The Transition Towards Industry 4.0: Business Opportunities and Expected Impacts for Suppliers and Manufacturers

Chiara Cimini(✉), Roberto Pinto, Giuditta Pezzotta, and Paolo Gaiardelli

Department of Management, Information and Production Engineering, University of Bergamo, via G. Marconi 5, 24044 Dalmine, BG, Italy
{chiara.cimini,roberto.pinto,giuditta.pezzotta, paolo.gaiardelli}@unibg.it

Abstract. Industry 4.0 is today one of the major opportunities for companies competing in the market. In last few years, more and more companies have started to define the path to move from their traditional production systems towards the Industry 4.0 paradigm; accordingly, different models have been proposed in literature to support the business transformation. This paper reviews the technological improvements proposed by Industry 4.0 to understand what are the main processes involved in the transformation and what are the suitable strategies to face the business and operational changes that are required. In particular, we identify and discuss two main perspectives: the suppliers and the customers. For both of them, different business opportunities are presented, and the expected performance improvements discussed.

Keywords: Industry 4.0 · Smart manufacturing · Business transformation

1 Introduction

The Industry 4.0 paradigm has opened high potentialities to implement new business and operational models. Many manufacturing companies around the world have been encouraged to invest in research and industrial projects to enable the realization of smart factories [1–3]. In this context, several technology providers have started offering products and product-service solutions (PSS) based on key enabling technologies that have achieved a stable and mature phase of their lifecycle, i.e. IoT for data acquisition and transfer, autonomous and collaborative robots, IT platforms for big data [4]. Despite this, many customers (i.e. manufacturing companies) are still restive to change their production processes to be Industry 4.0-compliant. There are several implementation barriers for smart manufacturing, not exclusively technology-related. The main issues refer to the business process transformation of manufacturers, and include, among others, organizational impacts and employees skills [5]. Further, some barriers depends on companies' business models and on their positioning in the supply chain.

H. Lödding et al. (Eds.): APMS 2017, Part I, IFIP AICT 513, pp. 119–126, 2017.
DOI: 10.1007/978-3-319-66923-6_14

The aim of this paper is to clarify what are the potentialities of implementing Industry 4.0 solutions in different contexts, discussing the potential business opportunities and benefits, and to provide a theoretical and practical contribution to the companies that are defining their path towards a smart manufacturing model.

2 The Vision of Industry 4.0

2.1 The Key Enabling Technologies

Different technologies have been classified as pillars for Industry 4.0 [6]. For example, a report from the Boston Consulting Group [7] identified nine key technologies that can support the smart transformation of an industrial production system.

A first class of technologies refers to autonomous robots and additive manufacturing, advanced "hardware" technologies based on innovative devices and equipment that support the automation of a production process. One of the main aspects regarding automation solutions is the shift towards collaboration, adaptability, and autonomy to react to external changes [8, 9], resulting in the implementation of Cyber-Physical Systems (CPS) that provide cognitive capabilities to physical assets [10].

A second class of technologies encompasses solutions for data management, acquisition, transformation, visualization, and integration [11]. In this class, we can identify technologies such as the (Industrial) Internet of Things (IoT) (the core technology for connecting objects and devices in manufacturing systems, allowing communication and cooperation [12]), big data analytics, cloud technology (along with cybersecurity solutions) [13], simulation and augmented reality that can be used in product and process design, production control, and optimization [14] using data coming from different sources.

These two classes of technologies allow the realization of horizontal and vertical integration [15]. Horizontal integration refers to the creation of a network enabling real-time communication among suppliers, manufacturers and final customers. Vertical integration involves the IT structure inside an enterprise enabling data exchange from the sensors/actuators level to the ERP level, in order to provide real-time decision-making and corrective actions from the business to the shopfloor.

Although technology represents one of the main aspects driving the transformation of traditional manufacturing companies, the introduction of innovative solutions has to be guided by strategic considerations about business opportunities from the introduction of Industry 4.0 principles. In the next paragraphs, a discussion of these business transformation opportunities is provided.

