# Societal impact of IoT-lead smart factory in the context of Industry 4.0

Kalsoom, Tahera; Ramzan, Naeem; Ahmed, Shehzad

*Published in:*
2020 International Conference on UK-China Emerging Technologies (UCET)

*DOI:*
10.1109/UCET51115.2020.9205484

Published: 29/09/2020

*Document Version*
Peer reviewed version

Kalsoom, T., Ramzan, N., & Ahmed, S. (2020). Societal impact of IoT-lead smart factory in the context of Industry 4.0. In *2020 International Conference on UK-China Emerging Technologies (UCET)* IEEE. https://doi.org/10.1109/UCET51115.2020.9205484

# Societal Impact of IoT-Lead Smart Factory in the Context of Industry 4.0


Tahera Kalsoom
*School of Computing, Engineering & Physical Sciences*
*University of the West of Scotland*
Paisley, UK
tahera.kalsoom@uws.ac.uk

Naeem Ramzan
*School of Computing, Engineering & Physical Sciences*
*University of the West of Scotland*
Paisley, UK
naeem.ramzan@uws.ac.uk

Shehzad Ahmed
*School of Business & Enterprise*
*University of the West of Scotland*
Paisley, UK
shehzad.ahmed@uws.ac.uk



***Abstract*— Transformation of traditional manufacturing into intelligent manufacturing has intrigued the manufacturing firms at a global level. The focal objective of the concept of Industry 4.0 is to distinguish highly digitized manufacturing processes where flow of information amid different devices is controlled in an environment with very limited human intervention. Different and complex physical and cyber technologies make Industry 4.0 a way to improve performance, quality, controllability, management and transparency of information of manufacturing processes. Although Industry 4.0 provides numerous potential opportunities to manufacturers, most firms still lack insight into the variety of technologies available in Industry 4.0 as well as the challenges and risks it poses to the society with its implementation. This paper summarizes the available technologies by reviewing existing studies on it, identifies challenges linked to Industry 4.0 and provides guidance to implementing smart factory in the context of Industry 4.0.**



***Keywords—Industry 4.0, IoT, Societal impact, Smart manufacturing, Smart factory.***


## I. Introduction

Industry 4.0, also known as the Fourth Industrial Revolution, is characterized by a rapid evolution of digitization and robotics in manufacturing processes [1]. This has led to a significant impact not only on supply chains, business models and business processes but society as well. By using smart technologies such as Internet of Things (IoT), Cloud Computing and Big Data Analytics, provision of seamless connectivity, interoperability and intelligent capabilities have enabled manufacturing industries to meet market demands through tailored and customized production [2], [3]. However, this disruptive change also represents risks and challenges among the potential opportunities for companies to adopt and innovate strategic advantage using these technologies [1], [4].

IoT is the next technological marvel enabling connectivity and information exchange between objects through the use of network-connected ubiquitous devices reducing human interaction. Firms are looking for the exploitation of business opportunities that come from the application of these new technologies to new markets [5]. It is also argued that IoT can enhance analytical skills, software development, infrastructure management and performance of the employees through behavioural monitoring and enhanced communications [4], [6]. In an attempt to understand the efficient use of IoT in manufacturing industry, it is imperative to recognize the different technologies that make the performance of manufacturing firms efficient using Industry 4.0.

Unlike internet, which has a well-documented design, architecture and infrastructure, IoT is considered to be an extension of internet, although it lacks global coherence. This raises issues primarily related to data security and privacy, creating implicit assumptions that data will be shared among things, applications and possibly sectors. Currently, academia has given a lot of attention to Industry 4.0 based supply chain, with main focus on different areas such as sustainability, organisational structure, lean manufacturing, product development and strategic management within the manufacturing industry. Majority of these studies focus on the contributions and threats of IoT related to flexibility, transparency, information sharing, connectivity, traceability and tracking within Industry 4.0. Although, comprehensive work has been done in these areas, it has been found that most firms still lack in-depth insight into the different types of technologies associated with Industry 4.0, and challenges as well as resources needed for successful implementation of a smart factory. This paper tries to fill this gap by identifying available different technologies of Industry 4.0 and identifying the requirements and key challenges associated with implementing a smart factory in the context of Industry 4.0. In addition, this paper reviews existing research that has been done on Industry 4.0; therefore provides a broad overview of the extant literature on Industry 4.0, summarizes risks and challenges of implementing a smart factory, and creates an agenda for future research that encompasses the vigorous evolution of Industry 4.0.

