

Manufacturing System and Enterprise Management for Industry 4.0

(Guest Editorial)

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INTRODUCTION

Industry 4.0 (I4.0) represents a significant step in the processes transformation in practically every industry, where the smart concept emerges in autonomous decisions and cyber-physical systems based production systems [1]. The role played by the usually referred technological pillars of I4.0 (such as internet of things (IoT), horizontal and vertical system integration, simulation, autonomous robots, big data and analytics, augmented reality, additive manufacturing, cloud computing and cybersecurity), based on technological advancements (mainly Information and Communications Technology (ICT)), in adhering to I4.0, are well known by the industry and academia (attending the huge number of research papers available), and have been implemented with more or less success. Notwithstanding the significant expected opportunities and impact of the fourth industrial revolution identified by researchers, experts are not convinced that the changes will be as significant as forecasted [2 - 4]. According to [5], only rare and recent attempts to understand the critical success factors of I4.0 implementation in manufacturing companies can be found in literature. A few recent studies reviewed in [5], point out that some of the critical factors are related to the management for I4.0. Cumulatively, the research in the field of management for I4.0, is still scarce, compared with the research on technologies for I4.0. The title of this Special Issue “Manufacturing System and Enterprise Management for Industry 4.0” is aligned with that concern and its content should be seen as a contribution to overcome management deficit problem of I4.0 implementation success. Nowadays, the challenges are related to the way how I4.0 is implemented and managed, in order to achieve the desired outcomes, economic, environmental, and social.

In the context of industry, where the profit is important within limited resources, the practice of the management is directly linked with the management of the production factors. In [6], factors of production are

defined as the resources required to produce economic goods. These are land (including all natural resources), labour (including all human work and skill), capital (including all machinery, tools and buildings) and the entrepreneurship. The number and definition of factors of production vary, depending on theoretical purpose, empirical emphasis, or school of economics [7]. However, there is a general consensus around these four principal factors. The type of investment and management of the production factors will influence the production efficiency [8].

For industry, the management for I4.0 should also be done over the factors of production, directly or indirectly, in order to improve their performance. The management of the factors of production in industry, is translated by the several domains of management that cover different functional areas. Some of these domains are related to: data management; project management; quality management; supply chain management; production management; human resources management; energy management; process management; product management; safety management; risk management; maintenance management; strategy management; materials management; education management; organizational management; sustainable management; information management and others. In the following section, these domains of management will be used to classify the main contributions of each paper of this Special Issue, in order to favour the understanding of its given contribution.

VOLUME'S CONTRIBUTION

In this section, we summarize and contextualize the contribution of the thirteen papers of this volume. The source of this Special Issue was through invitation to the authors of selected papers presented at the international conferences “9th International Conference on Business Sustainability – BS 2020” and “8th International Conference on Virtual and Networked Organizations Emergent Technologies and Tools – ViNORG'20”, both

held in December 02-04, 2020, in Guimarães, Portugal, in online mode, to submit extended version of the papers. All papers were evaluated independently through double blind review and after taking into consideration of the reviewers' comments and recommendations, the revised versions were submitted and after final evaluation the papers were accepted for inclusion in this Special Issue.

The papers' contributions focus on exploring a wide range of management methods, models, frameworks, and applications for I4.0, from an academic and industry perspective, but to be applied in the industry. The main focus and scientific contribution of the papers presented on this SI are mapped in the Table 1 (where '1st' refers to the first paper in this Special Issue, '2nd' refers to the second paper in this Special Issue, etc.), according to the management domain addressed by the particular paper. Some papers were classified as contributing to more than one domain, independently of the importance given to each one of them.

Table 1. Management domains addressed by papers

Management Domains	Papers	Number of Papers
Human Resources	1 st , 9 th , 10 th , 11 th , 12 th , 13 th	6
Organizational	1 st , 3 rd , 4 th , 5 th , 7 th	5
Education	11 th , 12 th , 13 th	3
Process	5 th , 9 th , 10 th	3
Production	5 th , 6 th , 8 th	3
Project	3 rd , 4 th , 5 th	3
Sustainability	1 st , 2 nd , 7 th	3
Quality	4 th , 7 th	2
Safety	8 th , 10 th	2
Strategy	2 nd	1
Risk	3 rd	1
Supply chain	4 th	1

As can be seen in the Table 1, in spite of this SI does not cover all the domains of management for I4.0, twelve management domains are addressed. Notwithstanding of the most domains of management discussed here being the Human Resources and the Organizational, it doesn't mean that these are more or less important than others. In fact, it is out of scope of this SI the assessment of that relative importance. Right after, follows a list of the main contribution of each paper of this Special Issue.

