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The Interconnections Between ICT, Industry 4.0 and Agile Manufacturing

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Abstract
Technological progress is the driving force behind industrial development. It is a multi-dimensional and multi-level phenomenon. In this article we focus on its three manifestations: information and communication technologies (ICT), Industry 4.0 and agile manufacturing. The aim of this article is to analyse the relationship between these constructs as they are undoubtedly interrelated. ICT plays a key role, but it is not a goal itself. They are a prerequisite for the implementation of Industry 4.0, but together with it they serve to achieve agility by the manufacturing system and, as a result, achieve a competitive advantage by companies operating in turbulent and unpredictable environment. The literature findings in this paper are part of a broader study conducted on the impact of ICT on agility of SMEs operating in India. Therefore, we include also subsections showing the level of this relationship in Indian SMEs.

Keywords
Information Communication Technology (ICT), Agile Manufacturing (AM), Lean Production, Industry 4.0, Small and medium size enterprise (SME).

Introduction

Agile manufacturing acknowledges the market uncertainty and aims to boost the production capabilities and competitiveness of the firm in order to meet the fluctuating customer needs. Agile methods are especially beneficial in achieving customer satisfaction and cost reduction for many organizations. In order to produce innovative and robust new products that meet customer expectations, it is imperative for enterprises to adopt technological improvements in their manufacturing process. Agility has emerged as a critical business requirement for firms to remain competitive and innovative (Teece et al., 2016). While technology is considered to be a crucial factor in enriching the agile aspects of an enterprise and plays a key role in enhancing the firm's agility. It has been noticed that ICT adaptation effects the productivity either directly or indirectly in a positive way. Its impact is phenomenal in terms of economic growth and performance for the firm. The ICT infrastructure in SMEs can ensure efficient internal communication and service quality, on-time delivery of better services, as well as provide better opportunities to integrate their services at local and international platforms. The development of ICT has led to the concept of Industry 4.0 that is one of the most widely discussed manufacturing subjects among the industry and academia around the world, and it is also regarded as the fourth industrial revolution, which will have a significant impact on manufacturing in the future (Kagermann et al., 2013). While agile manufacturing and the concept of Industry 4.0 both sets the direction for the development of manufacturing systems. The essence of agile manufacturing is the ability to response quickly for created and recognized market opportunities that appier in turbulent business environments, (Trzcielinski, 2021; Trzcielinski, 2017).

Previous studies have shown a small but optimistic effect of Industry 4.0 on operating efficiency of firms including SMEs, despite of little investment and expertise in cloud computing (Radziwon et al., 2014). However, as it is just the start of Industry 4.0 era, its real benefits and implications for SMEs are yet to be realised.

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The question that arises is whether improved efficiency is the result of companies being introduced on the path of Industry 4.0 or whether it is the result of increased agility of the company.

The aim of this article is to analyse the relationships between ICT, Industry 4.0 and Agile Manufacturing, as they are undoubtedly interrelated. ICT determines both the implementation of solutions specific to Industry 4.0 and agile manufacturing. ICT plays a key role, but at the same time it is ancillary to agile manufacturing. Their development is not a goal in itself. Ultimately, it is about making companies competitive in a dynamic and unpredictable changing environment. Achieving competitiveness is fostered by agility, the essence of which is the ability to recognize and exploit market opportunities that arise precisely because the environment is changing.

We achieve this goal through a literature analysis conducted according to the model shown in Fig. 1.

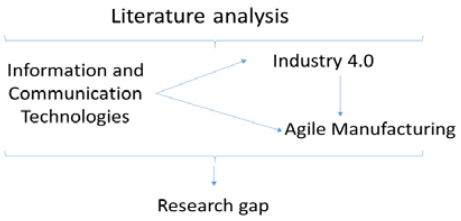

Fig. 1. Research Model

Such model of analysis is implemented not only to present the general picture of these relations but also to analyze the state of the three concepts in Indian SMEs. The special interest in Indian SMEs is because this article is a piece of a broader research in the sector of these companies operating in India. The real potential and benefits of ICT combined with Industry 4.0 for Indian SMEs are not yet fully known or accomplished due to limited awareness, technological skills, resources and funds etc. However, this study is part of an effort to gain insights and identify the research gaps towards latest technology adoption by implementing ICT and Industry 4.0 particularly in SMEs. This research can also be useful in the context of Indian SMEs that intend to adopt advanced manufacturing technologies such as Industry 4.0 and integrate with its current ICT infrastructure.