## II. Industry 4.0

Originating from Germany in 2011, the term 'Industry 4.0' was used to label the strategic German industrial policy that promoted computerization of manufacturing [11]. Industry 4.0 instantly developed to be the focus of German government and is now being used globally indicating self-sufficient manufacturing processes, by using machines and devices that

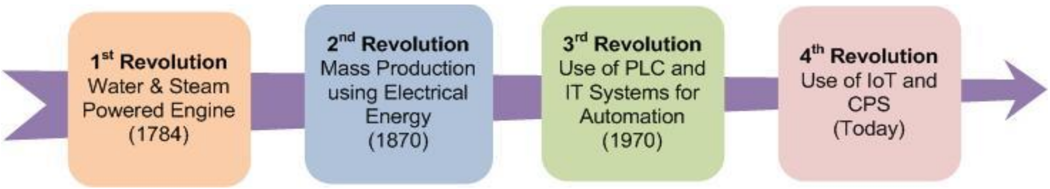


Fig. 1. Four Industrial Revolutions [15].

communicate with each other through digital interconnectivity [12]. Fig. 1 illustrates the differences between the four industrial revolutions.

Extensive use of internet is one of the founding pillars of Industry 4.0, which serves as a passageway to connect machines, devices, sensors and people. In addition, it aides in the creation of new product information and features due to the ability of using internet as a source to gain real time information [13]. As a result, huge volumes of sensor data in the form of diagnostics and predictive maintenance collected from multiple locations and plants will help in reduction of maintenance costs [14], increase in asset availability and creation of new usage-based business models [11], [15]. Technological advancements and innovations in business models have an impact on firm performance and long-term sustainability [1], [2].

The focal objective of the concept of Industry 4.0 is to distinguish highly digitized manufacturing processes where flow of information amid different devices is controlled in an environment with very limited human intervention [1], [16] . The term Industry 4.0 signifies the integration of Cyber-Physical System (CPS) with the production processes, thereby altering business paradigms and production systems [12], [16]. The key distinction between Industry 4.0 and Computer-Integrated Manufacturing (CIM) is that Industry 4.0 enables industrial production to achieve a quality leap by connecting people, machines and machines [8], [9], [16] . Therefore, an upsurge in new production systems with quick and more targeted information exchange has been created [11], [17].

## III. Key Technologies in Industry 4.0

Industry 4.0 is heavily dependent on use of technology in different processes. The four main drivers of Industry 4.0 are IoT, cloud computing, big data and analytics and robotics [8], [11] as illustrated in Fig.2. Key technologies are discussed in this section.

### *A. Cyber-Physical Systems (CPS)*

CPSs work to automated exchange of information by using globally accessible information and communications network in which production and processes are matched [18], [19]. According to [19], CPSs are networks of IoT devices that contain small sensors and actuators that regulate, multiple and distribute artificial intelligence in industries [1], [8]. These sensors and actuators are mounted as embedded systems in different materials and machine parts, which are then connected with each other through the internet [9], [16]. Use of these sensors in CPSs enabled machines helps to discover failure occurring in machines and automatically prepare for fault repair actions on CPSs. In addition, each workstation is utilized to an optimum level with the help of cycle time required for the operation performed on that station [11]. Hence, CPSs merge the physical world with digital world, by gathering and exchanging data over the internet [15]. Following are the main features of CPS:

- Decentralization allows the CPSs own decision making and autonomous task performance [15], [17].
- Interconnections between different devices and equipment allow the machines, devices, sensors and people to connect and communicate with each other [8], [11].
- Information transparency is the accessibility to huge amounts of data that is produced by digital plant models and sensors and is stored as a virtual copy in the physical world [15], [19].
- Technical assistance allows digital systems to aide humans in informed decision making and solving urgent problems on short notice by intensively accumulating and visualizing information gathered from sensor data [11], [19].