2.2 The Design Principles of Industry 4.0

Smart factories are characterized by the following features, or design principles, conceived to develop production processes aligned with the Industry 4.0 vision [16]:

- Interoperability. Horizontal and vertical integration among different systems require the creation of specific standards and protocols. Although some attempts of standardization have been made by the German *Plattform Industrie 4.0* with the Reference Architecture Model for Industry 4.0 [17], the definition of interoperability standards still represents an open research issue.

- Virtualization. In CPSs, each physical asset is characterized by a virtual counterpart that is used to perform simulation and optimization in a virtual environment [18].
- Decentralization. If changes occur along processes, distributed intelligence embedded in physical assets allows faster and more responsive corrective actions, facilitating decision-making processes, which can be managed at local level [19].
- Real-time capability. The IoT enables real-time information flows, with the possibility to achieve real-time optimization inside the processes [20].
- Service orientation. CPSs, together with cloud technologies, enable the implementation of service-oriented architectures (SOA), where computation capabilities can be accessed via the web, and process operations can be performed only when required by products through sensing technologies.
- Modularity. Advanced manufacturing solutions are conceived as modular, in order to be adapted to the different needs of the production. Reconfigurable Manufacturing Systems provide an example of a modular structure [21].

The abovementioned features suggest that Industry 4.0 does not influence production processes exclusively from a technological point of view. Business processes require also a change of perspective to fulfil horizontal and vertical integration. For this reason, a deeper insight about business transformation proposed by Industry 4.0 emerges as essential.

3 The Business Transformation of Industry 4.0

3.1 The New Paradigm of Collaborative Business Processes

To understand the business transformation that will involve the factories of the future, it is necessary to study in depth the changes in business processes, as proposed by the Industry 4.0 paradigm. The Industry 4.0 is a wide and global vision, involving the whole manufacturing environment, proposing new perspectives for business processes too. Thanks to the connectivity offered by IoT, a manufacturing process can be seen as one of the main elements of a more complex system (Fig. 1). Here, the factory is one of the crucial points for data generation, while data exchange is always bidirectional, making suppliers, customers, transportation systems and employees fully integrated and relevant for the optimization of the whole system. In such a context, the network of stakeholders, products and equipment, allows an end-to-end engineering integration along the value chain [22], while five value creation factors - products, processes, equipment, humans and organization - can be identified, and thus properly managed by companies to undertake the Industry 4.0 transformation.

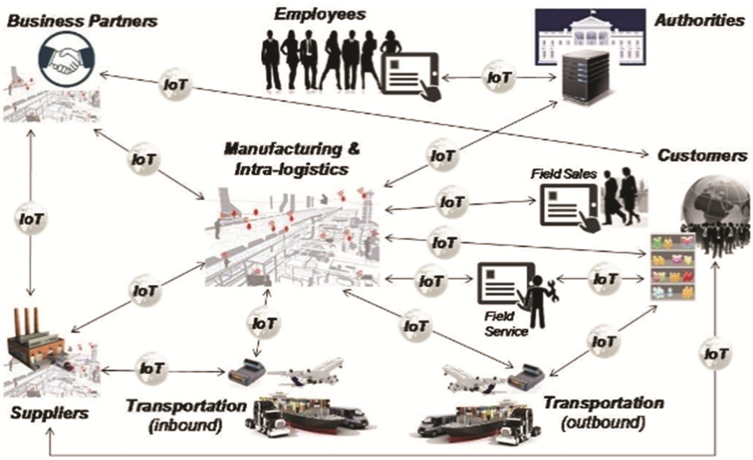

Fig. 1. Business scenario of Industry 4.0 [17]

Products become smarter, because they have embedded sensors and identification technologies [3]. They can do computations and communicate with the environment, providing their identity, state and properties [23]. To communicate with these smarter products, the equipment and the processes have to change. Indeed, the factory becomes conscious and intelligent enough to make decisions at decentralized levels and in real time about machines maintenance and production control [3]. Also the work organisation changes, moving to "human cyber-physical system", defined by [24] as a "system engineered to: (a) improve human abilities to dynamically interact with machines in the cyber- and physical- worlds by means of 'intelligent' human-machine interfaces, using human-computer interaction techniques designed to fit the operators' cognitive and physical needs, and (b) improve human physical-, sensing- and cognitive capabilities, by means of various enriched and enhanced technologies (e.g. using wearable devices)". Finally, relevant impacts at organizational level emerge. In particular, among the 68 competences identified as relevant for Industry 4.0 in [5], technological skills, mainly related to the use of data analysis and IT, as well as behavioural competences (i.e. teamwork, collaboration, negotiation), have cross relevance to succeed in an Industry 4.0 context. Further, an increasing importance is given to long-life learning and knowledge management, also regarding legislation and safety awareness.

