Schoen, 2017; Zarour & Alharbi, 2017; Zhou, Li, Li, Wang, & Liu, 2017)		

4.1 | Stage 1: Preparation

In Stage 1, the opportunity analysis is carried out as to the requirements in the current situation and planned future concerning the operational efficiency and optimization of the business model. Operational efficiency analysis and optimization of business models must be made in the planning phase, as they determine the direction of the other phases.

The risks/challenges are discussed, including understanding the functioning of the sensors and the lack of compatibility between the systems (Penas et al., 2017), labor replacement, and the highly automated factories (Teles et al., 2018). The risks of lack of compatibility between

TABLE 5 Strategic requirements—change and learning

Change and learning		
Thematics	**Corporate business.**	**Organizational learning.**
Objective	Offer companies opportunities to invest in new trends at an early stage and to benefit from disruptive innovations and exponential technologies.	Make the most of the potential of exponential technologies to achieve digital transformation for the industry 4.0.
Challenges	Creating new business areas.	The use and integration of exponential technologies must be gradual, but stable. Learning is the key to sustainable organizational development.
Risks	Diffusion of the new technological scenario for students and researchers.	
Gaps	Changing conceptual perspectives and developing the challenges related to software and areas of study.	
Advantages and tendencies	The advantages come from the technological development that business and knowledge brings to the organization. They address active learning and new forms of study that integrate and contribute to the development of the industry. This movement of science allied with practice tends to break down barriers within and outside technological organizations.	
Literature	(Bi, Li, Li, & Zhou, 2016; Bologa et al., 2017; Prause & Weigand, 2016; Sivanathan, Ritchie, & Lim, 2017; Teles et al., 2018; Vila, Ugarte, Ríos, & Abellán, 2017)	

systems and the challenge of replacing labor should be discussed at this planning stage because they are significant and complex challenges with risks to bring complications to the organizational strategy.

4.2 | Stage 2: Workshops

The workshops are held in an integrated and complementary way. It stands out because this stage is the moment to connect the actions and to delimit the most significant challenges. It is the moment for the discussion and consolidation of the ideas of integration and the effective management of the innovation and technologies reached or aimed. During these steps of the workshops phase, the general requirements that can be discussed and analyzed are disclosed. The study provides a basis for discussion, with the following requirements being considered for analysis of the current situation and the future planning of information technology. In particular, the issue of IT integration and IT security management, new interfaces, and data are discussed. New intellectual property management, data analysis, management, and cloud-based applications; integrated and intelligent management are analyzed with particular attention to smart logistics, smart supply chain, and life cycle management.

The general requirements related to information technology demonstrate how the organization is involved with technology and how it intends to modernize and manage these future transformations that should occur at all levels of the company, be it on the cloud-based Internet, or the security involved in the IT operations and the different and necessary ways to innovate in several areas creating the difference. The risks/challenges to be discussed are those regarding security and robustness of information systems, such as transmission failures in machine-to-machine communication, protecting the organization's know-how (Sha et al., 2018), more reliable transactions (Bologa et al., 2017), information security, intellectual and cultural property rights concerning the data generated (Wang et al., 2017), the need for expansion of mobile and fixed Internet services with adequate bandwidth for new data traffic (Martinez et al., 2017). Discharge of telecommunications services—aimed at increasing electronic commerce as a necessary platform for the new competitive environment (Martinez et al., 2017).

The general requirements for data analysis and management should be analyzed in this step, where the team needs to organize and be concerned about the quantity and quality of the data found. Proper administration of the extensive database collected for the understanding of the other stages should occur, such as 6Cs of the "big data" or large and complex data structure (Wang et al., 2017). An extensive database needs complete data management, so there are risks related to data loss, loss of part of the information, or even lack of understanding of data. Knowledge about connection, cyber, content, community, cloud, and customization are required.