The first paper, "*Organizational Efficiency Prospects for Management in Industry 4.0*" by Pedro Pinheiro and Goran D. Putnik, assesses the possible benefits for the efficiency of the organizations resulting from the implementation of Industry 4.0. The effects on the hierarchical structures of organizations are estimated numerically, namely those related to specialization, authority, and span of control. The results show that technological advances and efficiency of industry 4.0, still do not respond satisfactorily to social needs and behaviour of the management. The main contributions of this paper, concerning the management domains, are in human resources, organizational, and sustainability.

The second paper, "*Classification of Sustainable Business Models: A Literature Review and a Map of*

Their Impact on the Sustainable Development Goals", by Eleonora Boffa and Antonio Maffei, presents the outcome of an extensive literature review based on a semantic approach that highlights the internal enablers and the most common application clusters for the Sustainable Business Models. Cumulatively the paper gives a further outcome showing how each Sustainable Business Models cluster impacts on each Sustainable Development Goals. The main contributions of this paper, concerning the management domains, are in sustainability and strategy.

The third paper, "*Applying Social Network Analysis to Support the Management of Cooperative Project's Behavioural Risks*", by Marco Nunes and António Abreu, proposes a model to contribute to the management of organizational cooperative networks, by addressing behavioural risks that usually emerge as organizations engage in cooperative networks to deliver projects. The model analyses how the four critical organizational cooperative informal networks (trust, problem-solving, advice, and communication), emerge and evolve throughout the different phases of a generic project lifecycle. The model was applied to a case study of a project for the initiating and planning phases and analysed how the four critical organizational cooperative informal networks evolved across the analysed period. The main contributions of this paper, concerning the management domains, are in organizational, project, and risk.

The fourth paper, "*Value Analysis as a Mechanism to Reduce the Complexity of the Selection of the Resources System for Agile/Virtual Enterprises in the Context of Industry 4.0*", by Paulo Ávila, António Pires, Goran D. Putnik, João Augusto S. Bastos and Maria Manuela Cruz-Cunha, presents a novel model, using Value Analysis in the phase of the pre-selection of resources, for the selection of the resources system for Agile/Virtual Enterprises. With a demonstrator tool developed by the authors, for a set of the problem formulations, the computational results validated the thesis regarding the benefits of the model proposed: Value Analysis reduces the complexity of the selection of the resources system process, in the context of I4.0 high connectivity level, even ensuring that the final system of resources achieve higher quality/value grade. The main contributions of this paper, concerning the management domains, are in organizational, project, quality, and supply-chain.

The fifth paper, "*Literature Review and Discussion on Collaborative Decision Making Approaches in Industry 4.0*", by Sousa A. C., Bertachini A. F., Cunha C., Chaves R. and Varela M. L. R., presents a literature review of decision making approaches that can be used in collaborative decision making approach, as a way of enabling better decision making processes in I4.0. This study identified the most used decision making approaches and concluded that during the last decade there was a predominance of studies of models based on Mathematics and Artificial Intelligence, when compared to models based on other approaches. Thus, confirming that Artificial Intelligence is one of the most relevant

pillars of the I4.0 under research and application. The main contributions of this paper, concerning the management domains, are in organizational, process, production, and project.

The sixth paper, *“How Environment Dynamics Affects Production Scheduling: Requirements for Development of Cyber-Physical Production Systems Models”*, by Cátia Alves, Goran D. Putnik and Leonilde Varela, presents the evaluation of how environment dynamics affects production scheduling, considering three scheduling models and three environment scenarios, through a case study. The results demonstrated that there is a positive correlation between environment dynamics and the total completion time with delay. The results obtained in this paper leads to the need of consideration the environment dynamics as a requirement in future Cyber-Physical Production Systems models developments, to deal with the disturbances by consideration of different scenarios. The main contribution of this paper, concerning the management domains, is in production.

The seventh paper, *“ISO 9001 Certification Benefits: A Principal Component Analysis”*, by Luis Fonseca, Maria Cristiana Cardoso, Maria Teresa Pereira, and Paulo Ávila, focuses on the benefits of the ISO 9001 adoption by the organizations. Through an extensive survey, three main categories of benefits were considered: operational improvement, profitability and, market. The study demonstrates that the ISO 9001 contributed to the improvement of learning processes and knowledge generation in the organizations; the increase of efficiency/productivity; and cohesiveness and standardization of the organization processes and subsequently quality achievements. Briefly, the authors address the challenges posed by the digital transformation, sustainability, and the emphasis on creativity and innovation as megatrends that are reshaping business landscape. The main contributions of this paper, in management domains, are in organizational, sustainability, and quality.

