Implementing industry 4.0 real-time performance management systems: the case of Schneider Electric

Industry 4.0 to grow must show its superiority in terms of performance. However, the available performance management systems from Industry 3.0 have several limitations and weaknesses. These weaknesses are mainly related to the human factor, whereas the latter is central in the model of industry 4.0 because this new model is centred on complex human-machine interactions. This perspective engenders specific managerial challenges, which will be due to human resistance to innovation and change. These non-technological changes are labelled management innovations. Our objective is to determine what characteristics a 4.0 Industry performance management system should have that explicitly integrating the human factor and on what main principles should it be based. Our findings revealed several specific features of performance management systems 4.0 and identified two main management principles of performance management system 4.0: adherence of all actors and solidarity between actors. Therefore, non-technological management innovations are paramount for the effective implementation and functioning of an Industry 4.0 performance management system.

Keywords: industry 4.0; performance management systems; management innovation; industry manufacturing; case study.

Introduction

From the first industrial revolution initiated in the 18th century in Great Britain to the present day, the industrial sector has evolved through a series of stages that dramatically transformed its functional and organizational characteristics (Vaidya, Ambad, and Bhosle 2018; Yin, Stecke, and Li 2018), leading to regular growth cycles in the world economy. Recently, researchers identified and predicted the development of the Industry 4.0 paradigm (Koh, Orzes, and Jia 2019; Gonçalves Machado, Winroth, and Ribeiro da Silva 2019; L. D. Xu, E. L. Xu, and Li 2018;), which imposes a new form of industrial organization founded on the direct control of all the elements of the value-added chain and facilitated by innovative technologies such as the Internet of Things (IoT), robotics, automation, big data and cloud manufacturing (Hermann, Pentek, and Otto 2016, Papadopoulos et al. 2017, Pereira and Romero 2017).

Industry 4.0 to grow must show its superiority in terms of performance compared to industry 3.0. Therefore, the performance management system is essential to demonstrate this greater efficiency (Akter et al. 2016; Wamba et al. 2017). However, the available performance management systems from Industry 3.0 have several limitations and weaknesses. These weaknesses are mainly related to the human factor, whereas the latter is central in the model of industry 4.0 centred on complex human-machine interactions that strongly impacts the work environment and the required professional competencies. This transformation results in the evolution of professional profiles and managerial practices (Johansson et al. 2017, Pereira and Romero 2017, Wang S et al. 2016). This perspective engenders specific managerial challenges, which will be, in large measure, due to human resistance to innovation and change. These non-technological changes are labelled management innovations in the extant literature (Birkinshaw, Hamel, and Mol 2008; Damanpour 2014). It is therefore essential to identify the role of the human and organizational factor in performance measurement system implementation adapted to industry 4.0.

Industry 4.0 instigates important changes in the structure and functioning of industrial organizations (Schroeder et al. 2019; Pereira and Romero 2017). Another important effect of Industry 4.0 implementation is the production and collection of a large volume of data – the so-called big data (Dubey et al. 2019; Gawankar, Gunasekaran, and Kamble 2019; Gunasekaran et al. 2017; Wamba and Mishra 2017; Wang G et al. 2016) – that can be processed to measure and enhance the performance of human-machine interactions: ‘Industry 4.0 will allow you to collect real-time information across the entire supply chain, from suppliers to users, and analyse and use this data to improve and enhance your operation, designs, and products through instant feedback, thus improving manufacturing productivity' (Kusiak 2018; Zhong et al. 2017).

In this study, our objective is to determine what characteristics a 4.0 Industry performance management system should have, which explicitly integrating the human factor and on what main principles should it be based?

Using a case study approach, within a large multinational organization – Schneider-Electric, our findings shown several specific features of performance measurement systems 4.0 that are (1) a real-time performance measurement based on clear and transparent indicators; (2) A necessary implication of all organizational actors in the industry 4.0 performance management system; and (3) an industry 4.0 performance management system in line with the firm's global strategy.

Our findings also identified two main management principles of performance management system 4.0: adherence of all actors and solidarity between actors.

Therefore, in addition to technological transformation and evolution, non-technological managerial innovations are paramount for the effective implementation and functioning of an Industry 4.0 performance management system, despite the focus of the extant literature on technology-related issues.

This paper is structured as follows. The literature review part discusses Industry 4.0 characteristics, presenting the main limitations of extant performance management systems and the role of human factor in transforming and improving these systems in the Industry 4.0 context. After explaining the methodological approach adopted to develop and analyse an in-depth case study, we present the relevant information regarding the systemic restructuring of the performance management system in Schneider Electric's business units. The findings are then presented and discussed, leading to a series of theoretical and managerial implications presented in the context of our study's limitations. The paper concludes by outlining the original contribution of this study to the extant 4.0 Industry literature and providing propositions for future research agenda.

Literature review

The concept and characteristics of industry 4.0

Definition of industry 4.0

Despite the increased attention given by researchers and managers to the Industry 4.0 concept, there is a widespread lack of consensus regarding its definition and characteristics. Its complexity qualifies Industry 4.0 as an umbrella term referring to a set of ongoing industrial transformations related to cyber-physical systems (CPS), the Internet of Things, the Internet of Services (IoS), robotics, big data, cloud manufacturing and augmented reality (Burritt and Christ 2016; Pereira and Romero 2017, Wang S et al. 2016), which integrate the digital and physical worlds to achieve better work coordination and higher productivity (Fatorachian and Kazemi 2018).

As Kovács and Kot (2016, 122) point out 'the essence of Industry 4.0 conception is the introduction of network-linked intelligent systems, which realize self-regulating production: people, machines, equipment and products will communicate to one another'. According to Vaidya, Ambad, and Bhosle (2018, 233), Industry 4.0 is 'defined as a new level of organization and control over the entire value chain of the life cycle of products'.

On the other hand, Sanders, Elangeswaran, and Wulfsberg (2016, 816) outline the impact of Industry 4.0 on manufacturing organization and dynamics: 'Industry 4.0 significantly influences the production environment with radical changes in the execution of operations. In contrast to conventional forecast based production planning, Industry 4.0 enables real-time planning of production plans, along with dynamic self-optimization' (Zadeh, Afshari, and Khorshid-Doust 2014).

Other authors centre their definitions on the concept of enhanced organizational competitiveness, indicating that Industry 4.0 will: "deliver greater flexibility and robustness to firm competitiveness and enable them to build flexible and adaptable business structures, [acquiring] the permanent ability for internal evolutionary developments in order to cope with a changing business environment […] as the result of a purposely formulated strategy implemented over time" (Koether 2006, 583);

Therefore, Industry 4.0 created intelligent factories and created a new manufacturing paradigm based on the adoption of new technologies regarding cyber-physical systems, the Internet of Things, the Internet of Services, robotics, big data, cloud manufacturing and augmented reality (Frank, Dalenogare, and Ayala 2019). Industry 4.0 transformed industry value chains by combining embedded production system technologies with intelligent production processes to pave the way for a new business age: "these technological revolutions will transform production and logistic processes into smart factory environments that will increase productivity and efficiency" (Preuveneers and Ilie-Zudor 2017, 1).

Characteristics and important changes derived from industry 4.0

The organizational implementation of Industry 4.0 requires the horizontal and vertical integration of various manufacturing phases and operations driven by real-time data collection, processing and interchange to enable customized production (Bibby and Dehe 2018; Piccarozzi, Aquilani, and Gatti 2018). Smart manufacturing systems are able to monitor physical processes and make effective decisions through real-time communication and cooperation among humans, machines and sensors. These integrated systems require reengineering processes that improve human-machine interactions (Weyer et al. 2015), combining decentralized control and decision making with efficient collaboration among various intra-organizational levels (Wang S et al. 2016) in which humans are completely integrated in the industrial process. Industry 4.0 is characterized by the prominent role given to human workers in this integrated system, while Industry 3.0 sought to reduce that role (Thoben, Wiesner, and Wuest 2017; Vaidya, Ambad, and Bhosle 2018). Although both researchers and practitioners agree on the potential advantages of implementing smart manufacturing systems, studies indicate that only a few companies have made real advances in developing the structured strategies and capabilities necessary to develop a consistent competitive advantage.

Although it is clear that Industry 4.0 development and implementation represent difficult challenges at the organizational and managerial level (Cagliano et al. 2019), extant research has many gaps regarding these problems: ‘scholarly inquiry on the economic and managerial effects of the digital transformation of manufacturing as well as its impact on business models’ innovation has transpired in the literature only recently, resulting in a limited understanding of this phenomenon’ (Savastano et al. 2019, 3).

According to Johansson et al. (2017); Pereira and Romero (2017); Vaidya, Ambad, and Bhosle (2018) and Zhong et al. (2017), a new important aspect of Industry 4.0 is the human-machine interface and the emergence of a new work environment, new skills development and new kinds of jobs (Cagliano et al. 2019).

This new interaction with higher levels of collaboration between humans and machines will have an impact on work management, organization and planning. Indeed, the virtual and physical worlds are currently merging. The number of robots and smart machines is increasing, modifying the current work environment. Industry 4.0 will introduce new types of interactions between humans and robots based on higher levels of collaboration with new ways to work collaboratively (Dubey et al. 2016; Johansson et al. 2017; Pereira and Romero 2017) that were not available under Industry 3.0. The efficiency of human-machine interfaces will favour the interaction among smart machines, smart products and employees. Therefore, future manufacturing systems should focus on the importance of workers. Autonomous robots will interact with one another, work with humans and learn from them. Therefore, intelligent machines support human-machine collaboration by helping workers in manufacturing sites with all their tasks and using speech recognition, computer vision, and machine learning. Thus, machines are essential to allowing both humans and machines to develop their skills, which complement each other. Human workers must consider machines their co-workers. In this specific context, workers are being integrated into decentralized decision making, and they are participating in engineering activities; thus, new competencies are required. Therefore, new managerial challenges will appear. Zhong et al. (2017) suggested that ‘one future research direction is an approach for “human-in-the-loop” machine learning, which enables humans to interact efficiently and effectively with decision-making models’. The conditions of the human-machine interface necessary to ensure the commitment of all human workers at all hierarchical levels will be identified.

Additionally, according to Savastano et al. (2019), the Industry 4.0 academic literature has two main shortcomings: first, many organizational insights are produced by consultancy reports and reviews of practitioners, which lack methodological depth and predictive power; second, many academic studies have a technical focus, exploring the engineering aspects of technology implementation but neglecting the managerial strategies, human involvement and organizational aspects required to mitigate disruptions in manufacturing and innovation practices (Cimini, Pinto, and Cavalieri 2017; Hahn, Jensen, and Tanev 2014). These shortcomings clearly indicate the necessity for in-depth studies of the extant best practices in implementing Industry 4.0 performance measurement systems and the managerial opportunities associated with this transformation (Kane et al. 2016; Puthiyamadam 2017).