ICT and agile manufacturing

The role of ICT in agile manufacturing

Manufacturing systems have evolved evolutionarily mainly through technological and organisational innovations. Sometimes, however, these innovations were so groundbreaking that they initiated a new level of technological advancement of these systems. Such breakthroughs are called industrial revolutions. The first revolution is symbolised by the steam engine of the mid-18th century and the second by the electric motor of the late 19th century. Electricity, the electric motor and the development of scientific management that began in the early 20th century led to a huge acceleration of industrial production. The symbol of this period is the fixed-load assembly line, equipped with machines built to produce a single product range. Industrial production technology and the organisation of manufacturing systems were adjusted to mass production. New possibilities to increase the variety of manufactured products and their components arose in the 1950s with the use of computer numerical control machines (CNC). This led to the organisation of production in the form of flexible manufacturing systems (FMS), i.e. flexible lines and cells and Computer Integrated Manufacturing Systems (CIM). In the 1960s, industrial robots were introduced. In combination with methods developed in Japan within the Toyota Production System, popularised in the world in the 1990s as Lean Production, Lean Management and Lean Enterprise, this led to increased production efficiency while maintaining high quality and better adjustment of products to customer expectations. The source of these effects is the elimination or reduction of waste. At the same time, in 1991, the report "21st Century Manufacturing Enterprise Strategy" was published. This strategy is agility, through the application of which companies strive to gain a competitive advantage in the conditions of novel, rapid and surprising changes which characterise the contemporary business environment. These changes create threats but they also create opportunities, the exploitation of which is the essence of agile enterprise.

Agile manufacturing aims to combine the organizational, technological and individual competences and in order to integrate and coordinate them among each other. Since manufacturing and development of customized products frequently relies on close cooperation with suppliers and consumers (Trentin et al., 2012), agile manufacturing includes a set of competencies and practices that are easier to achieve with the help of supply network partners (Sindhwani & Malhotra, 2018; Trzcielinski, 2021). Furthermore, in order to become agile, businesses must invest in IT in order to develop key organizational capabilities and strategic processes (Ngai et al., 2011; Qrunfleh & Tarafdar, 2014) as well as develop supply and demand-side competencies (Blome et al., 2013). Agile companies enable the employees to learn in a teamwork and build a cul-

ture of learning to achieve the desired goals (Kumar et al., 2017; Trzcielinski, 2017). ICT should be used also use to boost cooperative teamwork, to increase coordination among employees and by providing supportive network systems that connect continuously (Ribeiro, 2009).

Agile manufacturing is defined in different ways in the literature, but the dominant view is that it is about the ability of a system to respond quickly to rapidly changing markets (Dove, 1992; Bessant et al., 2000; Gunasekaran & Yusuf, 2002; Rotondi et al., 2010). To realise quick responsiveness agile manufacturing systems use ICTs that support product engineering and increase the efficiency of production technologies (Fig. 2).

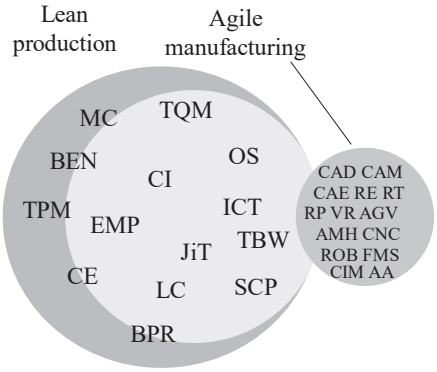

Fig. 2. Product customization and quick response tools of agile manufacturing. Source: (Trzcielinski, 2017)