The eighth paper, *“Safety 4.0 for Collaborative Robotics in the Factories of the Future”*, by Luca Caruana and Emmanuel Francalanza, addresses the safety and security issues that should be take into account in the design and development of technological advanced manufacturing systems. The research presented in the paper take into account a structured procedure that foster safety and security features in designing ergonomic and collaborative manufacturing systems. The authors propose a design and development methodology to address issues of safety and security in the design and implementation of cyber-physical production systems for new Industry 4.0 collaborative environments. The main contributions of this paper, in management domains, are in production, and safety.

The ninth paper, *“Robust Assembly Sequence Generation in a Human-Robot Collaborative Workcell by Reinforcement Learning”*, by Dario Antonelli, Qingfei Zeng, Khurshid Aliev, Xuemei Liu, tackles the Human-Robot Collaborative (HRC) role in manufacturing cells. The adoption of advanced robotics

in the Industry 4.0 revolution, namely the HRC technology, poses practical challenges for the researchers and developers of these solutions. The paper authors address the practical requirements of robot programming simplification and the worker cognitive effort level during the manufacturing operations. The research approach is based in Reinforcement Learning (RL) designed to support a robust industrial assembly process in a HRC workcells. The developed solution is a method for the online collaborative generation of robot tasks sequence that adapts to the changing behaviour of the human workers. To test the robustness of the RL training, simulations and practical tests were executed resulting in interaction improvements between HRC and human workers. The main contributions of this paper, in management domains, are in human resources, and process.

The tenth paper, *“An Empirical Study of the Work Conditions and Productive Performance After Collaborative Robotics Implementation in a Manufacturing Assembly Process”*, by Ana Colim, Rita Morgado, José Dinis Carvalho and Nuno Sousa, focus on the collaborative robotics application in industrial scenarios, namely the physical implementation of Human-Robot Collaborations (HRC) solutions. In specifics, the paper describes the implementation of a collaborative robot in an assembly process. The authors description of the implementation case includes an impact analysis on performance and ergonomic work conditions of the labour force. As overall results, the research study results show a positive impact regarding ergonomics and production performance. The integration of the HRC robot supported the creation of workstations prepared for workers with physical limitations. In terms of material flow, the collaborative robot solution, resulted in a positive impact on the downstream manual operations with an increase in the overall performance. The main contributions of this paper, in management domains, are in human resources, process, and safety.

The eleventh paper, *“Academic Performance of Micro-Entrepreneurs in Business Training Programs: Evidence from the Application of an I4.0 Educational System During the COVID-19 Pandemic”*, by Julianna Ramirez Lozano, Kelly Rojas Valdez, Renato Peñafior Guerra, addresses the academic performance of an I4.0 educational system during the COVID-19 pandemic. Through surveys made to micro-entrepreneurs with little knowledge of digital technologies, the authors’ research showed that the students achieved a satisfactory academic performance. The study also showed that the students accomplished the objectives of the training program in business-related topics when using a set of i4.0 educational system tools based on IoT, cloud services, social networks and educational web services. The main contributions of this paper, in management domains, are in human resources, and education.

The twelfth paper, *“Application of the Industry 4.0 Technologies to Mobile Learning and Health Education Apps”*, by Nuno Mateus-Coelho, Maria Manuela Cruz-Cunha and Paulo Silva Ávila, introduce 31 of the

current state-of-the-art mobile health education applications and analyse the results of an inquiry to medical students and junior doctors during the confinement, designed to understanding their knowledge, use and trust regarding these apps. The results show that several applications are well perceived by their users and deserved their trust, confirming a good correlation between use and trust on the applications analysed. The main contributions of this paper, in management domains, are human resources, and education.

At last, the thirteenth paper, “*Specifications for a Digital Training Toolbox for Industry 4.0*”, by Emmanuel Francalanza, Jonathan Borg, Erwin Rauch, Goran Putnik, Cátia Alves, Magnus Lundgren and Catalin Amza, presents the finding of a study carried out to analyse the knowledge and skills gap, preferred learning methods and styles of trainers, for students in engineering. The requirements analysis has led to the conclusion that to appropriately address the I4.0 skills gap and mismatches, an open and digital training toolbox needs to be developed according to the specifications identified by the authors. The main contributions of this paper, in management domains, are human resources, and education.

CONCLUSION

Undertaking this special issue, addressing the management for I4.0, which contributes to sustainable outcomes, was a challenging and rewarding task for the Editors of this special issue. The diversity of the manuscripts demonstrates the broad scope of the present management for I4.0 discipline and of the available methods, models, frameworks, and applications to improve the success of I4.0 implementation and achieve sustainable outcomes.

At the end, the Guest Editors hope, and would like, that this Special Issue will be useful, meeting the expectations of the authors and wider readership and serving for enhancing the individual and collective learning, theoretical insight and practical applications, and to incentive further scientific development and creation of new research and technical papers.

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