### *B. Cloud Computing*

Cloud computing has taken digitalization of manufacturing processes to a new level through heightened data management and storage abilities [15], [20]. Therefore, cloud computing has delivered more consistent services in terms of virtualized storage technologies which serve as data centres [16], [19]. These storage platforms are located globally, are concealed in the background and receive data from ubiquitous devices and sensors, which is then analysed and interpreted to allow users easy to comprehend web-based virtualization [11]. In cloud computing, on-demand self-service features are proven to be essential for the enterprises in terms of reducing costs, providing flexibility to the system, increase in profits and competitiveness [2], [15]. Therefore, cloud offers an flexible solution for data application in terms of storage space and computing ability which can be changed on demand [8], [19].

### *C. Big Data Analytics*

Big data is another key enabling technologies in Industry 4.0, where manufacturers leverage data created throughout their processes [21]. Adoption of data mining techniques by manufacturers is not a recent process. Manufacturing companies distributed globally have found significance in increasing potential of using big data analytics [1], [21]. These firms own several manufacturing plants generating huge amounts of data which can be analysed to improve process efficiency, product quality, speed up cost reduction, value addition and better services of production optimization [11], [21].

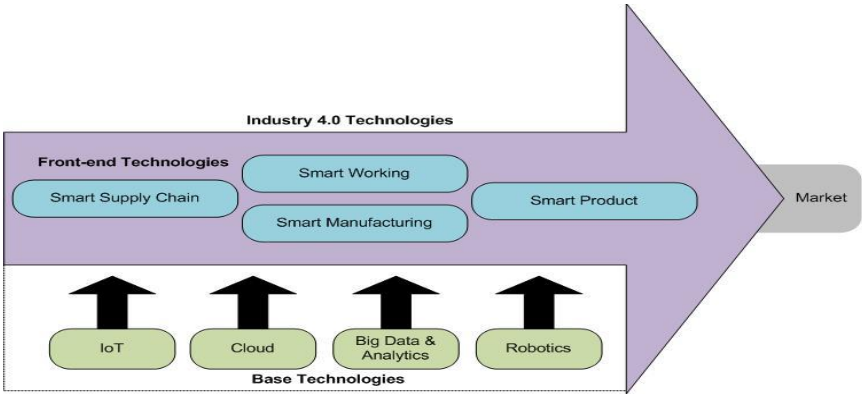


Fig. 2. Industry 4.0 Technologies [15].

### *D. Robotics*

The need to increase product quality, enhance safe production environment and quick response to changing customer demands are some of the motivating factors behind the development of advanced industrial automation, although it has long been linked with the increase in manufacturing productivity [19], [22]. The demand for more flexibility on the manufacturing plant requires innovative robotic technologies that allow manufacturers to handle large amounts of variability in products easily [4], [6].

Robotics, a base technology of Industry 4.0, which serves as high-level building blocks with the aim of composing a task or completing a robot program [6], [23]. Using their sensory devices, robotics use object recognition and pose estimation functions to detect low-level parameters, therefore performing the tasks which are considered difficult or unsafe for human workers. Hence, use of robotics enables the manufacturing firms to experience enhanced performance, both in operational as well as production processes [16], [19], [23].

### *E. WSNs*

The true feature of an Industry 4.0 adopted smart factory lies in its capability to readjust and evolve along with the growing needs of the organization [7], [13], [14]. These needs can be categorized into the changing customer demands, emergence of new markets, development of new products and services, enhanced productive approaches to operations and use of advanced technologies in maintenance processes [4], [13]. The ability to tailor and learn from real time data makes the smart factories more receptive and predictive to avoid operational downtime and other possible failures in the processes [19]. The sensors, in the form of WSNs, in production phase enable the smart factories to monitor specific processes throughout the factory which enhances awareness on what is going on at multiple levels [11]. A mobile platform offering high speed and low cost communications anywhere and anytime can be achieved through Wi-Fi, Bluetooth and WiMAX in smart factories [2], [16].