Performance management systems

As Neely et al. (2005) point out: “A performance management system can be defined as a set of metrics used in a process”. The increased competitive pressures that are manifest in many markets have forced companies to reconsider their performance management system, to achieve additional gains in productivity, quality and market responsiveness (Bititci, Carrie and McDevitt 1997; Bittitci et al. 2018 ; Bititci et al. 2006; Bourne 2005; Bourne, Melnyk, and Bititci 2018; Buchner 2007; Mettänen 2005; Nudurupati and Bititci 2005). Boswell and Boudreau (2000) identify two specific objectives of performance management systems: evaluative – appraising the specific performance level of each employee; and developmental – providing indications regarding the development potential of every person, in time. Other authors (Gunasekaran et al. 2001, 2004; Gunasekaran and Kobu 2007) distinguish different objectives of performance management system like as measures that focus on strategy, operations, or tactics and operational planning and control. Finally, authors also underlined the role of performance management system on manufacturing organizations (Bellisario and Pavlov, 2018).

Performance management systems in the industry 3.0 environment

Armstrong and Baron (2004) suggest the inevitable existence of a tension between the interests of the employee and those of the organization – and the performance management systems attempts, often unsuccessfully, to conciliate these two visions. Unfortunately, both academic researchers and professional consultants outline the failure of personal appraisal systems (Cunneen 2006; Gratton and Ghoshal 2002; Markus 2004), which have become rigid rituals in many organizations that are realized for the sake of the regulation but that provide no clear information regarding the potential of or the possibilities for future improvement. Overall, we can identify the existence of two distinct systems of performance appraisal: one that focuses on past events and a second that attempts to unveil the future potential of employees. The best approach is likely a combination of these two perspectives facilitated by an honest conversation between supervisors and employees (Gratton and Ghoshal 2002), which can integrate both the past and the future into a dynamic, learning perspective and link it with organizational goals and values (Spangenberg and Theron 2001).

Armstrong and Baron (2004) consider the shift in terminology from performance appraisal to performance management, which they consider a completely different vision and approach to the performance evaluation process. In Industry 3.0, this process is redefined as a holistic, total approach that engages all the stakeholders of the organization in a continuous process of improving everyone and, therefore, the overall performance of the whole organization. In terms of implementation and deployment, performance management systems need to be clearly understood and controlled by line and team managers (Armstrong and Baron 2004; Rees and Porter 2003a, 2003b) and fully supported by senior management (Wolff 2005). On the other hand, ‘a trap that organizations can fall into is not recognizing that the implementation of performance management system is a change process. Too often, organizations just look over the fence to what others are doing and do the same’ (Colville and Millner

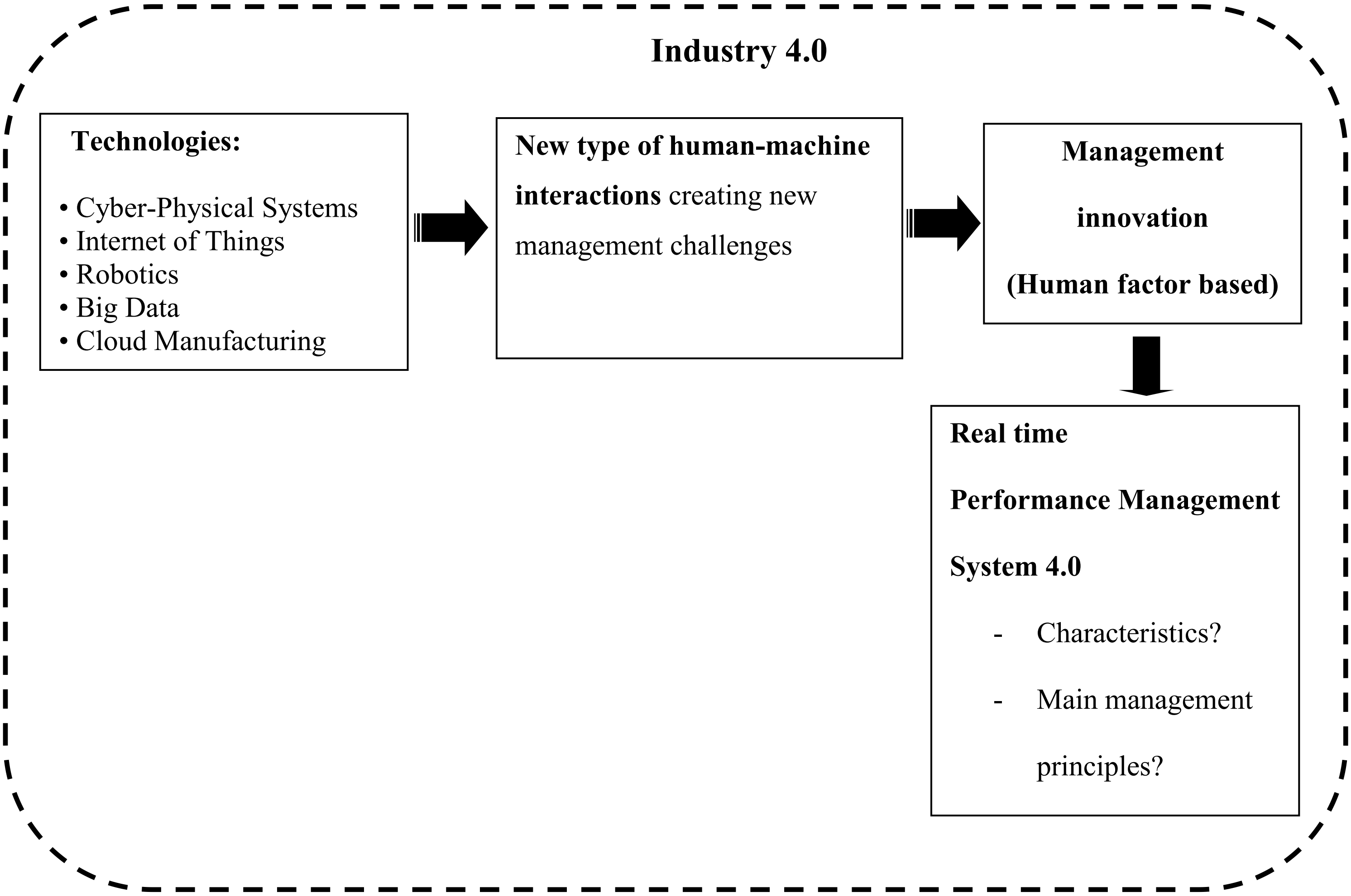
2011, 35). The implementation of a flexible, inclusive performance management system is a challenge for any Industry 3.0 organization. Markus (2004) suggests a twelve-step framework for successfully implementing such a system: (1) ensure that the strategy and values are clear; (2) outline organizational objectives; (3) update job descriptions; (4) ensure everyone has a current job description; (5) engage in performance planning; (6) plan for feedback; (7) have a clear methodology to address poor performance; (8) plan to align the consequences; (9) realize personal evaluations; (10) define the characteristics of the evaluation process; (11) implement; (12) ensure the integrity and functionality of the performance management process. A possible criticism of this approach and other similar models is the excessive concern with the personal evaluation of employees, which, in some respects, puts personnel in a passive role, as the performance evaluation is done to them.

Industry 3.0 performance management systems are characterized by three important shortcomings related to human factor (Bourne et al. 2003; Buchner 2007; Coens and Jenkins 2000; Gliddon 2004): (1) a lack of or delay in feedback, which is often only a review of the performer's activity during the last period (usually one year), without a deep analysis of the processes and operations performed by that person, consequently resulting in superficial suggestions regarding specific points of improvement; (2) a lack of performer empowerment, as often performance management systems are top-down initiatives that little consider the specific profile, characteristics and knowledge of the performer – who is often considered as a 'standard operator'; (3) a lack of a direct correspondence among various performance indicators and measures at various organizational levels. Although performance can be measured at various organizational levels, different performance measures must be consistent with the company's strategy (Bourne 2005). However, most performance management systems do not provide a clear and smooth connection among various performance measures and do not have a global dimension (Bourne 2005). These criticisms are validated by professional surveys (Markus 2004): a survey conducted in New Zealand indicates that 30% of managers did not have any performance appraisal in the last year, and this percentage is almost double in smaller organizations. Many organizations only recently introduced individual tools of performance appraisal and management, and some of them go through repeated reinventions or the restructuring of performance management systems.

The obsolescence of 3.0 performance management systems

The necessity to restructure the performance measurement systems used in Industry 3.0 markets and organizations is determined by their obsolescence in the 4.0 Industry context (Bititci et al. 2015). The main shortcomings of 3.0 Industry measurement systems are related to human-machine interactions, which evolve significantly under Industry 4.0, representing a central element in the management and functioning of new organizational structures (N. Kumar and J. Kumar 2019). Despite predictions that the role of humans will diminish in Industry 4.0 production systems (Roblek, Meško, and Krapež 2016), for the time being, the interaction of operators with machines becomes even more important in the first phases of Industry 4.0 implementation (Pereira and Romero 2017), requiring a drastic reorganization of management levels and functions (Lorenz et al. 2015). Although some decisions today are based on a holistic vision of the value-added chain (Fatorachian and Kazemi 2018) based on artificial intelligence and real-time data processes (Kamble, Gunasekaran, and Gawankar 2018), the local operator does not become obsolete; his/her role evolves from a physical interaction with machines to a quick interpretation of available data, a finer calibration of the machine to eliminate waste and unnecessary delays, and the prevention or solution of potential problems regarding the manufacturing process (Gölzer and Fritzsche 2017; N. Kumar and J. Kumar 2019; Zhong et al. 2013). In an organizational framework structured on hierarchical levels, the lower level directly generates data regarding machine and operator interactions (Mourtzis, Vlachou, and Milas 2016), which provides precious information, enabling organization performance, adaptivity and flexibility.

The efficiency of Industry 4.0 systems should be based on cooperation, complementarity and communication rather than on competition (Kovács and Kot 2016). However, this perspective engenders specific managerial challenges, which will be, in large measure, due to human resistance to innovation and change (Robert et al. 2019). The organizational and managerial changes that are needed to restructure human-machine interactions (Pereira and Romero 2017) and the seamless interdependence between various phases of the manufacturing chain should result in clear gains of productivity and competitiveness to justify their importance and necessity for the work force (Lolli et al. 2019; Lorenz et al. 2015). These non-technological changes are labelled managerial innovations in the extant literature (Birkinshaw, Hamel, and Mol 2008; Damanpour 2014). Considering the role of these managerial innovations in restructuring the performance measure systems a timely answer to the introduction of the performance measure systems of Industry 4.0 we propose the following model (see Figure 1).



(Source the authors)

Figure 1. The role of human factor in facilitating the implementation of Performance management systems 4.0

Management innovation has been defined as ‘The invention and implementation of a management practice, process, structure, or technique that is new to the state of the art and is intended to further organizational goals.’ (Birkinshaw, Hamel, and Mol 2008;

825). One year later, Mol and Birkinshaw (2009, 1269) focused on the performance dimension of this concept, emphasizing that ‘The introduction of management practices is intended to enhance firm performance’. These authors also draw on Hamel’s ideas that this type of innovation leads to major breakthroughs for firm performance: ‘management innovation changes the way managers do what they do, and does so in a way that enhances organizational performance’ (Hamel 2009, 5). Likewise, Damanpour and Aravind (2012, 424) underline the direct relationship between management innovation and performance: ‘Managerial innovations are new organizational structures, administrative systems, management practices, processes, and techniques that could create value for the organization’.