All the general requirements related to integrated and intelligent management are discussed at this stage because they are directed to the factors of production. In order to have a competitive technological product or service, one must be concerned with its life cycle, logistics, and all the layers of the supply chain, as well as how to manage the new intellectual property conditions. This concern is justified because it is a stable and innovative environment, which needs specific capacities and care to face the constant change in the technological scenario. The possible risks/challenges should be discussed at this stage concerning the impact of extremely exclusive consumer and product relationships (Determine how customer dissatisfaction and possible discards should be regulated) (Giorgio et al., 2017). The challenge of managing customer dissatisfaction and managing exclusive products is related to the capacity and organization of production management and strategic management, so the importance of understanding consumer relations and avoiding the risks of dissatisfaction.

4.3 | Stage 3: Execution

In the final stage of the systematics, corporate business requirements and organizational learning is discussed and analyzed. Organizational learning and the idea of an expanded corporate business, such as, for example, the incentive for startups, puts the company in a proactive position about the challenges of the industry. Showing that the organization is willing to develop in an innovative environment and with learning in all processes and changes. Systematics should always be under review, even after the end of the process, so that all the information gathered is devoted to strategic business. Finally, the challenge of being open to the academic community and researchers should be further discussed, and these can bring significant advances in processes, structures, models, and approaches, whether in management, technology, innovation, or the value chain. The risks/challenges should be discussed at this stage as to the need to disseminate the new technological scenario for students, who will be responsible for the implementation and maintenance of technologies applied in new factories and service companies. Bring the community of technology researchers to the discussion forum (Teles et al., 2018). The systematics can be identified in Figure 1.

The aim is to demonstrate how a systematic approach to business needs can be developed, adding the general innovative and technological requirements that were worked during the research. The systematics does not seek to be prescriptive but, as a generalist proposal, are open for change and adaptation and based on discussions during the process. The analysis should be focused on the alignment between what was identified and the company's strategy (Pillkahn, 2008). It is vital that the team members keep the expected results in mind at the end of each stage, not just to keep the focus on the relevant points, but to ensure that, at the end of the whole process, the team has the blocks and levels for integration. It is desirable to check the system periodically in order to monitor the changes and assess the achievement and progress toward the goals.

4.4 | Analysis of specialists

The proposed theoretical systematics was constructed based on the literature review on the themes. The systematics has been subjected to expert analysis to verify its practical suitability for business environments. The practical adaptation of the systematics was carried out with three specialists who develop activities related to the concepts of industry 4.0, both in the academic and/or business spheres. The experts' analysis used a questionnaire as a means of collecting data, and it was validated through a pilot test. In the pilot test, the specialist was asked to analyze the questionnaire considering their questions (Table 6). The specialists indicated small changes in the format and recommended it as a means of collecting the data in electronic forms, to facilitate the fulfillment by the respondents. The questions were the following: “What is your critical opinion about systematics? Would you add or remove a requirement? Which element is the most important and/or most relevant? Because?” The specialists were selected according to their academic background and experience in industry 4.0, and the engineering area. The leading specialists were selected on the platform

TABLE 6 Description of experts for the pilot test

	Selection criteria	
	Field of academic and practical knowledge	**Experience**
Specialist 1 (pilot test)	Doctor of electrical Engineering from UNICAMP. Post-doctorate in electronics. He is currently an adjunct professor. Acting mainly on the following themes: Emerging technologies and future networks.	Projects in data architecture. Works with the concepts of the internet of things, next-generation mobile communications networks and IoT solutions. Research and development platform for smart cities. Publications and works in the area of innovation and industry 4.0 as a business model (quality, supply chain, sustainability, logistics, optimization, virtual and augmented reality, among others). Experience of more than 8 years in industry 4.0.