Lean has introduced a number of methods and tools into management that support organising production in such a way that is directed towards eliminating or reducing waste of: overproduction, inventory, defects, waiting, overprocessing, transportation, motion, untapped human potential. These methods and tools are also known as World Class Manufacturing Practices (Rameshwar & Gunasekaran, 2014). Agil manufacturing makes use of these practices to some extent because as (Kidd, 1994) points out a company cannot be agile if it has unused capacity and employees, has excessive inventory and the production cycles are long. Hence both Lean and Agil manufacturing use such management concepts and methods as TQM (Total Quality Management), MC (Manufacturing Cells), TPM (Total Productive Maintenance), OC (Outsourcing), SCP Supply Chain Partnering), TBW (Team-Based Working), EMP (Empowerment), JiT (Just in Time), CE (Concurrent Engineering), BPR (Business Process Reengineering), LC (learning Culture). Whereas system agility, understood as "quick response capability" (Dove, 1992) requires the use of technologies shortening the cycle of product development and increasing the efficiency of the production process. The first group includes CAD/CAM/CAE systems, RE (Reverse Engineering), RP (Rapid Prototyping), RT (Rapid Tooling), VR (Virtual Reality), the second, although the border is blurred, CNC machines, ROB (Robots), AMH (Automated Material Handling), AGV (Automated Guided Vehicles), FMS (Flexible Manufacturing Systems, CIM (Computer Integrated Manufacturing) and AA (Automated Assembly). Application of these technologies increases "response ability" as it increases flexibility of production assortment, shortens the cycle of product development and introduction to the market, shortens production cycles, increases the ability of the system to reconfigure, while ensuring high quality of products tailored to customer expectations both in terms of their functionality and quantity.

ICT and agility in Indian SMEs

Agile methods have proved to be effective in raising customer satisfaction and lowering costs in big companies, which has pushed researchers to find out possible solution to the challenges that SMEs confront in a competitive environment at domestic and international markets. Several studies undertaken has focused on specific agile enablers in SMEs. Some of these studies, in which the usability and efficacy of IT solutions in SMEs were evaluated, the most important findings showed the need to improve workforce skills and expertise in terms of ICT implementation. Though SMEs are known to be flexible, they still need continuous and extensive training sessions to educate its employees about the agile methodology, objectives and principles through formal and informal trainings (Glinska et al., 2012). However, some of the common barriers identified in SMEs towards implementing agile methods include lack of managerial skills, technological limitations and lack of workforce expertise. The inefficiency of top management in properly scanning the consumer demands, rival's strategies, technological advances, government regulations and supplier's status would result in a weak product portfolio choice that may miss the current opportunities thereby increasing the cost of products by an inefficient production system (Iqbal et al., 2018). Therefore, one of the main responsibilities of the manager/owner is to identify the firm's core competencies and formulate strategies for adopting agile methods. The next step would be to communicate this strategy with other team members and employee for effective implementation. Indian SMEs adopt a wide variety of strategies depending on the resource availability and the conditions in which they operate. Mostly due to its

smaller size and low bargaining power SMEs in India tend to establish trusted relationships with its suppliers and customers. It helps the SME entrepreneurs to obtain a good understanding of the market requirement and to anticipate the potential changes required in the future.

Communication and interaction with main suppliers, clients and providers is crucial in an agile business environment. The customer relationship is majorly dependent on the connectivity factor in SMEs. ICT supports external communication and transactions as well as it is an effective tool for information sharing within the company. ICT plays key role in the competitiveness of Indian SMEs since it enables the SME to quickly respond to opportunities and adopt to changing market conditions. Moreover, ICT facilitates the integration of internal functions, which allows the firm to benefit by quickly reacting to customer's demands and productivity (Marinagi et al., 2014). However, SMEs in India need to improve their ICT capabilities and upgrade the ICT infrastructure in order to reach a bigger market not just locally but also internationally. "ICT capability" is the firm's ability to use digital media/information technology to support its business operations since it enables to improve the efficiency and effectiveness of business processes while being quick and reactive towards market changes, thereby gaining a competitive edge. A firm's ICT capability is also critical for reacting to challenges related to financial services, retail, communication, and customer reach etc. It is argued that knowledge-oriented ICT capabilities are more directly linked to the sensing potential of the firm, whereas process-oriented ICT capabilities are more directly supportive to responsive nature of an enterprise. ICT is crucial in the buyer-seller relationship because it represents a shorter lead time, higher product quality, a larger shared market, and financial income for both the partners (Claro et al., 2018). In this context, the ICT adoption level is also linked to the implementation of e-commerce as stated by (Zaied, 2012). While the number of SMEs that embrace e-commerce for the purposes of flexibility and the ability to react to fresh market opportunities and innovations is steadily increasing (Cosgun & Dogerlioglu, 2012). E-commerce allows SMEs to be highly transparent and provides direct access to market trends, pricing factors and customer insights. Nevertheless, e-commerce enables Indian SMEs to promote and to sell their products and services directly through internet and can eliminate the traditional business style. It is emerging as a valuable ICT tool that can assist competitive firms while providing access to new markets locally and globally. ICT infrastructure plays a vital role in a successful e-commerce activity and (Gäre & Melin, 2011; Lee et al., 2013) found a strong link between ICT implementation and the level of collaboration with other businesses, various types of suppliers, and external actors in general. While e-commerce enables consumers to interact at any moment and from anywhere with their vendors adding flexibility to the business. Recently India's e-commerce industry has witnessed a positive growth due to significant increase in the usage of technology products, an overwhelming increase of internet users and due to new payment alternatives availability. According to (Gäre & Melin, 2011), (Tomlinson & Fai, 2013), ICT products emerge into firms through partnership with external actors capable of deploying various types of technologies depending on the user's demand. Smartphones cannot be denied as one of the essential ICT tools for Indian SMEs, since the continuous interaction among employees, managers and with customers is easier and much more flexible through smartphones. Moreover, customer-vendor communication is cost effective and can save time for both the partners with smartphone usage. Smartphones serves as a means for competition for SMEs among other competitors by reaching out for wide range of audience while creating excellent business opportunities for Indian SMEs.