A major issue for the management of Industry 4.0 organizations is obtaining employees’ adhesion and commitment to the necessary technological, structural and functional changes (Bauer et al. 2015, EFFRA 2016). As presented above, the literature about Industry 3.0 performance management systems identifies three major shortcomings related to human factor: a lack of or delay in the provision of feedback; a lack of performer empowerment; and a lack of direct correspondence among various performance indicators and measures at various organizational levels without identifying adapted solutions. In addition, we identify another knowledge gap regarding the managerial challenges related to the new type of human-machine interaction. Moreover, the Industry 4.0 literature rarely presents clear best practices regarding how a manufacturing firm implements an effective performance management system in the context of new human-machine interactions 4.0 (Piccarozzi, Aquilani, and Gatti 2018; Bititci, Cocca and Ates 2016). It is therefore essential to identify the role of the human and organizational factor in the implementation of a performance management system adapted to industry 4.0. In this work, we will seek to determine what characteristics a

4.0 Industry performance management system should have that integrating the human factor and on what mother principles should it be based? (cf. Figure 1)

To address this gap, we use a specific methodology, which allows for the in-depth analysis of a real organization that has initiated the Industry 4.0 transformation: the Schneider Electric case.

Research method

Considering the problems associated with Industry 3.0 performance management systems, we present a real-life example of an organization that implements effective solutions for these shortcomings. To achieve this goal, we adopt a grounded theory approach (Glaser and Strauss 1967) based on a combination of theoretical information obtained through a comprehensive literature review and practical observations of a real-life performance management system. This choice is justified by the complexity of the research problem and its application context as well as by the lack of a complete theory regarding the development/implementation of a management performance system as a central component of an Industry 4.0 organization, although we recognize and use elements of existing theories and models. Grounded theory is useful in analysing the contextual, evolving and dynamic nature of Industry 4.0 performance management system implementation by focusing on human agency – the actions taken by various level managers to coordinate the implementation of an Industry 4.0-oriented management innovation (named short interval management, SIM) by Schneider Electric.

To reproduce and analyse the complexity of the real system in a written case study (Eisenhardt 1989; Junior and Filho 2016; Ketokivi and Choi 2014; Wamba et al. 2015), we use triangulation (Miles and Huberman 2003), combining secondary and primary information collected from various sources located at different organizational levels to provide a complete picture of the implementation stages, the advantages and the associated challenges of this new performance management system (Childe 2011). Our survey took place between 2010 and 2103 using longitudinal approach (Kelliher, and McAdam 2018; Pettigrew A. 1990; Wamba et al. 2015). This complex approach to data collection guarantees a multidimensional view based on a wide range of research materials: ‘various sources are highly complementary, and a good case study requires the use of a large number of possible sources’ (Yin 2009, 101).

Data collection

Data were collected in three stages. First, in the exploratory stage, we collected secondary information regarding the characteristics, implementation process, and functioning of the SIM performance management system. These data offered us the opportunity to develop a general but rather superficial vision of the SIM system and provided a basis for developing the tools and methods for primary data collection. In the second stage, we contacted a series of employees and managers of Schneider Electric, and we conducted 30 semi-structured interviews in five different business units at multiple hierarchical levels (see Table 1), obtaining rich verbatim comments from a wide range of managers and employees – from senior employees to team leaders. Each interview lasted between one and six hours. The interviews were conducted *in situ* during the 2010-2013 period. Several key respondents were interviewed several times to refine the understanding of the investigated phenomenon. Finally, in the third stage, we engaged in participant observations, following *in situ* all the activities developed for implementing the SIM performance management system.

Table 1. Categories, number and functions of respondents.

Categories of respondents	**Number of respondents**	**Function of respondent**	**Function of respondent**	**Function of respondent**	**Function of respondent**

Top Executive	4	Vice president quality and industrial performance	Corporate chief responsible for industrial performance in charge of SIM deployment	Director for manufacturing, France	Human resources department manager
Business Unit “A”	4	Plant manager supervisor: Low voltage manufacturing supervisor	Team direction (TD): Technical productivity supervisor	Team direction (TD): Supply chain excellence and industrial performance supervisor	Team direction (TD): Business unit human resources supervisor
Business Unit “B”	4	Plant manager (PM): Regional director of industrial automation	Business coordination manager	Business manager	Senior account manager for industrial automation
Business Unit “C”	4	Plant manager (PM)	Team manufacturing supervisor (TMS)	Industrial performance manager	SIM implementation supervisor
Business Unit “D”	4	Industrial performance manager	Team direction (TD): Business unit human resources supervisor	Team leader (TL)	Team leader (TL)
Business Unit “E”	10	Plant manager (PM)	Business unit human resources supervisor	Team manufacturing supervisor (TMS)	Industrial performance manager
		Technical productivity	Supply chain supervisor	Head of technical services	Technical officer (TO)

supervisor		(HTS)
Team manufacturing supervisor (TMS)	Team direction (TD): Head of production services	

Data processing

To describe, analyse and understand the mechanisms and the outcome of implementing SIM management innovation, the content of various discourses was divided into units of meaning (Allard-Poesi 2003), parts, units or groups of sentences related to the same theme, and we classified them into several categories. The size of these units was defined using two criteria (Lincoln and Guba 1985): the selected unit of analysis (1) must contribute to answering the research question and (2) must be interpretable without additional information. The link between the retained units and categories was realized through a relation of inclusion (unit X is a type of Y category), which does not involve any interpretation for open (Strauss and Corbin 1998) or descriptive coding (Miles and Huberman 2003).

To frame and organize the collected data in relation to the formulated research objective, we applied a two-stage procedure: (1) open and (2) axial coding. By applying the grounded theory framework, in the first phase we identified the main social worlds (i.e., universes of discourse) using four qualifying elements (Strauss 1978): individual profile, work location, organizational responsibility, and contribution to the implementation and functioning of the SIM management innovation. During the open coding phase, we used these social worlds as semantic anchors for identifying and categorizing the operations and outcomes related to the implementation of the SIM management innovation and their specific manifestation.

During axial coding, we considered various activities, challenges and outcomes that were organized in relation to the proposed analytical framework, both chronologically and functionally: implementation, correction, improvement, and daily functioning. The cross-tabulation among the individual, situational and institutional factors, on the one hand, and the specific challenges and outcomes of the SIM implementation and application, on the other hand, represent an interpretative matrix developed through the careful analysis of the collected interviews. The next section presents the case study resulting from this matrix.

The case study

Schneider Electric SE is a French multinational corporation founded in 1836 and incorporated in 1981. The company specializes in electricity distribution, automation management and installation components for energy management. It is headquartered in Rueil-Malmaison, France, and has a global presence with operations in more than 100 countries.

The context

At the beginning of the new millennium, as presented in the internal corporate document New 2004, Schneider Electric decided to pursue an aggressive strategy of internationalization by diversifying its production in new units, which were mostly developed in developing countries with low labour costs in Central and Eastern Europe as well as Africa, South America and Asia. This international development was realized through a series of acquisitions of approximately twenty new companies every year (e.g., Lexel, Digital, TAC, Clipsal, Andover Controls, ESMI, Crouzet), which rapidly and significantly increased its brand and product portfolio, permitting Schneider Electric to enter new market segments (e.g., movement control, security, energy saving).

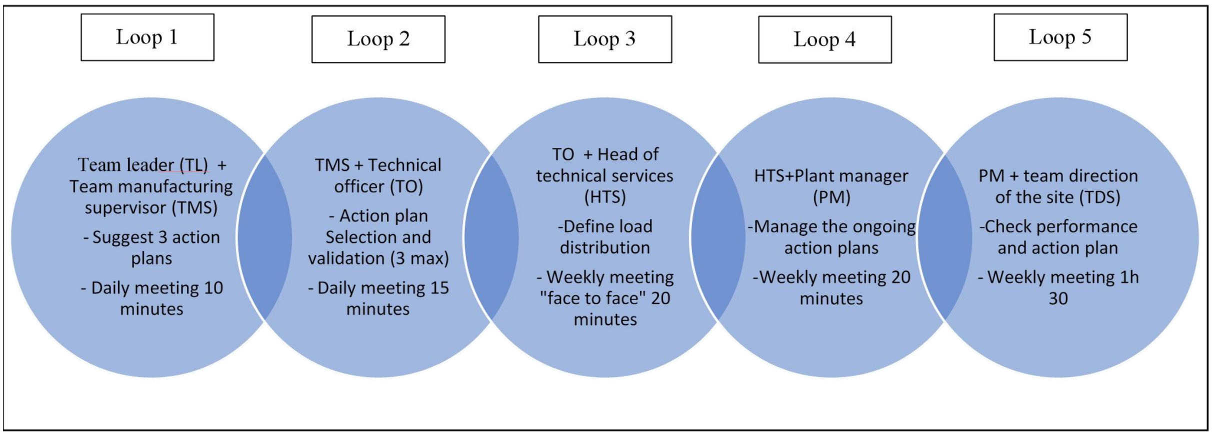
On the other hand, starting in 2009, the company mitigated the risk of brand and identity dilution by launching the programme One based on a strong vertical integration of all brands, products and activities under the corporate umbrella brand of Schneider Electric. Today, this corporate group includes and controls more than 100 different brands.

The idea of introducing a management innovation was determined by these rapid and dramatic changes in the structure, strategy and functioning of the company. The new production units located in developing countries with low labour costs have created a threat to the survival of the traditional production units located in developed countries, especially in France. In fact, the initiative of implementing new management practices was taken by a group of business units and department managers that were suddenly confronted with significant differences in labour productivity between the new production units and their own production units, which, over the long term, were in danger of being closed as businesses. The top management team accepted the challenge and decided to support this initiative by providing the necessary human, financial and organizational resources for the development, implementation, and refinement of management innovations that could boost work productivity:

> Our level of labour productivity was between 1 and 3% before the implementation of the new management system. Since our labour costs were significantly higher than those from developing countries, the only solution was to achieve productivity gains of 7% or more
>
> (Interview 5).

Description of the management innovation (short interval management)

Short Interval Management (SIM) is essentially an innovative system of management that is based on recurrent sequences of animation ('SIM loops'). These sequences involve different hierarchical levels to measure performance and produce corrective action plans. The goal of these action plans is to improve overall performance. The SIM method starts with loop one and finishes with loop five (see Figure 2). All the identified dysfunctions in loop one must be solved throughout the entire process. At all levels, operators and managers must look for a solution to the identified problem. If no solution is identified, the dysfunction is elevated to a higher hierarchical level of management. Top and middle levels of management are inextricably linked to the operators who have identified the problems that emerge in the organization. SIM facilitates the discovery and implementation of effective solutions to all organizational challenges.



(Source the authors)

Figure 2. A representation of SIM

Considering its novelty and originality, we can consider the SIM system a complex management innovation. The specificities of SIM are obvious; its main feature lies in the fact that the different loops closely overlap, linking all of the company’s hierarchical levels and stakeholders.

Findings

The collected data indicate that the essential elements for the successful functioning of Industry 4.0 performance management systems are as follows: (1) a real-time performance measurement based on clear and transparent indicators; (2) A necessary implication of all organizational actors in the industry 4.0 performance management system; and (3) An industry 4.0 performance management system in line with the firm's global strategy.