3.2 Industry 4.0: A Model for Business Transformation

The main challenge faced by companies embarking upon an Industry 4.0 transformation refers to the alignment of their business strategy with the vision proposed by the smart manufacturing paradigm. This point, referred to as the "Envision" stage in [25], represents the first out of three steps characterising an Industry 4.0 transformation. It requires a deep understanding of the concepts at the basis of the Industry 4.0 paradigm, as well as a clear idea of the aims each company wants to achieve exploiting new technologies. For this reason, it mainly involves the management.

Also customers, suppliers and technology partners can take part in this stage due to their influence on business model configuration. This phase, which ends with an investment estimation, is followed by a second stage concerning the formulation of specific roadmaps to translate long-term strategies into practical areas of development. Readiness assessment models and maturity models [26, 27] play an important role in identifying companies' strength and weaknesses, and to understand the best development actions, according to the main organisational and business drivers characterising the Industry 4.0 environment where companies operate. Finally, during the "Enact" phase, a pilot project can be implemented in the company. Different opportunities can be envisioned, including either technological or organizational and infrastructure projects. A clear objective and a wide collaboration of all the involved stakeholders, with the composition of cross-functional teams, is needed to succeed. Only by identifying improvements and real advantages, it can be possible to extend pilot projects at large scale, transforming them into operational standards.

4 Different Perspectives on Business Transformation

The optimal path of business transformation towards Industry 4.0 is highly affected by different company's features and position in the supply chain. Suppliers, technology providers, and machines/equipment manufacturers (suppliers for short) can be characterised by sophisticated PSS business models, where the product offering is bundled with services, support, and knowledge [28]. Customers and users, instead, are usually manufacturing organisations using the technologies in their processes. Thus, suppliers embed the technology in their products-services, whereas the customers use the technology to make their processes more efficient and high-performing. Being the technology one of the main drivers for Industry 4.0 transformation, this differentiation strongly affects the opportunities that smart manufacturing introduction can bring to companies.

Also the other drivers of the transformation (e.g. product, processes, organization, governance) [26] can be related differently to the two perspectives of suppliers and customers. In addition, the expected impacts of Industry 4.0 in terms of measurable key performance indicators (KPIs) are not the same. While suppliers can benefit of major revenues for the increasing offering of digital solutions (made of services and products), customers can gain efficiency from a real-time controlled production, able to manage changes and predict failures and issues potentially generating downtimes or quality problems. All the aspects discussed above are presented in Table 1.

However, for the suppliers the transition towards Industry 4.0 is mainly supported by technological improvements, allowing them to develop their strategies through offering advanced PSSs. Here, the main challenges concern the acquisition of new technical competences, mainly to be used in R&D and IT departments. On the contrary, the most relevant business opportunities for customers involve operations management, for instance maintenance and quality practices or logistics issues. Also the workforce at the lowest level is involved, making the path to smart manufacturing more difficult [29], due to the complexity in acquiring technical competences about IT infrastructure and data management, coordinating actions among different departments, defining new practices in operations management, and estimating the return on investments.

Table 1. Suppliers and customers perspectives

	Business opportunities	KPI	Challenges
Suppliers	New digital business models	• Increasing of sales revenues from added services on products • New sales revenues from platforms and cloud-based services	• Privacy issues in sharing data with external stakeholders • Investment in integrated digital tools • Business partners not able to collaborate around digital solutions • Lack of digital skills in the workforce
	Digital engineering	• Reduced time to market, thanks to availability of integrated digital tools for product development • High level information from field for R&D improvements	
	Digital sales and marketing	• Better customer relationship with the possibility to offer personalized products/services	
Manufacturers	Vertical operations integration	• Faster decision-making • Improved quality, with real-time process control • Increasing of energy efficiency	• Investment in infrastructures for machines' connections • Cultural transformation to manage operations using digital technologies • Economic benefits and return on investment more difficult to estimate
	Horizontal integration	• Lower transport and logistics costs, due to real time supply chain optimization • Lower warehousing costs and spare parts management costs	
	Smart maintenance and service	• Preventive maintenance, thanks to real-time information from field • Increasing of asset utilization and availability	
	Digital workplace	• Better and faster training for operators • Increasing of productivity	