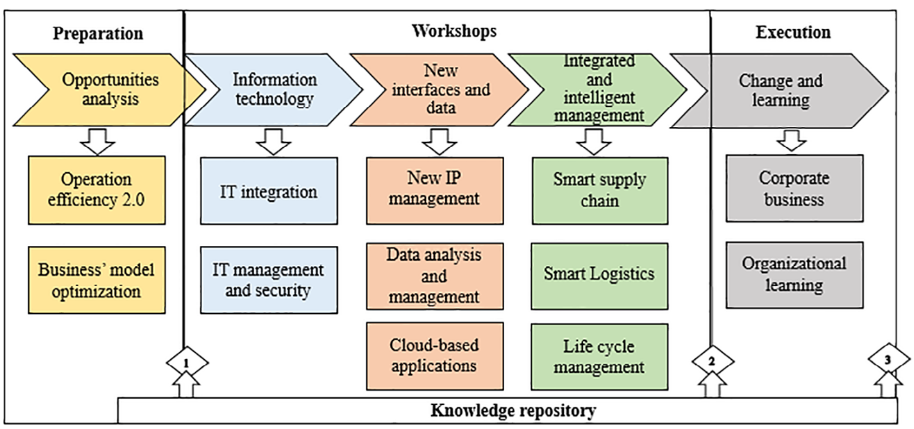

FIGURE 1 Proposed systematic [Color figure can be viewed at wileyonlinelibrary.com]

through the search of curriculum, professional performance (engineering), and subject (industry 4.0). Table 7 shows the data.

Four waves of research submissions were performed. Table 8 shows the time, the number of specialists, and responses.

TABLE 7 Potential specialists

Filters	Number of lattes curriculum found
Area of expertise: Engineering, has a doctorate	1,058
Experience of more than 8 years in industry 4.0	10

The fourth wave was sent to try to reduce the error variation, but there was no response, therefore, interrupting the sending. For the trials, carried out in the period from March to April 2019, have the description of the specialists (Table 9).

The specialist 2 considered all the essential requirements without removing any of them. However, the same specialist emphasized the important parts of each step and added comments on it. In the dimension of the opportunity analysis, he advised to consider the infrastructure risk, since it is often the case of innovative technology, but the infrastructure requires high investment to make the initiative viable. An example is a mobility that uses tablets for operational efficiency and requires Wi-Fi in the manufacturing environment. Usually, Wi-Fi capability, when available, does not meet the need. Other aspects related to cybersecurity and internal information

TABLE 8 Sending waves

Date of sending wave	Number of specialists	Number of answers	Number of refuses
May 15	10	1	-
May 22	9	1	1
May 29	7	1	1
Apr 06	5	—	—

TABLE 9 Description of the specialists for the adequacy of the systematics

	Selection criteria	
Specialists	Field of academic and practical knowledge	Experience
Specialist 2	Ph.D. in Production Engineering in the Management and Optimization Area with an emphasis on Project Management by UNESP. HCMP Certificate—Human Change Management Professional by HCMI, PMP Certificate—Project Management Professional by PMI—United States, Certificate in Lean Manufacturing at the University of Michigan, MI, United States, Green Belt Certificate by Siemens, Postgraduate in Project Management by the Vanzolini Foundation/USP.	Current "Regional Americas Process Automation & Execution Systems Leader" at Johnson & Johnson. Area of automation of processes and production, microprocessors, digital electronics. Experience in companies such as Siemens. Publications on optimization and industrial projects. Experience of more than 8 years in industry 4.0.
Specialist 3	Ph.D. in Electrical Engineering from UNIFEI. Coordinator of higher courses in Control and Automation (Engineering and Technology) by INATEL and professor of higher education at INATEL. Experience in the area of Electrical Engineering, with emphasis on Control of Electronic Processes, Feedback, working mainly on the following topics: industrial networks, Ethernet, physical media, industrial instrumentation, industrial actuators and industrial controllers.	Coordinator and project manager in industrial automation on Sense Eletrônica. Area of Electronic Automation of Electrical and Industrial Processes. Publications (books, articles) in the area of automation systems and industrial networks and industry 4.0, having more than 8 years' experience in the field.
Specialist 4	Ph.D. in Production Engineering from UNIMEP. Currently holds post-doctorate in Production Engineering at UNICAMP. Has a qualification certificate in Project Management (PMI) and Green Belt. Specialization course in Continuous Improvement (5S, Kaizen, Lean). Coordinator of the Sustainable Business Lab-Sustainable Business Lab—Has 23 years of professional experience as an International Project Manager.	Research in the areas of Industry 4.0/Advanced Manufacturing/Industrial Internet of Things—Entrepreneurship/Business Canvas—Emerging Technologies/Disruptive Technologies. Collaborator at the following institutions—Collaborative Research Network on Supply Chain 4.0. Member of SC4—National Association of Research and Development of Innovative Companies (ANPEI). Member of the Interaction Committee on Science and Technology—Innovation Plant/AgTechValley. Articles, works, books and congresses on industry 4.0 and its aspects. Experience of more than 8 years in Industry 4.0.

technology policies that block and/or delay project progress too much. It was also appointed to stage the operations technology (OT) issues, aiming the gap between information technology activities to higher levels of the automation pyramid without experience at lower levels. This procedure causes a huge gap and relevant stops of productive processes. A simple upgrade of a patch (a program that updates or fixes software) from the operating system can stop the production of a factory. One of the points considered relevant is the IT regulation issue.

