Industry 4.0 revolution: state-of-the-art of the Italian manufacturing context

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Abstract: Higher global competition and more complex customer demands pushes manufacturers to provide value-added products to the market in a faster and more reliable way. Companies can exploit the outstanding improvements in digital technologies whose adoption has brought to the so-called "Industry 4.0" (I4.0) revolution. Indeed, technologies such as Additive Manufacturing (AM), Industrial Internet of Things (IIoT), Big Data & Advanced Analytics, Virtual & Augmented Reality and Cloud Manufacturing are transforming companies into smart enterprises characterized by the interconnection of processes and assets. Though the adoption of technologies and the benefits related to this new paradigm has been quite debated in the literature, it seems that no study has been conducted regarding the adoption level of Industry 4.0 principles in Italy. This article shows the results of an exploratory survey, in which a sample of 105 companies has been involved, covering the most important manufacturing sectors. The main objective of this study is the provision of a state-of-the-art review on how the Italian manufacturing enterprises are involved in the I4.0 journey. Except for IIoT and AM, our findings indicate that Italian manufacturing companies have a limited knowledge for I4.0 enabling technologies. The survey results also revealed that the medium and large companies, characterized by a high level of automation and computerization capability, tend to be much more incline to adopt I4.0 paradigm and related technologies. In the next future, by adopting the same methodology, we will extend the boundaries of the research involving companies of other countries, in order to highlight contingent differences compared to Italy.

Keywords: Industry 4.0, Digital technologies, Digital competencies, Survey

1. Introduction

In recent years, the manufacturing context has been characterized by several phenomena such as the increase in competition among companies in worldwide range and the growing complexity of customer demands (Bozarth et al. 2009; Vogel and Lasch, 2016; Tang et al. 2017). As a response, manufacturing companies struggle for creating value through, on the one hand, lead time and time-to-market reduction, and on the other hand, product availability and reliability enhancement (Kurilova-Palisaitiene et al. 2018; Hirsch-Kreinsen, 2016). Because of these trends, several initiatives raised by both highly industrialized countries and emerging economies, such as 'Industrie 4.0' by Germany, 'Manufacturing USA' by United States and 'Made in China 2025' by China. All these initiatives have been developed integrating Information & Communication technologies (ICT) with some operational ones (OT) to facilitate the connection among humans, machines, products in an intelligent way for the purpose of satisfying customized demands (Zhou et al. 2016; Chen, 2017; Li, 2017). Besides manufacturing processes, the application of digital technologies may have impact on other aspects related to the enterprises, such as supply chains organization (Vendrell-Herrero et al. 2016), logistics processes (Strandhagen et al. 2017), business strategies (Butner and Lubowe, 2015), advanced services provision (Ardolino et al. 2017) and sustainability (Bressanelli et al. 2018). Such literatures have shown that a wide range of sectors has been impacted by I4.0 paradigm, and the common attribute is that this smart ecosystem is fuelled by technology enablers (Almada-Lobo, 2015). Tentative on investigation of specific technology application has no doubt deepen the technological knowledge, while it seems that a global perspective is missing, especially from a national point of view. More concretely, the literature lacks an overall empirical study within national level, in order to get a general review of how I4.0 is adopted and implemented in manufacturing enterprises. This paper is aimed at investigating the adoption level of Industry 4.0 paradigm, trying to provide a state-of-the-art review on how Italian manufacturing practitioners are involved in the I4.0 paradigm. The rest of paper is structured as follows: Section 2 presents the research background. Section 3 describes the proposed research approach, and corresponded results will be shown in Section 4. Section 5 draws conclusions and Section 6 indicates the future prospective of this topic, both for researchers and practitioners.