A real-time measure of performance based on clear and transparent indicators

At Schneider Electric, the real-time evaluation of work productivity is based on a categorization of the labour time in 'green time' – a positive, useful time that creates product value, and 'red time' – the negative, wasteful time, which does not create value, augmenting production costs and, therefore, the final price paid by the client (see Figure 3). In the production flow, 'everything that advances in a proper rhythm is green, while red corresponds to delays or blockages' (Interview 5). The principles applied to differentiate the various time categories are the following:

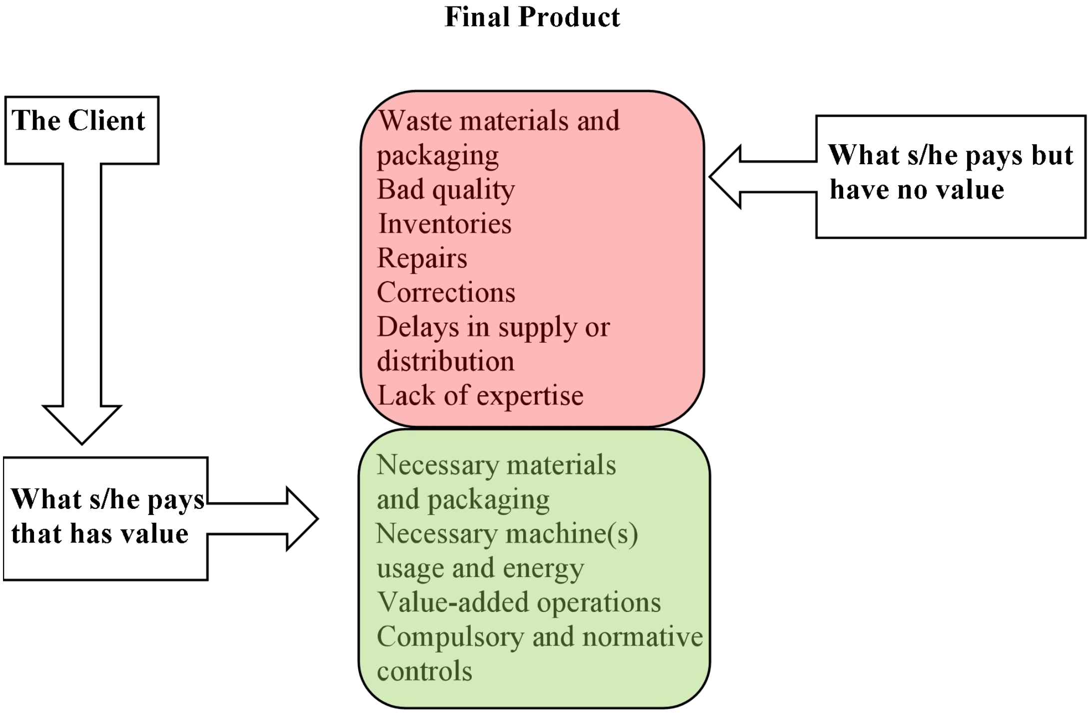


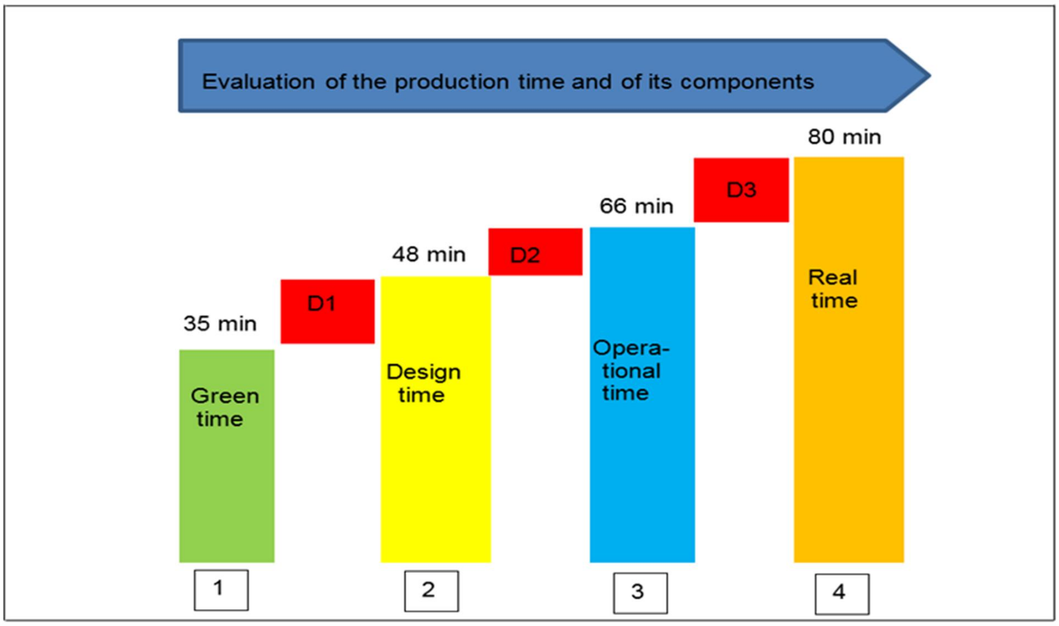
Figure 3. Useful time *versus* non-useful time
(adapted from Schneider Electric)

- Any product realized by the company is composed of two parts in relation to production time – 'green' time and 'red' time.
- 'Green' time corresponds to what the client wants to buy and includes the following cost elements: raw materials, consumed energy and the depreciation of machinery, necessary packaging, and all the operations that augment the perceived and real value of the product, including compulsory quality controls. 'Green' time – or useful time, is the reference for the entire performance management system. For each realized product, there is a specific 'green' time, which represents the base against which all the productivity gains are measured because 'the short interval management system allows the immediate identification of any "red" time' (Interview 2).

- ‘Red’ time represents the additional costs paid by the client, which do not reflect any product value and include the following elements: loss of raw materials and packaging, excess inventory of raw materials or final products, delays and/or blockages in the normal production flow, lack of necessary supplies, additional production time, and maintenance problems or repairs. All this waste and time loss are due to inefficient human-machine interactions. The identification of the ‘green’ and ‘red’ parts of the production time and process represent the core of the new performance management system, which is perceived as a cultural change at the corporate level: ‘in our culture, we start with defining and identifying the red and the green’ (Interview 7).

After separating these two ‘time’ categories, the line and team managers define the main components of ‘red’ time in more detail to target each of these elements with solutions and improvements. The process always starts with the rigorous calculation of the ‘green’ time required to realize a specific product and ‘the design time’ – which is the production time that integrates the inevitable losses related to the design, structure and functioning of the existing production lines. This time therefore includes all the additional operations that are not useful in absolute terms but that are inevitable given the present state of the production unit design and structure (D1). The elimination of these operations is potentially possible but requires large costs and a great deal of time, which prevents the firm from engaging in major production line restructuring. In addition, because of specific space or flow restrictions, the design of an ideal production flow that eliminates all unnecessary operations may be, in reality, impossible. Thus, the ‘design time’ is always larger than ‘the green time’: ‘our methods give to the production a reference time that already incorporates the inevitable losses in relation to the ideal value that should be paid by the client on the basis of the green time’ (Interview 11).

A third time category is then defined and acknowledged: ‘operational time’ (see Figure 4). Operational time is composed of the design time plus a certain number of production operations that are considered inevitable but which further degrade the level of performance, such as the batch change, the set up and control of machines, production incidents, defects, lack of sufficient supplies, and maintenance and repairs (D2). In comparison to ‘design time’, which takes into account the productivity loss determined by the design and structure of the production line(s) (D2), operational time also takes into account the delay and loss determined by the momentary capacity of the machines employed in the production line.



(adapted from Schneider Electric)

Figure 4. The various elements used to evaluate the real production time and its components

Finally, a fourth category of production time is the ‘real manufacturing time’, which includes, in addition to the ‘operational time’, the delays and losses related to the usage of the production line (D3) (see Figure 3). These elements of cost are the ones that will be carefully identified and monitored by the team manufacturing supervisors (TMS) and technical productivity supervisors (TPS), as ‘they represent the real possibilities for improving productivity by applying the appropriate correcting measures’ (Interview 11). D2 and D3 are mainly due to an inefficient interaction between humans and machines.

The various categories of production time are important, as they progressively integrate both the positive and the negative sides of labour productivity and consider the reality in terms of inevitable delays. Once the various categories of delays are identified (D1, D2 and D3, as represented in Figure 3), it is then important to identify proper actions and initiatives to reduce or even eliminate, when possible, these delays.

In terms of operational performance management systems, the reduction in time D1 is the mission of the production department and logistics, which have to find the most productive design possible in relation to the location and structure of the production line. Time D2 represents the action area of support services – for example, the maintenance and repair of the technical elements of the production flow, which can reduce the delays related to dysfunctional machines or installations. Finally, time D3 is the main target of SIM management innovation and is also extended to time D2, as the support services are also included in this particular performance system.

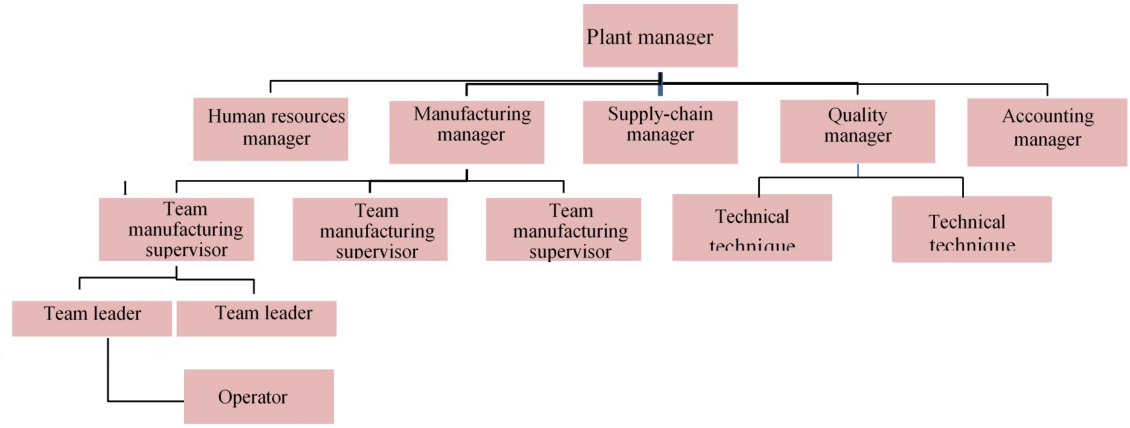
The clear categorization of various delays (D1, D2, D3) and the precise localization of these losses permits the organization to identify potential corrections and evaluate the productivity gains that represent the effect of the SIM actions: “The final indicator of productivity, and thus of the performance, is the gap between the time employed by the personnel in the current year, in comparison with the previous one. This operating time has to be 7% shorter than in the previous year, and by using this simple evaluation criterion, we can look month by month if we are in line with the projected result. The variation in production volume is neutralized by the calculation in the form of percentages, while the variations in the product mix are taking into account in the 'design' time" (Interview 11).

A necessary implication of all organizational actors in the industry 4.0 performance management system

To increase employees' implication in the performance management system, the company increased their autonomy, responsibility and accountability, which had a strong impact, especially on the first management level, as the number of hierarchical levels was reduced. This strategy increased employee autonomy, and the task diversity facilitated and accelerated the adherence of the first management level to the implementation of an innovative Industry 4.0 performance management system. The consequent results indicate a good management practice that can improve personnel commitment, accelerate learning, and consequently accelerate the adoption of the new performance management system.