5 Conclusions

This paper presented an overview of the vision of Industry 4.0 in terms of key technologies and design principles. We illustrated the new paradigm of collaborative business processes to highlight its main impacts on traditional manufacturing. Discussing the point of view of suppliers and customers, it emerged that the former have to face more issues related to the transformation of operational processes, whereas the latter can benefit of the maturity of many key technologies that can be embedded in their products-services.

Such considerations call for the necessity to deeper investigate the different business opportunities of Industry 4.0 for suppliers and manufacturers, in order to provide proper advices about the design of path towards Industry 4.0, taking in consideration company-specific characteristics and requirements.

References

1. Thoben, K.-D., Wiesner, S., Wuest, T.: "Industrie 4.0" and smart manufacturing - a review of research issues and application examples. Int. J. Autom. Tech. **11**(1), 4–19 (2017)
2. Kang, H.S., Lee, J.Y., Choi, S., Kim, H., Park, J.H., Son, J.Y., Do Noh, S.: Smart manufacturing: past research, present findings, and future directions. Int. J. Prec. Eng. Manuf. Green Tech. **3**(1), 111–128 (2016)
3. Qin, J., Liu, Y., Grosvenor, R.A.: Categorical framework of manufacturing for industry 4.0 and beyond. Procedia CIRP **52**, 173–178 (2016). Newman, S., Nassehi, A. (eds.), Elsevier BV, Amsterdam
4. Geissbauer, R., Vedso, J., Schrauf, S.: Industry 4.0: Building the digital enterprise. Technical report, PricewaterhouseCoopers (2016)
5. Prifti, L., Knigge, M., Kienegger, H., Krcmar, H.: A competency model for "Industrie 4.0" employees. In: 13th International Conference on Wirtschaftsinformatik (WI 2017), St. Gallen, pp. 46–60 (2017)
6. Mittal, S., Khan, M., Wuest, T.: Smart manufacturing: characteristics and technologies. In: Harik, R., Rivest, L., Bernard, A., Eynard, B., Bouras, A., Bouras, A. (eds.) PLM 2016. IFIPAICT, vol. 492, pp. 539–548. Springer, Cham (2016)
7. Rüssmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., Harnish, M.: Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. Technical report. The Boston Consulting Group (2015)
8. Chaplin, J.C., Bakker, O.J., de Silva, L., Sanderson, D., Kelly, E., Logan, B., Ratchev, S.M.: Evolvable assembly systems: a distributed architecture for intelligent manufacturing. IFAC-Pap.OnLine **48**(3), 2065–2070 (2015). Dolgui, A., Sasiadek, J., Zaremba, M. (eds.)
9. Park, H.S.: From automation to autonomy-a new trend for smart manufacturing. In: DAAAM International Scientific Book, vol. 3, pp. 75–110 (2013)
10. Lee, J., Ardakani, H.D., Yang, S., Bagheri, B.: Industrial big data analytics and cyber-physical systems for future maintenance & service innovation. Procedia CIRP **38**, 3–7 (2015). Erkoyuncu, J.A., Tapoglou, N., Tomiyama, T., Tiwari, A., Mehnen, J., Roy, R., Tracht, K., Shehab, E. (eds.), Elsevier BV, Amsterdam
11. Khan, A., Turowski, K.: A survey of current challenges in manufacturing industry and preparation for industry 4.0. In: Abraham, A., Kovalev, S., Tarassov, V., Snášel, V. (eds.) IITI 2016. AISC, vol. 450, pp. 15–26. Springer, Heidelberg (2016)
12. Da Xu, L., He, W., Li, S.: Internet of things in industries: a survey. IEEE Trans. Ind. Inf. **10**(4), 2233–2243 (2014)
13. Brodsky, A., Krishnamoorthy, M., Menascé, D.A., Shao, G., Rachuri, S.: Toward smart manufacturing using decision analytics. In: Chang, W., Huan, J., Cercone, N., Pyne, S., Honavar, V., Lin, J., Hu, X.T., Aggarwal, C., Mobasher, B., Pei, J., Nambiar, R. (eds.) 2014 IEEE International Conference on Big Data, pp. 967–977 (2014)