### *F. RFID*

Besides sensors, several RFID applications have been successfully implemented in smart factories. It has the capability to disclose information of the product at a low level in an autonomous, instantaneous and touchless method [13], [14]. Unlike barcodes, RFID tags do not need a direct line of vision to transmit data, making it likely to scan different tags as a batch synchronously. Information visibility can be enhanced using RFID at different stages of a business supply chain including acquisition of raw materials, manufacturing, logistics and retail [7], [15]. Reduced uncertainty as a direct result of information visibility and transparency is one of the most probable benefits of RFID.

### *G. M2M*

Traditionally, technologies where integrated with physical components at a rapid rate, however now IoT and machine-to-machine (M2M) are rapidly incorporating data and system flows that form the foundations of the global economy at an alarming speed and accuracy [1]. Fixed broadband technologies are restricted to household implementations around the developed world, while on the other hand, a mobile broadband platform places electronic devices to almost 4 billion end users by connecting billions of new devices across the globe [4], [22].

## IV. Impact of Indystry 4.0 on Society

The real-time dynamic of data analytics, the basis of manufacturing industries, is giving rise to new opportunities and challenges for business leaders. In order to have a continuously working complex smart factory environment, both smart hardware and software is necessary for a smart factory. However, some underlying technical and non-technical issues have to be addressed.

### *A. Cyber Security*

Billions of smart assets, when networked together to store information on the cloud, become exposed to cyber security risks [1], [19]. These cyber risks pose threats ranging from personal devices to complex IT systems, making both individuals and organizations vulnerable to financial and operational damages [13], [14]. In addition, a bad data injected into the smart system has the potential to be as damaging as data extracted from the system through a data breach. Therefore, both the systems and the communications need to be secure, as huge number of systems communicated with each other over vast distances, making them vulnerable to security breaches.

### *B. Impact on Jobs*

The role of employees will continue to evolve from what they are actually doing in today’s factories, as the smart factory continuously evolves. As automation will take up the tasks that are repeated, mundane or impacted by labour shortage, people will take on more complex roles in these factories [2], [11]. In addition, special skills and knowledge will be required to fill top managerial positions in smart factories. For example, IT managers with no skills in smart manufacturing face problems in meeting deadlines. A huge skills gap will be created with the retirement of experienced and skilled workers [17].

TABLE I. SUMMARY OF KEY IOT TECHNOLOGIES USED IN MANUFACTURING INDUSTRY

| *Key IoT Technologies* | *IoT Impact on Manufacturing Industry* | *Sources* |
|---|---|---|
| Cyber-physical systems | • Evaluate real-time information sharing.<br>• Self-monitor and govern the processes.<br>• Foresee actions or need of users.<br>• Self-organizing production. | [15], [18], [19] |
| Big Data | • Using historical data to provide proactive risk alerts.<br>• Reduce issues related to product quality and failure.<br>• Flexible in combining data from different sources for business intelligence. | [1], [11], [21] |
| Augment Reality | • Management of emergency situations.<br>• Enhancing maintenance activities by providing remote assistance and guidance.<br>• Providing new ways of design and manufacturing process integration. | [11], [14], [19] |
| RFID | • Inventory shrinkage.<br>• Saving processing, scanning and recording times.<br>• Accurate and timely delivery.<br>• Inventory accuracy and shelf replenishment. | [7], [13] |
| M2M | • Progressive benefits to shipper, receiver and customer.<br>• Real-time visibility.<br>• Quality controlled logistics. | [3], [4] |
| Sensor Technologies | • Autonomous decision making.<br>• Visibility, theft reduction.<br>• Reduce repair cost and maintenance downtime through better monitoring.<br>• Safety and security. | [7], [11], [13] |
| Cloud Technologies | • Quality control.<br>• Real-time visibility.<br>• Enhanced security measures.<br>• Adjusting to market volatility by making SCs wary of how resources should be used in the event of a collapse.<br>• Increased scalability abilities. | [15], [16], [19] |