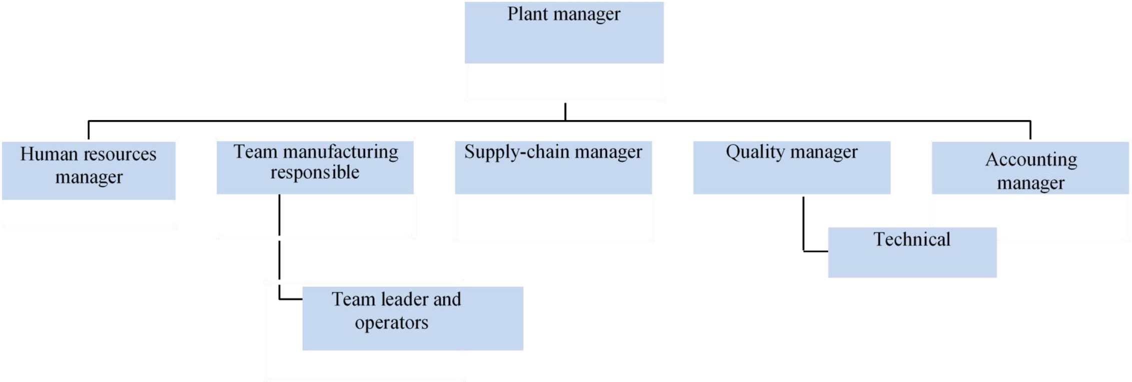
Our findings outline the importance of the active participation of employees in the implementation of new performance management systems, and the effects are significant, especially in terms of learning, personal motivation and even enjoyment. Frequently, during the interviews, the respondents expressed their satisfaction regarding the perceived job enrichment as a by-product of increased task diversity and personal responsibility. The feeling that employees' decisions and actions matter and directly contribute to the continuous improvement of the firm increased employees' participation in the continuous improvement of company performance. However, this outcome is contingent upon providing clear performance objectives, creating feedback loops that facilitate real-time performance appraisal, and increasing the responsibility and accountability of the line operators with regard to the daily efficiency of the manufacturing process: ‘The SIM approach, which uses both smart technology and management innovation, induces a reduction in hierarchical levels and job enrichment and an increase in employees’ versatility and skills, which results in productivity gains for the entire organization’ (Interview 2).

The company extensively changed its organization by reducing the number of hierarchical levels from five to three within each business unit (see Figures 5 and 6): ‘The fewer hierarchical levels there are, the more there is a direct link between a problem and the decision or action required to solve it efficiently’ (Interview 3).



(adapted from Schneider Electric)

Figure 5. The hierarchical organization of a business unit before SIM implementation



(adapted from Schneider Electric)

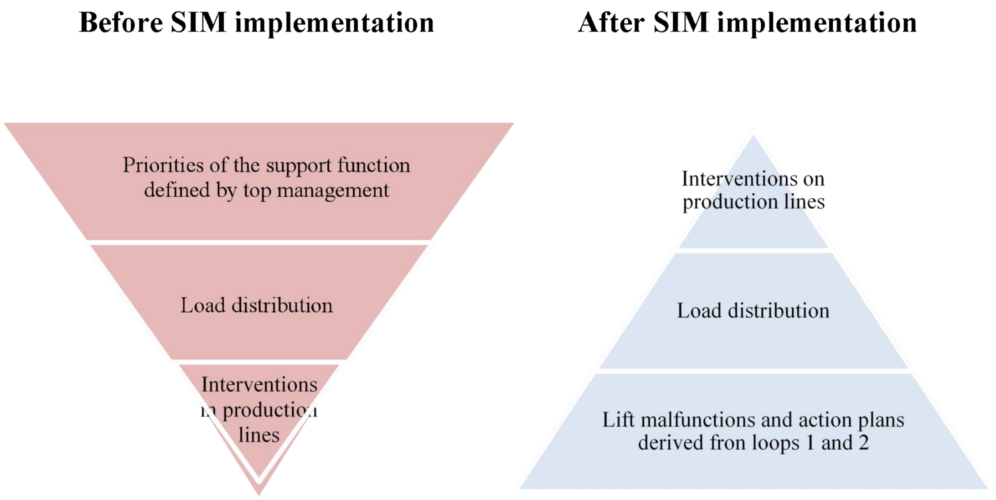
Figure 6. The hierarchical organization of a business unit after SIM implementation

To increase commitment among employees, the company developed a system of inter-related feedback loops and decision-making responsibilities that involved all the hierarchical lines. This decision-making system required the active participation of all company employees in direct relation to their place and objective within the general manufacturing system of the business unit. Functionally, the objectives and the action plans associated with the Industry 4.0 performance management system (see Figure 2, loops 2) were developed and validated during daily meetings of the involved operational team. However, this method can function only if each team member is present and contributes directly to identifying the existing manufacturing line shortcomings and then finds solutions to reduce or eliminate them.

Furthermore, the systemic interlocking between the different feedback loops ensures the solidarity of all the hierarchical levels, guaranteeing the success of the entire process. It should finally be noted that the company’s top management team leads by example by also participating in this system due to the addition of the fifth loop, which involves business units’ top managers and supervisors: ‘We are in a system based on gears that fit together, so the best way to be efficient is to work at the same speed as the others, creating energy through involvement and dynamics and avoiding becoming a brake in the system’ (Interview 4); ‘if you don’t believe in the system, you are not able to create a dynamic evolution in the right direction’ (Interview 15).

Short decision-making circuits favour the personnel’s adherence to the implementation of the Industry 4.0 performance management system, creating solidarity among all actors and facilitating a quick identification and treatment of all malfunctions. Our findings show that reducing the hierarchical levels allows for better reactivity by reducing decision-making time. Action plans are quickly developed in relation to the existing needs and circumstances, and inter-level communication is improved: ‘Today, in our business units [due to the SIM method], the performance objectives are not established per month, but rather per hour, day, or week, at the maximum’ (Interview 18). The effective use of smart technologies also increases the speed and efficiency of information flows, allowing the first hierarchical levels, which identified the malfunction, to obtain a quick response to their proposals for improvements. A short decision circuit avoids demobilizing the first levels of management. With a slow decision-making process, the first management level may stop suggesting new corrective actions, subsequently disrupting the entire process. The loss of commitment and motivation could lead to the failure of the Industry 4.0 performance management system.

To preserve the personnel's commitment, management also created a connection between all the departments. A member of each support department participates in the second feedback loop (see Figure 2), contributing to the definition of action plans and objectives. In the loop system, the departments are thus inextricably linked. The SIM loops ensure a string of seamless responsibility between all the departments and hierarchical levels. As a consequence of these changes, some departments lost their decision-making autonomy regarding the performance of management priorities (i.e., particularly the support departments, such as method maintenance, logistics, and quality control departments). The action plans and objectives are developed in an 'ascending' rather than a 'descending' manner (see Figure 7), and those selected in the second loop become the priority (see Figure 1 loops one and two); the 'SIM method has a beneficial effect because the loop of retroactivity includes the support functions, requiring these departments to regularly analyse performance gaps and determine the action plans that can further improve production and performance' (Interview 11). We schematize this reversal of perspective in Figure 7.



(Source the authors)

Figure 7. Changes in the support departments' priorities as a consequence of SIM implementation

The Industry 4.0 performance management systems are efficiently implemented thanks to a management innovation based on two principles: (1) the adhesion of all organizational actors to the implementation and functioning of this system and (2) the solidarity of all the actors in terms of responsibility and accountability to continuously improve the performance and competitiveness of the company. These principles lead to the following best practices: defining and using transparent performance indicators; evaluating individual and collective performance; increasing the initiative and autonomy of the first levels of management; enriching/diversifying the tasks, missions and responsibility of the first level of management; shortening and increasing the speed of the decision-making circuits; and creating solidarity and joint responsibility among all the departments and hierarchical levels.

Another element that enhances personnel’s acceptance and adoption of the new performance system is the use of transparent performance indicators and the open sharing of best practices.

Operators could follow in real time the positive impact of the improvements introduced in the manufacturing system and therefore understand the importance of feedback information and regular meetings at the team level. The company used specific communication tools to display the performance improvement data – such as a digital information panel located at the centre of each business unit. Performance data clearly demonstrate that the performance of integrated manufacturing lines increase significantly if the operational time required for human-machine interactions is optimized and ultimately reduced. A significant number of the respondents argued that human/machine interactions with the SIM performance system allow business units to reach and continuously improve the performance levels defined by the top management: ‘The best engine for SIM adoption and use is demonstrating the efficiency of this method; it's been 10 years since we changed gears in terms of performance and continuous improvement. Efficiency is our best ally’ (Interview 4); ‘Without the SIM method, the introduction of new machinery would have taken more time. I was impressed by the speed at which complex machines were installed and adopted. The results are remarkable’ (Interview 5).

An industry 4.0 performance management system in line with the firm’s global strategy

A performance management system aligned with the firms’ strategy requires interdependent and seamless responsibility and accountability among all the hierarchical levels. Our findings highlight how a strong link among all the hierarchical levels generates solidarity among all the organizational actors to achieve strategic and performance objectives. In our case study, the Industry 4.0 management performance system is based on successive management activities and interventions structurally planned at various hierarchical levels, which are facilitated and amplified by smart technologies. The loop system guarantees that the identified dysfunctions are timely considered. These dysfunctions are then analysed and addressed through action plans, which often require specific adjustments at the operational, functional and systemic levels. If these problems cannot be resolved at the level of the first or second loop, they are quickly communicated to the middle management level and then through the fourth and fifth loops, finally reaching the plant manager. Therefore, in this system of successive loops, all the hierarchical levels and all the departments of the company are directly involved – depending on the gravity and specificity of the identified problem – in developing and implementing corrective action plans. No employees (operators, middle managers, top managers) can operate outside of this system and the firm's global strategy. The higher hierarchical levels must also contribute to solving difficult problems by providing the necessary resources in terms of time, expertise or assets: 'the SIM that integrates smart technologies is a powerful method to ensure an identical pace of progress at all the company's hierarchical levels' (Interview 5).

In a nutshell, the SIM method designed and implemented by Schneider Electric successfully transforms the structure and functioning of the business units: first, the established feedback loops are interdependent, and each level is embedded in the superior levels, which makes the feedback information in real time, relevant and context-dependent; second, the employees are empowered to take charge of their performance management process and propose ways to continuously solve problems and improve performance; third, the alignment between the company's strategic objectives and its Industry 4.0 performance management system stems from the close involvement and accountability of all the personnel and the permanent interaction of various hierarchical levels. Centred on the human-machine interaction and enhanced by the introduction and use of Industry 4.0 technologies, the performance management system implemented by Schneider Electric improves the efficiency of the manufacturing process and gradually increases work productivity through problem identification, processing and solving.