2. Research background

2.1 Industry 4.0

Over the years, worldwide manufacturing context has been characterized by disrupting breakthroughs leading to radical changes in production and related processes. The advent of steam machine brought to the first industrial revolution in 1700's with the usage of steam power as a source for moving old-fashioned machines. The second revolution was along with the electricity bringing the diffusion of faster means of transport. Coming to the third industrial revolution, computer-aided engineering becomes the main enabler off the so-called 'flexible automation' that is the ability for a system to be quickly and easily re-tasked. Nowadays, the fourth industrial revolution refers to a further evolution, combining both IT and OT technologies applied to the whole value chain through the diffusion of internet. The fourth industrial revolution is generally referred also with the term 'Industry 4.0', proposed at Hannover fair in 2011. The reason why every economy is moving toward 4.0 era, is that Industry 4.0 may act as a lever for manufacturing revival, especially for those industrialized countries. Catching up the opportunity of transforming manufacturing from "traditional" towards 4.0 paradigm, for both enterprises and countries, could be an important benefit because of the increase in profits and revenue flows in parallel with lower operational expenditures and a more sustainable health and safety manufacturing development (Gilchrist, 2016)

2.2 Industry 4.0 enabling technology

A variety of I4.0 enabling technologies has been investigated in the literature. According to a literature analysis conducted by the authors, six main I4.0 technologies emerge: Industrial Internet of Things (IIoT), Additive Manufacturing (AM), Big Data & Advanced Analytics, Virtual & Augmented Reality, Cloud Manufacturing and Collaborative Robotics.

Table 1: Summary of I4.0 enabling technologies

Name	Description	References
Industrial Internet of Things (IIoT)	A dynamic global information network created by embedding smart electronics in industrial environment	Ungurean et al. 2016; Zhang et al. 2017; Atzori et al. 2010; Wollschlaeger et al. 2017;
Additive manufacturing (AM)	Process of joining materials in successive layers to make objects from 3D model data	Holmström et al. 2010; Petrovic et al. 2010; Mellor et al. 2014
Big Data & Advanced Analytics	Storage and analysis of large and or complex datasets using a series of techniques include statistical models and other empirical methods that are aimed at creating empirical prediction	Shmueli and Koppius, 2011; Matthias et al. 2017; Ward and Barker. 2013
Virtual & Augmented Reality	The natural extension of 3D graphics with advanced input and output devices	Mujber et al. 2004 Azuma, 1997; Regenbrecht et al. 2005; Ilic and Fleisch, 2016
Cloud Manufacturing	A new manufacturing paradigm developed under the support of cloud computing, IoT and virtualization	Tao F et al. 2011; Xu, 2012
Collaborative Robotics	A system which intends to physically interact with human and machine operating in a shared learning environment cooperatively	Gleeson et al. 2013; Cherubini et al. 2016; Rozo et al. 2016; Maurice et al. 2017

Attempts on integrating AM in supply chain design have been demonstrated by (Petrovic et al. 2010) and (Ashour Pour et al. 2017). Furthermore, (Evans et al. 2011) and (Tao et al. 2011) discussed the use of Cloud Manufacturing and IoT as enablers for enterprise's service update. Notwithstanding, many enterprises still struggle to benefit from technology applications and they find difficulties in understanding the real benefits of I4.0 paradigm (Sanders et al. 2016).

2.3 I4.0 application in different countries

Due to historical, political and geographical characteristics, different countries have their own manufacturing pattern. In order to benefit from I4.0, several governmental institutions have started to study and evaluate the way through which promote this new paradigm. The very recent literature provides a few contributions concerning the implementation of I4.0 in different countries. For example, there are studies concerning the adoption level of digital technologies in Czech Republic (Basl, 2017) and Croatia (Veza et al. 2016). Moreover, (Jäger et al. 2016) focus on the German Rhine-Neckar Region trying to understand how the enterprises are familiar with I4.0. (Beier et al. 2017) debate about the changes that digitalization is expected to bring by comparing a highly industrialized (Germany) with an emerging (China) industrial economy. There are also some contributions aimed at understanding the development of I4.0 in non-European countries, such as the study by (Tortorella and Fetterman, 2017), who examine the Brazilian manufacturing context. There are also further studies focusing on the identification of the necessary skills and expertise to be developed in young workers to be ready for the I4.0 framework (Motyl et al. 2017). However, it seems that little research focus is put on the technology-related aspects, such as the corresponded benefits, obstacles and current adoption level in the enterprises. In particular, much less attention has been received by Italy. The only exception is the study by (Rauch et al. 2017), but they only investigate a small region in the North of Italy focusing on the relationships between 4.0 paradigm and the practices of lean product development.