The dimension of integrated management was indicated to talk about the point of integration between information technology and business, eliminating the previous structure that focuses only on corporate financial systems and operates in a stratified way between routine services and innovation projects. A recent structure envisions an area focused on business (enhancing the role of the analyst and/or business manager) and a product line area, which has experts for various solutions that support the business. Cybersecurity was placed as another relevant point. It should not be confused or embedded in the approach to regulation, but rather in internal policies and procedures that modernize information technology and focus on IT and OT integration. Cloud storage should be placed on the constraints of cybersecurity. Most productive machine vendors have already included in their portfolio predictive maintenance with applications running in the cloud. The point is data collection in the manufacturing environment and sending it to the external cloud (local or somewhere in the world). This result can be done directly using the firewall and VPN, yet out of many information technology policies, constituting yet another roadblock to advance the industry 4.0 projects.

Regarding the specialist 3, the proposal and requirements are adequate and coherent. He proposed that in the IT tables, new data interface and management could be better detailed, referring to how and what will be done at all three levels. It was suggested the description of more technologies in the workshop stage and improvements in the texts to indicate how, where, and by whom the information management will be carried out, for example. Besides, all five requirements are essential because of the waterfall interdependence between them. However, if an execution had to be chosen as the most important, it would be the last one.

Regarding the specialist 4, all requirements are important, highlighting the steps of information technology and analysis of opportunities. On the step of new interfaces and data, emphasis must be given in terms of big data and cloud storage. The specialist did not indicate to withdraw any requirement. However, each step should be explained in all its concepts. After incorporating the suggestions of specialists, the systematics was consolidated in the tables with the suggested changes. The systematic practice maintained the requirement structure.

5 | CONCLUSION

The study sought a TRM for software development in the industry 4.0. Through the bibliographic review, the general requirements for industry 4.0 in the context of software development were found to be the following. IT integration, data analysis and management, cloud-based applications and operational efficiency 2.0, optimization of the business model, intelligent supply chain and logistics, IT security management, new intellectual property management, life cycle management, corporate business, and organizational learning. In addition, to the principal risks/challenges of software integration and new technologies such as lack of systems compatibility, labor replacement, the impact of consumer relations, "big data" structure, security, and robustness of information systems (legislation). From the general requirements, it was possible to find the differential that would guide the systematic proposal. Based on the concepts of management and engineering, it is possible to propose the system, which modifies the TRM, through current and future state protocols of the company during three stages, where the general industry requirements 4.0 and the potential risks/challenges are discussed.

The research brought light to the study of the different and more updated aspects of software development in the context of industry 4.0 in integration with other essential approaches related to the new way of managing innovations and strategies. The study develops technical and academic knowledge in these areas, which are relevant for technological and organizational development. The study seeks to delve deeper into industry 4.0, which needs to be appropriately interpreted and applied in software development organizations. The results of the research sought to demonstrate the relevance of management and its opportunities to deal with issues and challenges that the new software industry brings about. Innovation management is reflected in the company's decision-making, which will opt for more significant and better means and tools to adapt its strategic vision in the long term. The study contributes to knowledge about the new ways of managing the technologies, adapting to technological changes, creating organizational value.

The study summarizes the research challenges that must be faced by researchers in the field. It also shows the practical implications that the theme has in common with universities, business, research, and development, the growth of industrialization, interconnection, among others. Showing industry 4.0 as necessary and challenging for software advancements, so the importance of studying and understanding the specificities of issues related to best practices and strategic decision making. This article contributes to knowledge about industry 4.0. The work could update previous studies and advance knowledge, bringing knowledge about new and different approaches.

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