Adapting ERP system in Indian SMEs can cut down the manual work to a great extent and can automate the business processes with high accuracy and efficiency. A well-planned ERP system can scale the business and can react to market opportunities much efficiently while customer-relationship and business performance can also be improved. Firms that operate in an uncertain climate must not only invest in IT resources, but also be able to effectively manage them. This orchestration entails the adoption of new IT applications and the taking effective measures to better manage IT resources and gives value to the firm's management and organization (Queiroz et al., 2018). Whereas, Cloud offers a solution for deploying ERP system in Indian SMEs with minimized infrastructure cost and low maintenance cost. SMEs that adopt cloud technology can have access to a customizable on-demand IT service that works on pay-on-use basis via Internet, hosted by a third-party service provider. The ERP software when deployed on a cloud-based model becomes a cloud ERP solution which is much feasible for Indian SMEs, especially when it is installed on "Software as a Service" (SaaS) platform. It is one of the useful technologies that ICT offers for a simplified business solution for Indian SMEs. Cloud adoption is most crucial for SMEs as it offers protected IT setup with high business continuity (Siddhu, 2013). SMEs can significantly bene-

fit from cloud-based services by enhancing their competitive position through a better understanding of market visibility, increased operational potency, and worldwide presence (Misra & Mondal, 2011). Apart from that SMEs can benefit from lower hardware investment costs, quicker service and application scaling, cost savings on infrastructure and technology, and faster software upgrades (Rittinghouse and Ransome, 2009). Since most of the Indian SMEs evaluate an ERP solution with respect to its cost and deployment perspective, the adoption of ERP system on a cloud-based architecture is simpler and cost-effective option. The cloud-based service model is relatively beneficial than other models and is expressed in the form of flexible usage-based payment choice, increased scalability, and simpler installation and upgrade processes (Géczy et al., 2012). The corporate community is starting to view cloud-based services as a realistic choice for lowering costs and improving IT and business agility (Wang et al., 2010). However, cloud-based ERP is manageable, easy to operate, very efficient and is within the budget of most of the SMEs in India. For example, the cloud users sometimes are dependent on dash-boards analytics and key performance indicators (KPI) to understand their business shortcomings and other performance issues through graphical images. This allows SMEs to include such tools in their cloud ERP system so that it helps in better managing their business. It enhances the agile aspects of SMEs while avoiding additional costs. Although, SMEs have the advantage of being flexible and quickly adapt to market changes and environment, and react accordingly (Ceptureanu & Ceptureanu, 2019). The integration and adoption of various ICT's such as e-commerce, mobile commerce, cloud-enabled ERP can help Indian SMEs to improve technical capabilities and business performance while strengthening its agility. Many researchers believe that investing in and effectively utilizing ICT tools can significantly boost the productivity of majority of Indian SMEs.