3. Objectives and Methodology

3.1 Research objective and questions

Our study targets Italian manufacturing enterprises wondering how they are facing I4.0 paradigm, the main benefits achieved and the challenges faced.

For reaching the above mentioned objective, we carried out a survey that involved 105 Italian manufacturing enterprises. The study was conducted in order to answer 4 main research questions:

- Q1: How do enterprises know the digital technologies that are enabling the I4.0 paradigm?
- Q2: How many enterprises are already adopting the digital technologies? And which business functions are affected?
- Q3: What are the expected benefits from their adoption?

- Q4: What are the main challenges and obstacles in adopting these technologies?

3.2 Survey design and data collection

3.2.1 Sample unit

The unit of analysis in this survey refers to the Italian manufacturing enterprises and Italian sites of multinational corporations. This research involves all types of companies, with no limits concerning their size (micro, small, medium and large companies are considered) and industrial sector. The diversity of sample selection is favourable in this exploratory survey because the main aim is to provide new insights on the phenomenon (Forza, 2002).

3.2.2 Data collection method

The survey was carried out from October 2016 to May 2017. The survey submission protocol provided to contact specific respondents: for each company a list of 2 or more respondents related to different business areas has been proposed and prioritized. Employees belonging to the R&D department, General Management and Executives, IT Systems and Production have been mainly involved. Considering the modular structure of the survey, coherently to the aims of the research, each company had the opportunity to involve different people to fill in the different sections at the same time, according to the specific competences. In total, 146 respondents were involved for the 105 collected questionnaires. The analysis of the business areas to which belong the respondents shed light on the most involved roles that fill in the questionnaire: CIO filled in the 37% of the sections, followed by R&D Director that provided the 19% of the responses. Production and Operations manager represents the 18% of surveyed people, while in the 14% of the cases are the General managers to give the answers. The remaining 11% is related to other functions & roles, such as Technical department and Chief Digital Officer.

3.2.3 Sample description

Sample description is represented in Table 2. Overall, a sufficient heterogeneous classification has been achieved, since more than 50% of the sample is represented by SMEs, and the others are large and very large enterprises. Moreover, different manufacturing sectors have been included. Most of our surveyed samples are from northern-Italy area (94%).

Table 2: Sample classification

Enterprise size	**Number**	**Percentage**	**Classification Criteria**
Small-Medium	59	56.2%	Revenue < 50 mln euro
Large	29	27.6%	50 mln euro < Revenue < 300 mln euro
Very large	17	16.2%	Revenue > 300 mln euro
Industrial Sector	**Number**	**Percentage**	**Classification Criteria**
Machinery	37	35.2%	NACE 28
Metal product	17	16.2%	NACE 25
Electrical equipment	14	13.3%	NACE 26/27
Metals	10	10.5%	NACE 24
Automotive	7	6.7%	NACE 29
Other industrial manufacturer	6	5.7%	NACE 32
Others	13	12.4%	Other

3.2.4 Questionnaire structure

A questionnaire with mixed open and closed questions has been sent to companies through web survey technique. The questionnaire was structured in 10 sections, as described in the following table.

Table 3: Questionnaire structure

Sec. 1	General information of respondent
Sec. 2	General information of enterprise Pre-technological requirements
Sec. 3	Business strategy for I4.0
Sec. 4-9	State-of-art of six main I4.0 enabled technologies
Sec. 10	Analysis of national industrial plan impacts

4. Results

In this section, survey result is shown respectively in 5 paragraphs by responding the research questions proposed in 3.1.

4.1 Knowledge level for I4.0 enabling technologies

The first set of questions aimed at understanding the knowledge level of the six investigated technologies. Figure 1. shows the company's knowledge level for each I4.0 enabling technology. Four-scaled classification is adopted to represent the results, which are 'no knowledge', 'superficial knowledge', 'medium knowledge' and 'profound knowledge'. 'No knowledge' implies that the enterprise is not aware of it; 'superficial knowledge' means that only the general application field of the technology has been gained by the company; 'medium knowledge' indicates that the enterprise has reviewed the state-of-the-art and understand the potential benefits of it, but still not entering into specific application. 'profound knowledge" means that the enterprise holds a deep knowledge of technology and has already evaluate all the benefits and costs of it.