Discussion

Implications to theory

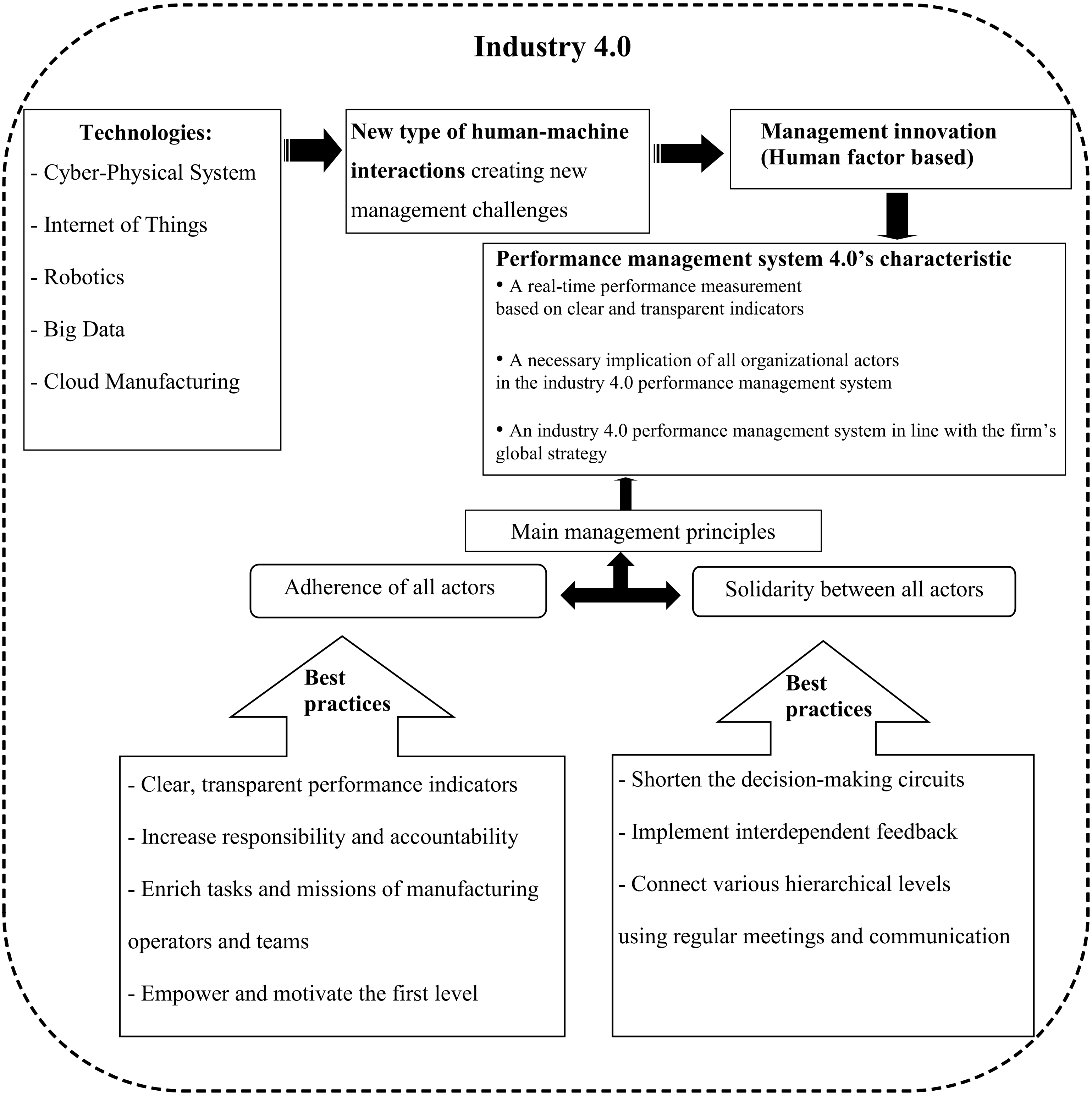
The SIM method represents a solution to the three main shortcomings of the Industry 3.0 performance management systems. The first problem concerns the introduction and use of performance measures based on clear, transparent indicators that are well-understood and shared by all organizational actors. In the case of Schneider Electric, the concepts of 'red time' and 'green time' are logic and easily measurable since they are centred on the value provided by the manufactured product to the final customer – which make sense for machine operators, team coordinators, middle and top company managers, creating a shared corporate culture oriented towards efficiency and competitiveness. From this perspective, our findings complement and validate the extant studies regarding the role and importance of performance indicators for effective manufacturing system management (Bititci, Cocca, and Ates 2016; Boswell and Boudreau 2000; Gunasekaran et al. 2001, 2004; Gunasekaran and Kobu 2007). Indeed, these authors underline that the measurement and metrics pertaining to performance management system have not received adequate attention from researchers or practitioners. In line with these works, we determined characteristics of a timely performance management system in industry 4.0.

The very short intervals of performance measurement solve the problem of insufficient and/or late feedback (Cunneen 2006), providing real-time information collected, processed and displayed by Industry 4.0 technologies. The ‘red time’ elements that degrade performance are directly and timely addressed in each work shift by analysing– in the first and second feedback loops, the identified performance gaps and proposing immediate corrective action plans. This result completes the work of Bourne et al. 2000 that underlined the use performance management system for action and reaction. With this result we can propose performance management system specific characteristics in order to produce a real time measurement and reactions in real time.

Second, the employees’ lack of empowerment regarding many Industry 3.0 performance management systems (Bourne 2005; Buchner 2007; Colville and Millner 2011; Mettänen 2005) is resolved by significantly increasing the autonomy, responsibility and accountability of the first-level operators in achieving the established performance targets and contributing to the continuous improvement of the manufacturing system. The innovative performance management system introduced by Schneider Electric to tackle the problem of poor performance was centred on quick reaction times to develop and implement effective problem-solving ideas that continuously address and correct the performance shortcomings. By actively participating in the identification of performance analysis malfunctions, manufacturing line operators have the opportunity to address and solve the problems they are directly facing, which results in increased professional pride, satisfaction, motivation and commitment. This result confirms Bititci, Cocca, and Ates, (2016)’s work by demonstrating that the evolution of the performance management system requires changes in the management and organisation mode of the company. In addition, our results complement Bellisario and Pavlov work's (2018) by stressing the importance of the involvement of the first hierarchical levels in the performance management system implementation.

Third, the lack of alignment between performance objectives and a company's strategy (Bourne et al. 2003; Buchner 2007) throughout the organization is addressed by reducing the number of hierarchical levels and introducing the system of interlocked feedback loops, which implicitly facilitates contact and communication between different employees and management levels. The 'bottom-up' approach, which consists of monitoring, identifying and correcting performance gaps, is thus combined with a 'top-down' approach, which defines and implements strategic objectives in direct relation to the information obtained from manufacturing lines. Our results complete previous works as Boswell and Boudreau 2000; Gunasekaran et al. 2001, 2004; Gunasekaran and Kobu 2007 showing the specific characteristics of performance management system 4.0 are required to continuously align the performance management system with strategy. Finally, it is important to note the correspondence between the suggestions made in the literature (Bourne et al. 2003; Buchner 2007; Colville and Millner 2011; Zadeh, Afshari, and Khorshid-Doust 2014) regarding the improvement of Industry 3.0 performance management systems and the main characteristics of the performance management system implemented by Schneider Electric.

Based on our findings, we propose an integrated framework for Industry 4.0 performance management system implementation (see Figure 8), where the management challenges raised by the transition to Industry 4.0 systems are addressed through a pervasive management innovation based on two inter-related principles, which are each expressed through a series of systemic best practices. Under these conditions, the efficient human-machine interaction is no longer an organizational problem but a central condition for permanently improving performance and competitiveness.



(Source Authors)

Figure 8. A framework for the successful implementation of a performance management system in the industry 4.0 environment

This diagram should be read as follows. Industry 4.0 is characterized by the emergence of innovative technologies such as the Internet of Things, the collection and processing of big data or artificial intelligence. These new technologies far from breaking the complex human-machine interaction have only strengthened it by making it ever more complex and sophisticated. This phenomenon generates organizational and managerial challenges that 4.0 companies face, and which can only be solved by the introduction of new management innovations.

In addition, performance measurement systems in Industry 4.0 must have several specific features distinct from industry performance measurement systems 3.0 to be efficient. These characteristics are (1) a real-time performance measurement based on clear and transparent indicators; (2) A necessary implication of all organizational actors in the industry 4.0 performance management system; and (3) an industry 4.0 performance management system in line with the firm's global strategy.

Our contribution is to highlight the importance of implementing managerial innovation simultaneously with technological innovation, to implement and operate a performance measurement system appropriated to industry 4.0. Complementary, we suggest two management principles relating to the 4.0 performance management system: adherence of all actors and solidarity between all actors. These principles are operationalized through six best practices.

The theoretical implication of this work is to show the need for a stronger application of the management innovation perspective in the theory and models addressing organizations' transition to an Industry 4.0 system. This approach can significantly increase the understanding of the real processes and management challenges related to this complex systemic transformation, notably, interaction human-machine. From this theoretical perspective, the study of new production planning and control systems can be effectively addressed through cross-fertilization among operational management theories, management innovation models, and human resource management principles, in line with Bititci et al.'s works (2006, 2015, 2018), about the organizational culture and performance management system.

Implications to practice

From a practical perspective, our findings outline the importance of several managerial innovation best practices that can significantly facilitate the implementation and functioning Industry 4.0 performance management systems.

Although the new technological evolution plays an important role in improving and maintaining the performance of Industry 4.0 management systems, these changes should be organically combined with non-technological innovations.

The restructuring of organizational systems and processes must address the problems engendered by the evolution of human-machine interactions to reduce or eliminate management's inertia and employees' resistance to change. Our findings suggest that the successful implementation and functioning of new performance management systems should also take into account the human factor through two main management principles based on best practices.

The first principle is to ensure adherence among all actors. This principle is reflected into the following good practices:

- To implement a visual system of clear, transparent indicators, accessible to all stakeholders
- To increase the responsibility of all stakeholders notably by involving the first hierarchical levels in the data production process to measure performance

- To enrich the tasks and missions of different actors through a process of decentralization of decision-making
- To develop the involvement and motivation of the first hierarchical levels by joining them with the detection of the dysfunctions and deficiencies of the performance management system and ensuring a reward for this involvement.

The second principle is to ensure solidarity among all stakeholders by:

- Shortening the decision-making circuit
- Introduce feedback loops between each hierarchical level to ensure solidarity between all stakeholders
- Organize management contact points on a regular and short frequency allowing communication between the different hierarchical levels ensuring the quickest resolution of malfunctions by implementing corrective action plan.

Finally, companies can increase their employees' extrinsic motivation by implementing individual and collective incentive systems based on real-time data that feed performance feedback mechanisms.

Firms must often retrain their employees, supervisors and managers to increase their knowledge and awareness regarding the new challenges raised by Industry 4.0 systems and their contribution to solving these problems. This training strategy will probably differ in large organizations – which, because of their financial resources, will often outsource the personnel training services to specialized organizations, and in SMEs – which will probably creatively use their internal expertise and employees' insights regarding the necessity of and best modalities for managing this organizational transition. Recruitment principles and criteria should also adapt to the work requirements of the Industry 4.0 environment, prioritizing people with adaptable, collaborative and more autonomous profiles.

Regardless of the size of the company, in Industry 4.0, human agents will still represent the main creators and coordinators of value creation. Thus, in addition to investing in new technology implementation and systemic restructuring, companies should increase personnel training efficiency by combining new information and communication technologies (ICT), such as virtual reality head-mounted displays.