ICT and Industry 4.0

The role of ICT in Industry 4.0

In recent years, rapid digitalization and process automation have increased dramatically, resulting in the development of new technologies. It has been widely accepted that Industry 4.0 is a new industrial stage, which allows integration of manufacturing operations systems and ICT where ICT mainly focuses on the transfer of data and information via wireless devices, sensors, digital tools etc. The key idea of Industry 4.0 is the "smart factory" and to implement it, MES and ERP technologies have an important role (Lasi et al., 2014). MES support and guide the entire production process with step by step instructions of all the activities involved during the transformation of the raw material into final product. An MES system can integrate multiple production execution systems with the help of MES software. It is designed to collect and track information of each product. MES connects planning systems such as ERP with controlling systems such as sensors and PLCs to assist in the production processes by utilizing manufacturing data. A PLC is a user-friendly microprocessor that can be easily programmed to control industrial equipment and machinery. PLC can be connected through external interfaces such as sensors, valves, actuators etc. Its main function includes monitoring essential process parameters and adjust the process operations accordingly. The Industry 4.0 model also aims to boost productivity by meeting consumer needs for faster real-time responses through decentralized production control. MES can help worldwide manufacturing organizations meet these objectives by improving performance, quality, and agility (Almada-Lobo, 2016). While SCADA is an acronym for Supervisory Control and Data Acquisition system which is a combination of software and hardware components used to collect, analyze, and monitor real-time data from processes in a variety of industries. They are designed to control the production process in real-time. The SCADA system is capable of controlling data from remote areas while also providing accurate monitoring results (Kaur & Bansal, 2016). SCADA can also be accessed through the internet or the cloud. Furthermore, the increasing complexity of industrial systems necessitates the acquisition, communication, and evaluation of an increasing amount of data from signal sources (González et al, 2017). As a result of the complexity of industrial systems and the integration of Information and Communications Technologies (ICT), advanced functionalities are enabled.

Manufacturing systems usually needs to process large amounts of data within short periods of time for decision making. The penetrating influence of ICT into the manufacturing systems, resulted in an increase in collection of data (Yin et al., 2018). Big data analytics (BDA) involves extraction of information and understanding of big data by finding hidden clusters and correlations in order to recognize systematic models and make better decisions. When these "big data" interpretations are combined with machine-to-machine interactions and with CPS enabled networks they become highly responsive and flexible towards manufacturing process. This integra-

tion leads machines to communicate, analyze, interact and co-ordinate with each other. ICT plays an important role in the coordination and communication of these machines via electronic devices and equipment. It helps in automation of processes, for instance ICT tools and devices can take corrective measures or actions when there is error detection by itself without human interventions. In an Industry 4.0 environment communication and interactions are possible between ICT devices, equipment and computers without human involvement for decision making purposes. It also constructs a bridge between physical and digital, and for this reason "sensors" play an important role as they accurately record all the information needed. However, the appropriate usage of these sensors connected via networks may provide useful information about the real-time status of connected devices, objects and things that can be used for better understanding, analysis, planning of operational activities (Höller et al, 2014). Due to existing issues with wired or short-range wireless networks, as well as M2M networks, low-power wide area networks (LPWAN) technology was introduced. The aim is to produce sensors with minimum cost, small-size, with long-lasting battery communication at very low data rates. One of the advantages of sensors is that they can convert perceived information into a dataset that can be reused for later analysis and automated decision purposes. Internet of Things is therefore a key connectivity enabler in Industry 4.0 which can enhance the ICT connectivity with advanced analytics. Here "IoT" refers to the objects or ICT devices that are capable of communicating with each other via network-based wireless technologies, ICT tools, sensors etc. Such integration of technologies can be beneficial for physical systems to communicate with each other and also with the human workers. It is expected that as part of Industry 4.0, ICT will be used as a means for integration of new developing technologies by providing solution for many industries in the future. ICT has become a milestone of manufacturing systems as a result of this rapid growth, with support from digital and virtual production, modeling, simulation, and presentation tools which enables the rapid and flexible design, production, and highly customized products (Ketteni et al., 2015). As evidenced by the literature on this subject, ICT will have an even higher impact on the implementation of Industry 4.0-specific solutions (Fenech et al., 2019; Whysall et al., 2019).