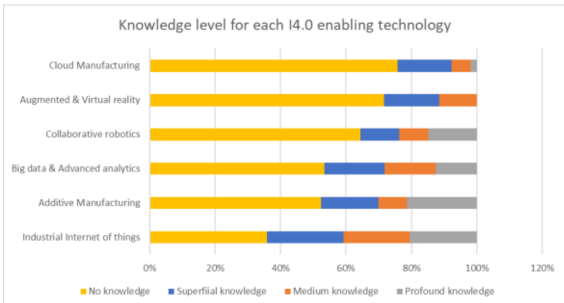

Figure 1. Knowledge level of I4.0 enabling technology

According to Figure 1., respondents are shown to have an overall limited knowledge level for surveyed technologies. Industrial Internet of Things (IIoT) is the only technology known at least basically by more than half of the sample (64%). Indeed, Collaborative Robotics, Augmented & Virtual Reality and Cloud Manufacturing have been received far less attention. 65% of respondents claimed to have no idea of basic principles of Collaborative Robotics, while 70% don't even know what are Augmented & Virtual Reality and Cloud Manufacturing. The fact that many enterprises declared to have knowledge on IIoT is not difficult to understand, since IIoT is the pillar technology for I4.0, and also widely spread. Additive Manufacturing is also shown to be recognized by almost half of surveyed sample, also more than 20% argued to have a profound knowledge. Due to the upgrade of material and technology, its application field is enlarged. As regards Augmented & Virtual Reality, application in the field is still real limited. At the same time, technology such as Cloud Manufacturing, is still in its initial phase and enterprises are consequently missing knowledge is easy to foresee.

4.2 I4.0 technology utilization level and involved business functions

The result of this set of questions is to answer to which extent the Italian manufacturing enterprises are adopting the six classified technologies, and what are the corresponded internal business functions effected. Figure 2 shows the technology adoption level divided in 4 categories, which are 'no knowledge' 'no action', 'preliminary study' and 'technology in use'. 'No knowledge' means that the enterprise does not know the technology; 'No action' means that the enterprise has not taken any measures although they know the technology; 'Preliminary study' indicates that the enterprise is activating related project by evaluating its technical-economic feasibility; 'Technology in use' means that the enterprise has already launched technology enabled projects.

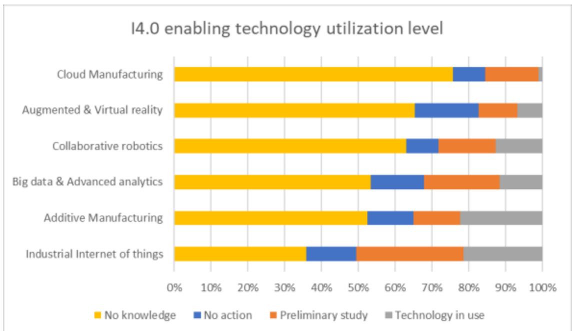

Figure 2. I4.0 enabling technology utilization level

According to Figure 2., AM is the most used technology, adopted by the 22% of surveyed sample, slightly higher than IIoT, which is 21%. The utilization level of technology is slightly different from the knowledge level mentioned in first part, where IIoT is the mostly recognized. Result of adoption level for Big data & Advanced analytics and Collaborative Robotics are coherent with the results for enterprise's knowledge level, which are 12% and 13% respectively, indicating a low implementation rate. In addition, no concrete project enabled by Cloud Manufacturing is activated up to date, even if there are some enterprises stating to have knowledge on it. Furthermore, a specific investigation on the business areas impacted by technologies has been conducted, aimed at understanding whether digital transformation is uniformly related to all business functions, or more related to some of them. Results are shown in Figure 3.