Limitations and future research agenda

Despite the positive results identified in the case of Schneider Electric, the implementation of Industry 4.0 performance management systems raises a series of complex challenges, such as the need for strong management support and policies; a pervasive and systemic adoption of new operational approach; and open, multi-level communication among management line operators, supervisors and managers. Unfortunately, the limits of our research project do not permit us to present and compare the challenges of implementing and adapting this system in various types of organizations. The academic and managerial implications of this case study indicate the necessity to develop and analyse more in-depth case studies of both successful and failed Industry 4.0 performance system implementations to understand their specific features and advantages and, consequently, to develop and propose better theoretical models and managerial practices.

Future studies should further develop, refine and validate our findings, either by using similar in-depth case studies or by adopting a quantitative approach based on modelling and analysing the relationship among various relevant factors and variables.

Thus, this work highlights the importance and role of management innovation combined with technological innovation in order to implement and sustain an optimal performance management system adapted to industry 4.0.

Based on this observation, two types of questions may appear. The first type would concern future researches on the articulation between the literature on management innovation and those relating to production planning and control systems, operational management and management human resources.

These works could identify how management innovations enabled the implementation of production planning and control systems as well as industry-specific operational management 4.0. In addition, others work could determine what kind of management innovations are best suited to set up a type 4.0 industry. Similarly, it may be relevant to identify the most appropriate HR profiles that can adapt to the new human-machine interactions in Industry 4.0.

Finally, a second type of questioning can be suggested. It would be a question within Industry 4.0 to study the link between management innovations and technological innovations. In this context, is it more relevant to introduce technological innovations first and then adapt the way the organisation manages to make technological innovations more efficient, according to a chronological model? Or is it better to simultaneously introduce managerial and technological innovations, using a synchronic model?

Conclusion

This study makes a threefold contribution to the extant literature on the implementation of Industry 4.0 systems in modern organizations: First, we develop and present a model of performance management successfully implemented by Schneider Electric to respond to the challenges engendered by the organizational transition to an Industry 4.0

environment. Second, we outline and explain the importance of human factors, which, together with new technological systems, represent a central component of sustainable Industry 4.0 performance management systems. Third, our findings indicate the necessity of managerial and organizational innovations to move from Industry 3.0 to Industry 4.0 systems, identifying a series of effective principles and best practices.

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Disclosure statement

The authors have no conflicts of interest to declare.

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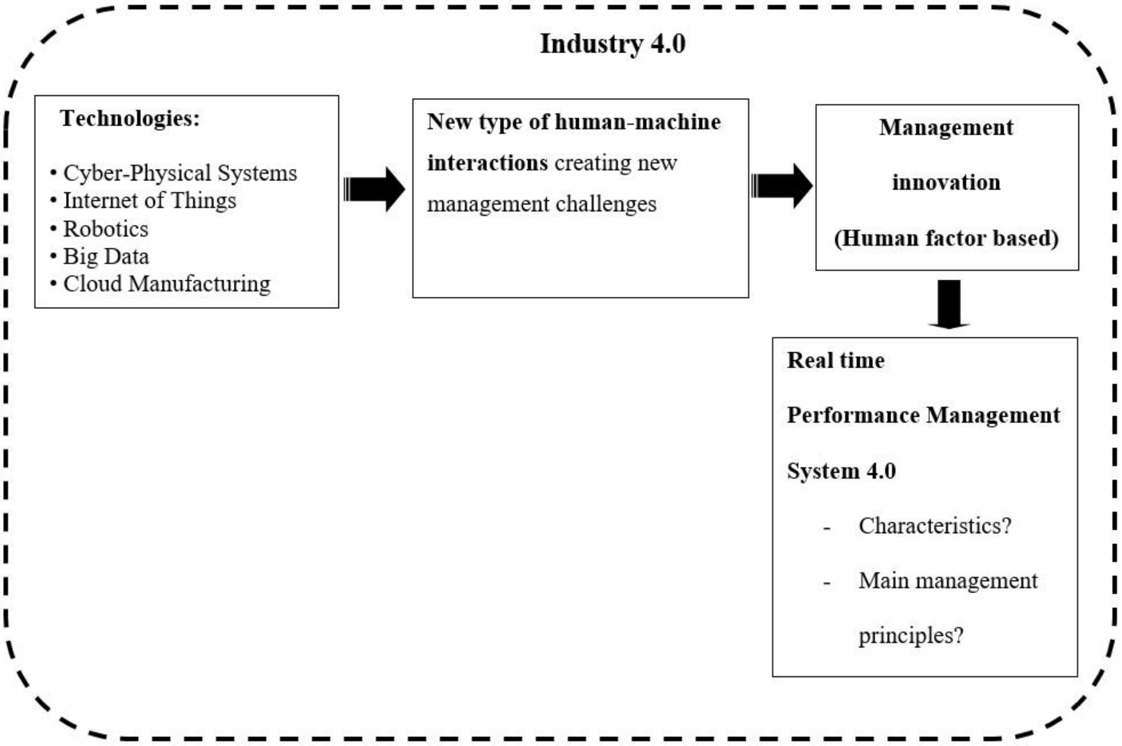
Caption Tables

Table 1. Categories, number and functions of respondents.

Categories of respondents	**Number of respondents**	**Function of respondent**	**Function of respondent**	**Function of respondent**	**Function of respondent**
Top Executive	4	Vice president quality and industrial performance	Corporate chief responsible for industrial performance in charge of SIM deployment	Director for manufacturing, France	Human resources department manager
Business Unit “A”	4	Plant manager supervisor: Low voltage manufacturing supervisor	Team direction (TD): Technical productivity supervisor	Team direction (TD): Supply chain excellence and industrial performance supervisor	Team direction (TD): Business unit human resources supervisor
Business Unit “B”	4	Plant manager (PM): Regional director of industrial automation	Business coordination manager	Business manager	Senior account manager for industrial automation
Business Unit “C”	4	Plant manager (PM)	Team manufacturing supervisor (TMS)	Industrial performance manager	SIM implementation supervisor
Business Unit “D”	4	Industrial performance manager	Team direction (TD): Business unit human resources supervisor	Team leader (TL)	Team leader (TL)
Business Unit “E”	10	Plant manager (PM)	Business unit human resources supervisor	Team manufacturing supervisor (TMS)	Industrial performance manager
		Technical productivity supervisor	Supply chain supervisor	Head of technical services (HTS)	Technical officer (TO)
		Team manufacturing	Team direction (TD): Head		

supervisor (TMS)	of production services	

Figures



(Source the authors)

Figure 1. The role of human factor in facilitating the implementation of Performance management systems 4.0

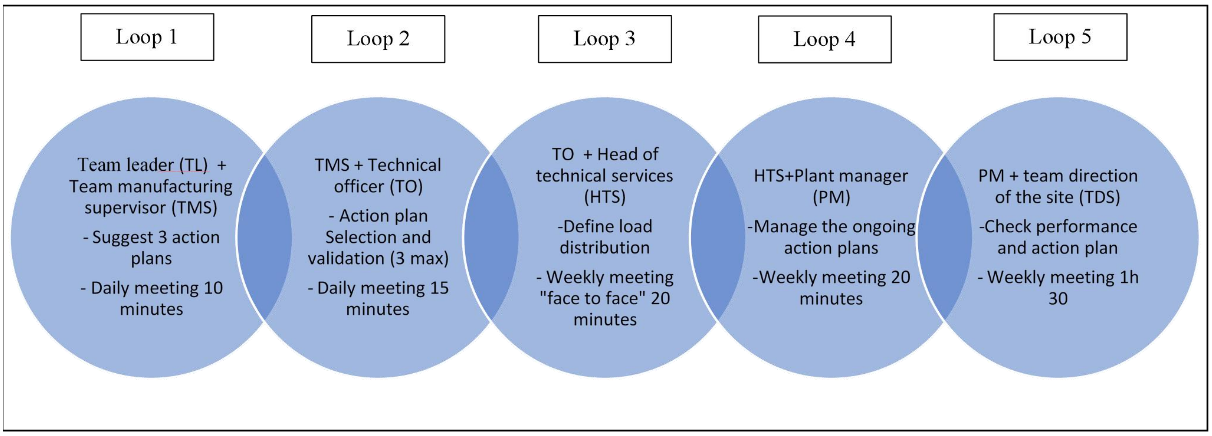


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Figure 2. A representation of SIM