The transformation in manufacturing systems enabled by the integration of the ICTs, IoT, and machines in CPS is a significant feature of this new industrial revolution. Cyber physical system that connects the real world with the cyber-world by using numerous devices which are normally related to IoT's, cloud and big data analytics, is a very complex process during which connections are established with a lot of physical devices (mostly ICT devices) and with domains and a large amount of data is analyzed. It is due to the extensive usage of independent ICT devices, CPS is now being implemented on (Level IV), and also due to the significant spread of networks of individual terminals along with improved data processing speed. CPS has now emerged as a concrete platform which has influenced the industrial sector in manufacturing, production and distribution. One of the reasons of CPS becoming so strong and important for the industrial sector is due to the rapid development of ICT's that has enabled the improvement of environment that can promote CPS. According to (Xu et al., 2014), CPS will have a significant impact on emerging ICT and enterprise systems technologies due to the evolution of wireless communication, smartphones, and sensor network technologies. Whereas CPS, according to (Monostori, 2014), is one of the most significant milestones in the development of ICT. This can also be linked to the technologies such as IoTs and CPS such that they are designed to support systems that collect and manipulate huge amount of data (Big Data) which is usually collected through sensors and other ICT devices in the real-world. CPS then analyze, coordinates and manage the resources in a very effective and efficient manner by using data management practices and ICT. However, one of the key challenges is to synchronize a large number of various electronic devices over time in order to obtain cost-effective results. It's worth noting that the criteria for synchronous CPS operation apply to the entire system, which defines the communication system requirements such as wireless sensor networks, wired networks, and mixed data transmission systems (Lee & Seshia, 2016). Nevertheless, an on-demand usage and enhanced resource sharing is possible during the production process with IoT technology, which is largely based on sensors and physical devices mainly ICT tools. This new industrial transformation has been possible due to the utilization of ICTs in industrial environments (Kagermann et al., 2013). Since ICT support organizations to increase their business agility, flexibility, and productivity, ICT is therefore viewed as one of the successful components in Europe's industrial competency.

ICT and Industry 4.0 in Indian SMEs

In recent years, the product development and execution in the manufacturing of new items have changed dramatically. CNC (Computer Numerical

Control) machines have become the industry standard for modern automated machines which lead to the quick advancements in manufacturing of precise parts and the processing of complex shapes. As a result, increasingly sophisticated CAD/CAM/CAE systems have been evolved. CAD systems are utilized for geometric modeling in the construction stage, CAE systems for engineering calculations, and CAM systems for producing control programs for CNC machines in the production stage, according to the product lifecycle (Ivanov, 2014). Combining the advantages of CAD and CAM results in more sustainable products, as well as more sustainable consumer and producer behavior (Lobos & Callie, 2013). CAD/CAM/CAE and CNC are basically challenging the traditional logic of production specially in SMEs, since these systems greatly support production processes with maximum returns on investments in assets related to SME industry. The computer aided engineering (CAE) system uses software applications in order to simulate performance to improve product design. The CAE is a cost-effective solution and can save time while improving product quality and durability. Moreover, the physical prototype testing can be avoided with CAE in industrial platforms. The ICT integration with Industry 4.0 can solve many issues related to complexity of products and supply chains in SMEs ensuring flexible enterprise-based production systems. The increasing integration of ICT into products, as well as the inclusion of services, is resulting in a revolution known as smart engineering (Kang et al., 2016), which relates to innovative product development approaches, procedures, and IT tool chains.

Many of the developing Industry 4.0 technologies and tools are applicable to large businesses, this may not be the case for SMEs (Matt et al., 2018). Indian manufacturing firm's need to rethink their product development and manufacturing methods as more products, their constituent systems, and sub-systems adopt IoT (Kang et al., 2016). This necessitates manufacturing firm's to be more responsive towards market dynamics, adaptable in developing customized world-class products, innovative, and cost-competitive, able to deliver products worldwide. This is particularly a challenging environment for an Indian SMEs to operate in (Iyer, 2018). For that, SMEs in India need be able to integrate their processes from design to production using digitalization and Industry 4.0, as well as simulate and verify alternative product designs and manufacturing methods. Indian SMEs are starting to assess Industry 4.0 digital technologies, with the goal of choosing them based on the consequent commercial benefits. Indian SMEs in order to compete with global firms, must meet international quality standards (PwC, 2014). To achieve this, it is imperative to be highly responsive while decisions are taken on-time, verified and incorporated into production processes. Indian SMEs can utilize smart edge IoT devices to operate, coordinate, and handle different machinery and manufacturing infrastructure while maintaining a migration path for future compatibility (Condry & Nelson, 2016). To realize Industry 4.0 advantages, it is important to be aware of equipment connectivity of various devices and machines in the production line. IoT and ICT solutions are the basis for sensors, processors, devices and other specialised software that can integrate with the advanced data analytics to provide combined functionality. The new sensor-based technologies can help Indian SMEs monitor the usage of machines, energy requirements and staff training on an ongoing basis. Sensors can be used for monitoring essential production line equipment continuously and the real time data can be transferred to the cloud for monitoring purpose. By thorough analysis of different Industry 4.0 technologies, data from various IoTs devices can be analysed to boost the sustainability of manufacturing operations (Wei et al., 2017). This in turn creates new and improved version of products and services for SMEs in India.