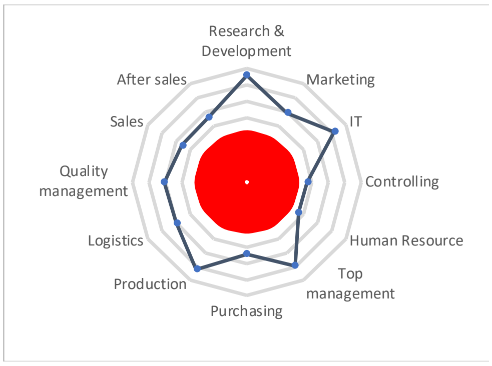

Figure 3. Involvement level of business functions

Research & Development, Production and IT seem to be the most impacted areas by I4.0 technologies. R&D is generally considered with the function of stepping in the frontier of most innovative technologies. It is evident that when the enterprise is facing such digital transformation, R&D firstly get in touch with it, and take the role of understanding and testing possible solutions, especially in the case of non-fully matured technologies. In addition, we can't neglect the production, where most of the technologies are implemented, sometimes after some pilot test in the R&D area. Furthermore, it is not surprising to see that IT is another most impacted area. This is due to the role of IT which facilitates the utilization of new technologies in other business areas of the company. Moreover, the survey results highlight a significant impact of digital technologies by top management, since it plays the primary role for leading other departments. Besides, purchasing, logistics, quality management, marketing, sales and after-sales service functions are less involved than expected. Therefore, it is quite reasonable to state that such application is not considered by companies yet.

4.3 Expected benefits from I4.0 technology

The third set of questions aimed at evaluating the advantages related to the introduction of novel technologies. For each technology, each respondent has been asked to define the type of expected benefits, namely: 'quality improvement', 'time reduction', 'minimized cost' and 'flexibility'. Any possible improvement in product aesthetics, function, performance (e.g. reliability, durability, compliance rate), is considered as quality-related benefit; 'Time reduction' mostly refers to the reduction of time-to-market. cost reduction contains reducing raw material cost, production waste, non-conformity rate and energy consumption. Lastly, 'flexibility' indicates a more agile and quick capability. Figure 4. shows which are the generally desired benefits by enterprises. Only respondents who have at least superficial knowledge on technologies are considered as surveyed sample here. The result shows that 'quality improvement' is the primary expected benefit stated by the 38% of the sample. And flexibility is the less appealing benefit concerning the adoption of I4.0 technologies. This result highlights that Italian manufacturing enterprises are more likely to be focused on developing high quality product. Indeed, thanks to the capability of intercepting customer's demand, they are more sensitive to understand the needs of the market.

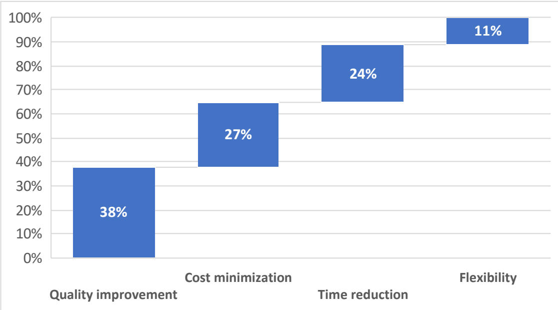

Figure 4. Expected benefits from I4.0 technology

4.4 Obstacles for implementing technology

This section introduces which are the obstacles according to the enterprise for applying I4.0 technologies. We classified these inhibitory factors into four groups, namely: 'Limited technology development', 'Absence of specialized provider', 'Difficulty of obtaining internal competency', 'High investment on equipment'. Figure 6 shows the surveyed result. 38% of the respondent state that limited/immature technology development is the biggest barrier for practical adoption. This result is coherent with the fact that enterprises confessed to have limited knowledge on new technologies. Then, the absence of internal competencies is the second barrier.