14. Tolio, T., Sacco, M., Terkaj, W., Urgo, M.: Virtual factory: an integrated framework for manufacturing systems design and analysis. Procedia CIRP **7**, 25–30 (2013). Elsevier BV, Amsterdam
15. Kagermann, H., Wahlster, W., Johannes, H.: Recommendations for implementing the strategic initiative Industrie 4.0. Technical report. Industry-Science Research Alliance (2013)
16. Hermann, M., Pentek, T., Otto, B.: Design principles for industrie 4.0 scenarios. In: Sprague, R.H., Bui, T.X. (eds.) 49th Hawaii International Conference on Competitive Manufacturing 49th Annual Hawaii International Conference on System Sciences, HICSS 2016, pp. 3928–3937 (2016)
17. VDI/VDE, ZVEI: Reference Architecture Model Industrie 4.0 (RAMI4.0) (2015)
18. Lee, J., Bagheri, B., Kao, H.A.: Recent advances and trends of cyber-physical systems and big data analytics in industrial informatics. In: International Proceeding of Int Conference on Industrial Informatics (INDIN), pp. 1–6 (2014)
19. Schoenthaler, F., Augenstein, D., Karle, T.: Design and governance of collaborative business processes in industry 4.0. In: Proceedings of the Workshop on Cross-Organizational and Cross-Company BPM (XOC-BPM) Co-located with the 17th IEEE Conference on Business Informatics (CBI 2015), Lisbon, vol. 13, pp. 1–8 (2015)
20. Hu, H., Wen, Y., Chua, T.S., Li, X.: Toward scalable systems for big data analytics: a technology tutorial. IEEE Access **2**, 652–687 (2014)
21. Koren, Y., Shpitalni, M.: Design of reconfigurable manufacturing systems. J. Manuf. Syst. **29**(4), 130–141 (2010)
22. Stock, T., Seliger, G.: Opportunities of sustainable manufacturing in Industry 4.0. Procedia CIRP **40**, 536–541 (2016). Elsevier BV, Amsterdam
23. Schmidt, R., Möhring, M., Härting, R.C., Reichstein, C., Neumaier, P., Jozinović, P.: Industry 4.0-potentials for creating smart products: empirical research results. In: Abramowicz, W. (ed.) BIS 2015, vol. 208, pp. 16–27. Springer International Publishing, Heidelberg (2015)
24. Romero, D., Bernus, P., Noran, O., Stahre, J., Fast-Berglund, Å.: The operator 4.0: human cyber-physical systems & adaptive automation towards human-automation symbiosis work systems. In: Naas, I., Vendrametto, O., Reis, J.M., Goncalves, R.F., Silva, M.T., Kiritsis, D., von Cieminski, G. (eds.) APMS 2016. IFIPAICT, vol. 488, pp. 677–686. Springer, Cham (2016)
25. Erol, S., Schumacher, A., Sihn, W.: Strategic guidance towards industry 4.0–a three-stage process model. In: 2016 International Conference on Competitive Manufacturing (2016)
26. Schumacher, A., Erol, S., Sihn, W.: A maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises. In: Newman, S., Nassehi, A. (eds.) Procedia CIRP, vol. 52, pp. 161–166. Elsevier BV, Amsterdam (2016)
27. Rockwell Automation: The Connected Enterprise Maturity Model. Technical report (2014)
28. Baines, T.S., Lightfoot, H.W., Benedettini, O., Kay, J.M.: The servitization of manufacturing: a review of literature and reflection on future challenges. J. Manuf. Technol. Manage. **20**(5), 547–567 (2009)
29. Bauer, H., Baur, C., Mohr, D., Tschiesner, A., Weskamp, T., Alicke, K., Wee, D.: Industry 4.0 after the initial hype-where manufacturers are finding value and how they can best capture it. Technical report. McKinsey Global Survey (2016)