Indian SMEs can expect improved operational efficiency and productivity, high degrees of automation as well as improved agility to meet the diversified needs of global consumers, by implementing Industry 4.0 solutions. An Industry 4.0-enabled manufacturing environment offers real-time data collection and analysis which improves the transparency of operations in every aspects of the manufacturing process. Data analytics can help Indian SMEs adopt predictive maintenance framework for its key assets to optimize maintenance and repair schedules and improve asset availability (Fatorachian & Kazemi, 2018). There are several challenges when implementing Industry 4.0 in business related to cyber security, handling big data, building flexibility etc. so it is better to adopt Industry 4.0 in phases rather than re-configuring the entire system at once (Wang et al., 2016). This is especially true in the case of Indian SMEs where there is less availability of technical and financial resources and limited number of skilled employees. Simplification is therefore needed in the Industry 4.0 ecosystem in order to extend the use of different knowledge domains and to make the use of Industry 4.0 solutions user friendly (Nilsen & Nyberg, 2016). Also, there is a need to introduce new technologies that do not cost huge investments for SMEs to replace their existing systems (Federmeccanica, 2016) which can ensure interoperability between the existing legacy systems. How-

ever, SME-oriented Industry 4.0 solutions (SMEI4.0) must also need to be flexible by allowing a gradual implementation of technology and ensure the possibility to reutilize the entire systems in case of adding extra components. The idea of manufacturing resources and capability sharing for SMEs has introduced a service platform which is SME-oriented cloud manufacturing service platform (Huang et al., 2013) which intend to exploit and share the manufacturing resources at the same time promote product design, operational management, capacity building and manufacturing abilities of the SMEs. This will enhance and improve the agility and increase the overall capabilities in manufacturing SMEs, specially in India. The integration of ICT and Industry 4.0 technologies will turn today's SME businesses into smart factories with substantial economic potential (Lee et al., 2013). Although Industry 4.0 being relatively new initiative for India, big companies should however, share their technology innovation with SMEs, so that they can train and improve their capacity to meet the expectations (Zhang et al., 2016). Industry 4.0 technology offers great opportunities for Indian SME sector to improve its competitiveness and is more likely to gain advantages from this shift. An agile business transformation is possible in Indian SMEs with ICT tools such as ERP and Cloud that can align with Industry 4.0 technologies to counter the challenges of rapidly changing business demands.

Agility and Industry 4.0

The importance of Industry 4.0, and its influence on manufacturing industries is growing constantly due to its Internet-based technologies. Manufacturing companies must become more flexible and agile in order to effectively respond to customer requirements (Lasi et al., 2014). Faster decision-making methods are therefore crucial in order to be flexible. Furthermore, manufacturing systems need to be self-adjusting and self-optimized apart from being adaptive (Möller, 2016). However, a growing trend is associated with the massive amounts of real-time data, both structured and unstructured is generated every day which is referred to as Big Data (Sivarajah et al., 2017). "Big data" has been identified as a critical component of Industry 4.0, contributing towards the extraction of benefits from industrial operations (Xu et al., 2018), (Trzcielinski, 2020). Whereas (Gunasekaran et al., 2017) investigated the use of big data in agile manufacturing, particularly in handling market turbulence and assisting firms to remain competitive and to achieve their business performance goals. Because the intensity of market turbulence varies by different companies, the level of agility required will be context-specific (Zhand, 2011). While many authors acknowledge that data is "the new raw material of business" (Mayer-Schönberger & Cukier, 2013). However, big data analytics (BDA) are used by firms primarily to enhance the organizational capabilities, so that it can help in sensing opportunities and threats in the environment, and to make necessary changes in the business accordingly. This will improve the agility of the firm by helping in seizing those opportunities and quickly reacting to the threats, which can also be perceived as sensing and responding process of agility (Trzcielinski, 2021). Many researchers believe that seizing opportunities based on big data is a difficult challenge that businesses are currently facing (Post & Edmiston, 2014). In order to fully benefit from BDA adoption and to make informed business decisions, firms must speed-up their responding process. Because it is important that a firm's reaction-time need to be optimal. The main purpose of Industry 4.0 is to improve the efficiency and responsiveness of the manufacturing system (Ahuett-Garza & Kurfess, 2018), and for that reason, BDA offers new possibilities to extract value from data. BDA also contributes to achieve sustainable business performance and competitive advantage (Wamba et al., 2017).