### *C. Human Behavioural Intentions on the Adoption of IoT*

Despite unpredictable circumstances, trust plays a vital role to encourage people to adopt modern technology [1], [2], [19]. In uncertain situations, trust helps the users of this technology to recognise the social surroundings of the technology, therefore decreasing vulnerability [4], [7]. Studies have shown that trust significantly enhances the behavioural intention of people to adopt IoT products and services, whereas lack of trust may result in difficulty to spread the IoT systems among people [7], [11], [13], [14].

### *D. Interoperability and Standardization of IoT*

Interoperability of IoT plays a vital role in producing around 40% of potential value developed by IoT in different settings [22]. In an environment where countless devices of different types and technical profiles will operate (e.g. from autonomous vehicles to drones), manufactured by thousand different brands (each with their standards), developing the ability for them to communicate with each other will be a technical challenge [16]. This interoperability and lack of standardisation of IoT devices may lead to individuals and businesses to have unequal access to data of value from the IoT [11]. In addition, these issues may lead to manufacturers and users of IoT to be confused over a huge network of platforms available.

## V. CONCLUSION

This paper has discussed different types of IoT technologies used in Industry 4.0. A comprehensive review of the existing literature is also presented on technology-lead smart factories. Societal impact of Industry 4.0 in terms of cyber security, job market, behavioural intents on technology adoption and interoperability & standardisation are investigated. Industry 4.0 exploits new technologies including IoT, CPS, cloud computing, big data analytics, artificial intelligence and robotics. With the help of these technologies, data flow is integrated horizontally between partners, suppliers, customers as well as organizations to develop a finalized product according to the customer demands. Therefore, the developing trend of a smart factory is human-machine collaboration, where major decisions are made by humans.

Although Industry 4.0 promises an endless range of benefits for manufacturing firms, there are some underlying challenges faced by these firms in implementing IoT. Therefore, implementing smart factories should take into account interoperability, vulnerability, decentralization, virtualization and real-time capability. Risks are mostly associated with eventual job losses, privacy and lack of standardization of IoT.

With continuous evolution of IoT devices, there is a vision of IoT in which the future-generation internet will stimulate the interaction between human, societies and smart things giving rise to a new phenomenon known as Opportunistic IoT [14]. The Opportunistic IoT addresses the link formed within different communities (by pairing devices) created by the opportunistic contact nature of humans and, therefore, focuses on the human side of IoT [11], [16]. This side of IoT can prove to be a revolution in future research studies on the impacts of IoT applications. In addition, it is vital to study the behaviour of users adopting IoT into their everyday life and how using this advanced technology is affecting their behaviour. This has given rise to behavioural IoT, which includes ethical issues related to the implementation of IoT devices such as data security, right to private life and rights on information sharing. These issues need to be taken into account for future studies.

## REFERENCES


[1] C. Cimini, F. Pirola, R. Pinto, and S. Cavalieri, “A human-in-the-loop manufacturing control architecture for the next generation of production systems,” J. Manuf. Syst., vol. 54, no. January, pp. 258–271, 2020.

[2] L. B. Liboni, L. O. Cezarino, C. J. C. Jabbour, B. G. Oliveira, and N. O. Stefanelli, “Smart industry and the pathways to HRM 4.0: implications for SCM,” Supply Chain Manag., vol. 24, no. 1, pp. 124–146, 2019.

[3] J. Holmström, M. Holweg, S. H. Khajavi, and J. Partanen, “The direct digital manufacturing (r)evolution: definition of a research agenda,” Oper. Manag. Res., vol. 9, no. 1–2, pp. 1–10, 2016.

[4] A. Zanella et al., “Internet of Things for Smart Cities,” IEEE Internet Things J., vol. 1, no. 1, pp. 22–32, 2017.