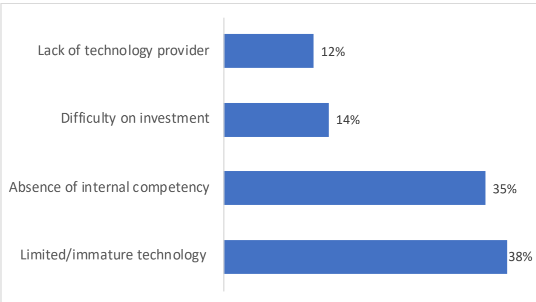

Figure 5. Obstacles for technology implementation

Since the percentage of immature technology development is high, it is worth discussing more in deep for this positioning. Generally, when the enterprises face with new technologies that they are not so familiar with, they tend to believe to be too anticipated to make investment on it. Indeed, if the enterprise misunderstands the technology evolution track, a superficial understanding will be formulated, and consequently, they will lose potential opportunity to become new technology adopter. In other words, until the practical benefits could be touched, companies won't feel the need to utilize it. This fact is also correlated to the second element of obstacle, which is the absence of competency. It is reasonable that without competitive person to evaluate available technological opportunities in the market, there is risk not to be able to identify appropriately the intervention for new technologies. Moreover, missing of competency exists not only in final technology user, but also in technology providers, who are unable to provide dedicated offering effectively.

5. Discussion and Conclusion

In this current research, we conducted a state-of-art review, addressing how I4.0 paradigm impacts on Italian manufacturing enterprises, trying to explore which are the desired benefits and the barriers they are facing with. Our finding shows firstly a scarce knowledge for I4.0 enabling technology by Italian manufacturing enterprises, except for IIoT known at least superficially by 64%. This result is quite aligned with (Basl et al. 2017), who indicates a 75% 'little awareness' of I4.0 technologies for manufacturing enterprise in Czech Republic. Moreover, in the investigation of (Veza et al. 2016) for Croatian manufacturing enterprise, an even non-optimistic result is given, since the average industry maturity level lies in the state of 2nd industrial generation. Scarce knowledge regards both technical and organizational aspects. Moreover, some companies are behaving much better respect to the others due to their existed higher informatized system and novel business strategy. Moving forward I4.0 enabling technology utilization level, due to the restriction of scant knowledge base, it is reasonable to foresee a low implementation level, and the investigation result has also proved our prediction, where the most utilized technology, AM, only occupies 21% of surveyed sample, IIOT, occupies 20%, and other technologies are implemented with lower frequency. It reveals that companies seem to be not so confident about those technologies, which are not widely adopted in the market. We also try to map the relationship between technology and single business functions, focusing our effort on giving a more purposeful understanding from organizational structure point of view in respect with existed contributions in the literature (e.g. Gambardella et al. 2010; Bharadwaj et al. 2013). Coherently with them, R&D, IT, Production and Top management are demonstrated to be the top involved areas. Concerning desired benefits, quality improvement is the most seeked advantage, since Italian manufacturing enterprises still want to attract customers through high value-added products and services, more than with low-cost strategies. Even though continuous improvement on quality could be the objective of digital technology implementation, missing a systematic understanding of technology becomes a potential risk, which may lead to an inappropriate assessment of technology track, as shown in our result as the biggest obstacle considered by the enterprise. Industry 4.0 is not only a nominally revolution concept, but a multidimensional integration of technical, organizational and strategical aspects. Knowing that the desire for providing highly customized product with excellent quality is most valued by Italian manufacturing companies, acquiring competences for I4.0 transformation becomes undoubtedly essential.

6. Limitations and future research

Our research assessed how the Italian manufacturing enterprise is positioned in the I4.0 journey. As any research, also this one comes with some limitations. First, although the Italian manufacturing context is characterized by a high percentage of SMEs, no specific investigation has been designed for this group. Then the second limitation is that, in spite of the complete review we have conducted, no reference model/framework is proposed. Attempt on providing set of roles for I4.0 paradigm from managerial aspect has been taken as the first step, but it still requires a more comprehensive and systematic approach as guideline/benchmark, in order to support Italian manufacturing enterprises speeding up their I4.0 transformation. Indeed, due to the limited sample number in this study, further sampling is required to establish a complete analysis of the state. First of all, in Italy, but as a second step, also in other countries, in order to have a comparison and more robust understanding of the context (Kull, 2014). Moreover, focus study on pilot I4.0 practitioners will be conducted to capture the root cause of successful case. It is expected to dedicate effort on developing both managerial and practical reference, helping Italian manufacturing enterprise consolidate and strengthen its position in global competitive market.

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