From the managerial viewpoint, several solutions can be suggested in order to enhance the firm's ability of responding, for instance by reinventing relationship with customers and by increasing organizational "clock-speed" that is improving the response time (Galbraith, 2014). Since Industry 4.0 brings dynamic changes in the relationship between customers and the manufacturers (Wynstra et al., 2015), seeking to shift perceptions, such as customer flexibility towards smart product features. This will have an impact on the real-time data collection and analysis. The analytic tools of "big data" and "intelligent machine learning" systems can be helpful in quick response towards market demands and customer needs when adopted in manufacturing firms. It effects the firm's organizational agility in sensing the opportunities by gaining knowledge about market requirements and better understanding of customer preferences, thereby customizing and improving products quality in response. However, BDA along with other Industry 4.0 technologies can help manufacturing firms achieve long-term goals by improving the working environment, employee morale, reducing lead times, providing customized items, and by improving product quality (Gunasekaran et al., 2017). At the

same time, IoT-controlled manufacturing systems are smart, because they are able to remotely operate all the connected devices with efficiency and high accuracy (Lee et al., 2017), (Lu & Cecil, 2016). An IoT system is capable to deliver user-specific as well as personalized products which a user can customize using a webpage. Real-time data collecting and sharing between various manufacturing resources, including machines, employees, materials, and jobs is possible through IoT-enabled manufacturing (Bi et al., 2014). Moreover, machines and equipment will be more adoptable to boost their performance by the use of mechanisms such as self-optimization and autonomous decision-making under IoT (Roblek et al., 2016). Nevertheless, IoT by connecting humans and machines, facilitates information and knowledge sharing among organizations and the insiders. More importantly, IoT under Industry 4.0 can change and improve the relationship among customers, producers, and the suppliers, where customers are also involved in deciding the quality of the product as well as its customization. It also helps the manufacturer in carrying out product specific measures and improvements and customization. IoT is therefore an important asset for manufacturing firms which can enhance the firm's agility mainly by sensing the opportunities about customer requirements and collecting relevant data and reacting to them quickly and effectively. However, "interoperability" is considered as one of the biggest advantages of Industry 4.0, where interoperability is the ability of two systems to understand each other and to use functionality of one another. Industry 4.0 technologies are interlinked and connected with each other, interoperability can enable information sharing and exchange of real time data among those technologies. It can be viewed as a major advantage for the firm in quickly sharing the relevant data among workers, machines, devices etc. which helps in coordinating manufacturing processes and in reducing the response time. It will also enable faster decision-making process and adds to flexibility of operations in production line and ultimately leads to a more flexible and agile manufacturing system. Although, in general the agile aspects of the manufacturing firms are greatly influenced by the combination of different Industry 4.0 technologies and by using the interoperability among themselves depending on the manufacturing need and process requirement. Manufacturing firms, however need to investigate the right mix of appropriate technologies available under Industry 4.0 to fully benefit and to improve the business performance and its agility.

Conclusions

Firms equipped with ICT infrastructure have relative advantage over others since they significantly can improve their competitive position and respond to market opportunities quickly. Digital ICT tools can enable SMEs to integrate their business processes with global partners, while being actively and continuously connected to customers. However, in order to compete at global markets, SMEs needs to improve its manufacturing capabilities. ICT plays a vital role in improving the manufacturing potential and efficiency of a firm. Moreover, ICT is a key component of Industry 4.0 technologies which are designed to improve the manufacturing system and the industry as a whole. When ICT is combined with Industry 4.0 technologies, it is bound to have positive effect on manufacturing outputs. This is particularly important for SMEs, since they are one of the largest ecosystems in the world and can significantly gain advantage from Industry 4.0 revolution along with ICT implementation. It can be seen through the integration of ICT and other innovative technologies such as IoT, cloud computing, digital manufacturing and CPS that collect, transfer and make sense of Big Data (Zhou et al., 2015) so that the fluctuations in the market demands for high-quality products can be responded quickly and efficiently. Industry 4.0 is still considered in its early stages for most countries, hence a strong leadership with an agile mindset is always crucial for companies that intend to adopt advanced technological changes with global markets reach. SMEs in India are also in need for innovative plans and effective business transformation strategies that can facilitate the integration of advanced manufacturing technologies along with Industry 4.0 and ICT. Bigger companies and global partners however need to step ahead and share their technology innovations with SMEs that are willing to adopt new methods and technology improvements. With high degrees of automation, 'Industry 4.0" concept is particularly revolutionary for Indian SMEs that can enhance their operational efficiency and productivity as well as significantly improve the business agility when integrated with modern ICT.

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