[5] V. Tsiatsis, S. Karnouskos, J. Höller, D. Boyle, and C. Mulligan, “Industrial Automation,” Internet of Things, pp. 249–256, 2019.

[6] L. Bibby and B. Dehe, “Defining and assessing industry 4.0 maturity levels–case of the defence sector,” Prod. Plan. Control, 2018.

[7] H. Fatorachian and H. Kazemi, “A critical investigation of Industry 4.0 in manufacturing: theoretical operationalisation framework,” Prod. Plan. Control, 2018.

[8] I. Castelo-Branco, F. Cruz-Jesus, and T. Oliveira, “Assessing Industry 4.0 readiness in manufacturing: Evidence for the European Union,” Comput. Ind., vol. 107, pp. 22–32, 2019.

[9] B. Afzal, M. Umair, G. Asadullah Shah, and E. Ahmed, “Enabling IoT platforms for social IoT applications: Vision, feature mapping, and challenges,” Futur. Gener. Comput. Syst., vol. 92, pp. 718–731, 2019.

[10] M. Ghasemaghaei, S. Ebrahimi, and K. Hassanein, “Data analytics competency for improving firm decision making performance,” J. Strateg. Inf. Syst., vol. 27, no. 1, pp. 101–113, 2018.

[11] A. G. Frank, L. S. Dalenogare, and N. F. Ayala, “Industry 4.0 technologies: Implementation patterns in manufacturing companies,” Int. J. Prod. Econ., vol. 210, no. January, pp. 15–26, 2019.

[12] C. Perera, C. H. Liu, S. Jayawardena, and M. Chen, “A Survey on Internet of Things from Industrial Market Perspective,” IEEE Access, 2015.

[13] F. Galati and B. Bigliardi, “Industry 4.0: Emerging themes and future research avenues using a text mining approach,” Comput. Ind., vol. 109, pp. 100–113, 2019.

[14] Y. Lu, “Industry 4.0: A survey on technologies, applications and open research issues,” Journal of Industrial Information Integration. 2017.

[15] E. Manavalan and K. Jayakrishna, “A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements,” Comput. Ind. Eng., 2019.

[16] S. Lass and N. Gronau, “A factory operating system for extending existing factories to Industry 4.0,” Comput. Ind., vol. 115, p. 103128, 2020.

[17] P. Dallasega, E. Rauch, and C. Linder, “Industry 4.0 as an enabler of proximity for construction supply chains: A systematic literature review,” Computers in Industry. 2018.

[18] K. Nagorny, S. Scholze, M. Ruhl, and A. W. Colombo, “Semantical support for a CPS data marketplace to prepare Big Data analytics in smart manufacturing environments,” Proc. - 2018 IEEE Ind. Cyber-Physical Syst. ICPS 2018, pp. 206–211, 2018.

[19] A. A. Wagire, A. P. S. Rathore, and R. Jain, “Analysis and synthesis of Industry 4 . 0 research landscape Using latent semantic analysis approach,” J. Manuf. Technol. Manag., vol. 31, no. 1, pp. 31–51, 2020.

[20] L. S. Dalenogare, G. B. Benitez, N. F. Ayala, and A. G. Frank, “The expected contribution of Industry 4.0 technologies for industrial performance,” Int. J. Prod. Econ., vol. 204, no. July, pp. 383–394, 2018.

[21] D. Kozjek et al., “Advancing manufacturing systems with big-data analytics : A conceptual framework,” Int. J. Comput. Integr. Manuf., vol. 33, no. 2, pp. 169–188, 2020.

[22] J. Holmström and J. Partanen, “Digital manufacturing-driven transformations of service supply chains for complex products,” Supply Chain Manag., vol. 19, no. 4, pp. 421–430, 2014.

[23] C. Wan et al., “Cloud manufacturing in China : a review,” Int. J. Comput. Integr. Manuf., vol. 33, no. 3, pp. 229–251, 2020.