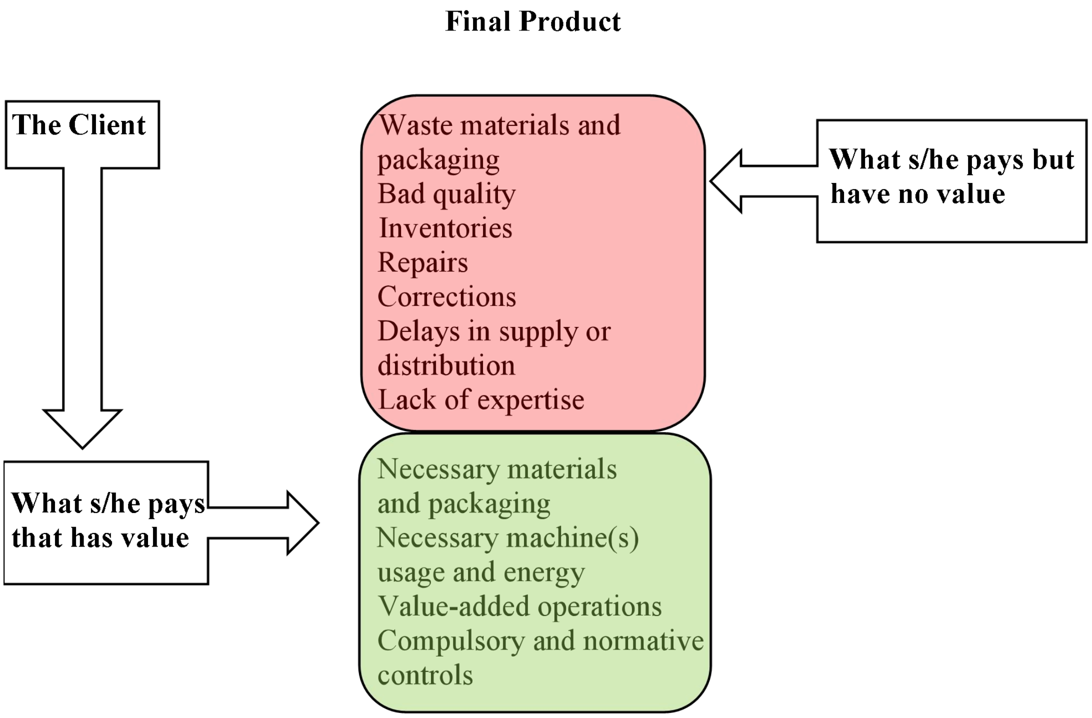
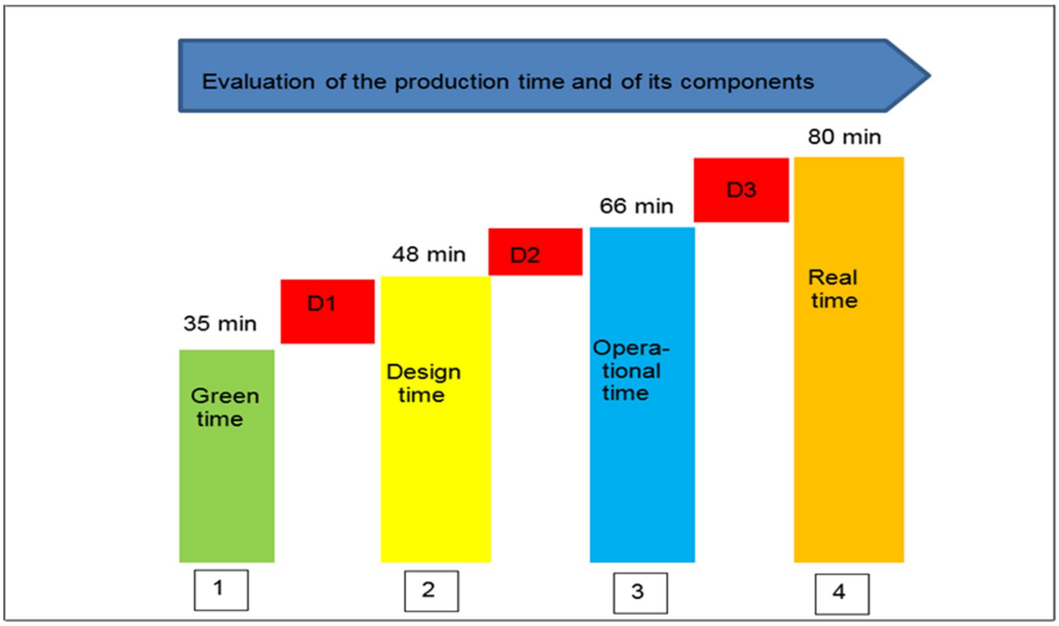
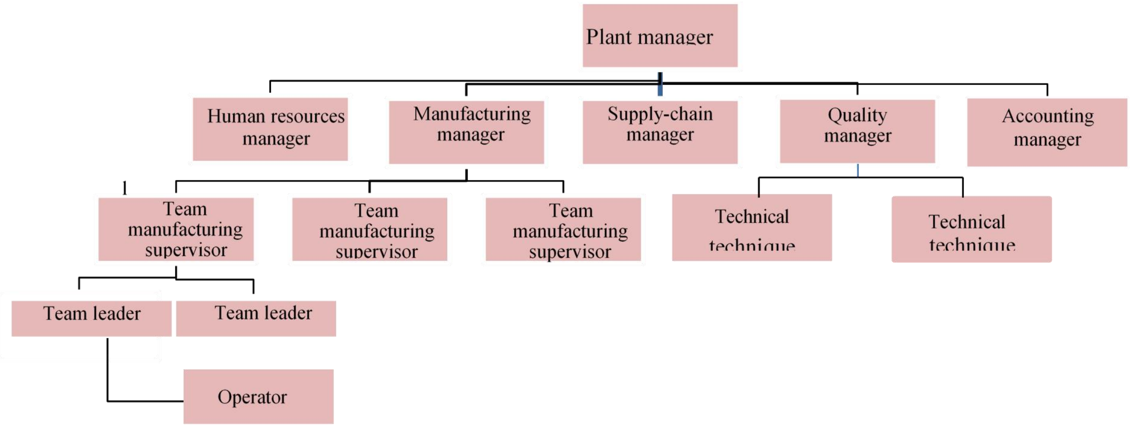


Figure 3. Useful time *versus* non-useful time
(adapted from Schneider Electric)



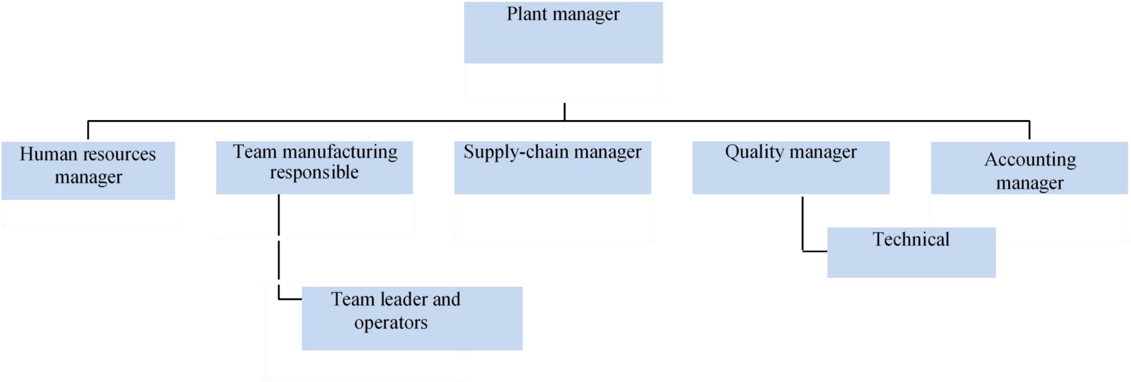
(adapted from Schneider Electric)

Figure 4. The various elements used to evaluate the real production time and its components



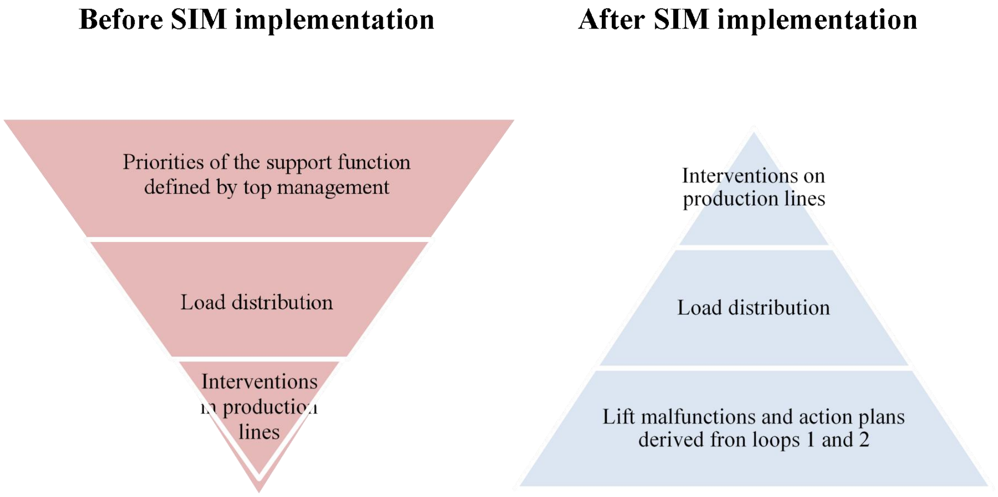
(adapted from Schneider Electric)

Figure 5. The hierarchical organization of a business unit before SIM implementation



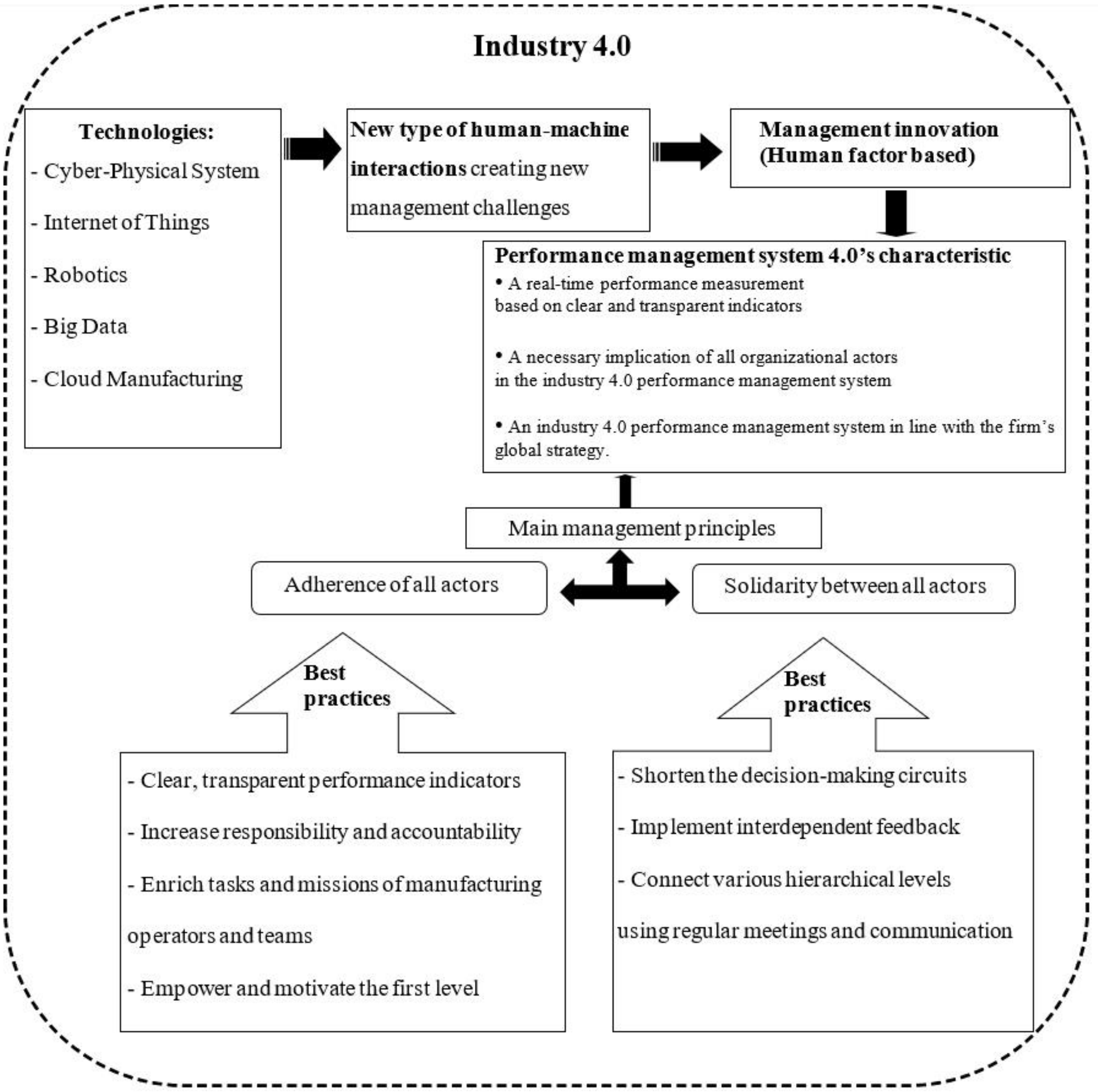
(adapted from Schneider Electric)

Figure 6. The hierarchical organization of a business unit after SIM implementation



(Source the authors)

Figure 7. Changes in the support departments' priorities as a consequence of SIM implementation



(Source the authors)

Figure 8. A framework for the successful implementation of a performance management system in the industry 4.0 environment.

Figure captions

Figure 1. The role of human factor in facilitating the implementation of Performance management systems 4.0

Figure 2. A representation of SIM.

Figure 3. Useful time versus non-useful time.

Figure 4. Evaluation of the production time and its components

Figure 5. The hierarchical organization of a business unit before SIM implementation.

Figure 6. The hierarchical organization of a business unit after SIM implementation.

Figure 7. Changes in the support departments' priorities as a consequence of the SIM implementation.

Figure 8. A framework for the successful implementation of a performance management system in the industry 4.0 environment.