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# PREFACE

## THE HUMAN SIDE OF DIGITALIZATION

The volume addresses the central point of the current debate on the relationship between *innovation 4.0* and *human resource management*. The interesting contributions respond effectively to the question in the title and clearly show the need to build virtuous complementarity between Human Resource Management and Technological Innovation.

At the present stage, both at the theoretical and operational management levels, we are discovering how full exploitation of new technologies is strongly interdependent with *organizational change*, the *quality of work* and *innovation of HR systems*.

In this volume different theoretical approaches are adopted, and a rich anthology of experiences and practices are collected coherently with the increase in complexity in the relationship between digital technologies and people. As the socio-material approach (Cecez-Kecmanovic et al., 2014) suggests, social and technical aspects are nowadays even more deeply intertwined than before, "the social and the material are inherently inseparable" stated Orlikowski and Scott in 2008 (p. 456). This far truer with digital technologies that are investing almost all the aspects of our private and working life.

The content of the book addresses the crucial aspects of the current trends. The introductory general section deepens the organizational implications of Internet of Things and *smart manufacturing*.

It underlines in a very appropriate way the necessity of relaunching the entrepreneurial spirit not only in start-ups and new ventures, but also within existing and well-established companies. Corporate entrepreneurship emerges as a key strategy for disseminating innovation, coupled with appropriate human capital training and development policies. The organizational change requires a radical transformation of HR departments that need to review their basic processes, taking into account how workers will interact with smarter machines.

The innovation of HR models is central to both access to new technologies and to evaluate how they are used and exploited.

The volume deals with the specific practices that must be developed by combining a growing autonomy of people with the growing need for collaboration between them. The empirical evidence presented and discussed shows that it is still unclear if one goes to greater standardization and work routinization rather than to greater autonomy and discretion of people involved. The emerging workplaces demand more and more versatility. On one side, people at work will be requested to have the ability to compile and analyse big data, to be able to effectively communicate what the data means, and to apply it to everyday business decisions. On the other, they will be requested to become proficient in using new collaboration approaches and tools (Colbert, Yee, & George 2016).

The contributions offer specific arguments on learning processes, new roles, new skills and competences required.

It emerges that the relationship between individual learning and organizational learning becomes more complex in the context of innovation 4.0 and this requires a deep transformation of business training. This becomes even more crucial if one considers that the labour market is showing shortages of new skills and competences and that the Italian university system shows significant delays in this regard.

The digital transformation of HR processes can lead to a greater weakness of its role - to the extent that selection, training and control are only based on big data - rather than to develop a new centrality of HR department if people managers take on the risk of giving meaning to such data.

The book is not aimed at providing all the answers, but it has the merit of raising the right questions to the attention of practitioners and scientific community.

The main node to be addressed at the organizational level regards the relationship between individual autonomy and managerial control. In addition, coexistence between young digital native workers and older workers is becoming a challenging issue within organizations, when younger employees are promoted into supervisory positions in which they then manage older subordinates (Kunze & Menges, 2017). A third issue, as far as the quality of work and HR processes are concerned, is the problem of polarization of competencies between high profiles - expected to be strengthened - and low profiles - which will tend to be marginalized – is well depicted. This opens a problem of fairness and requires a serious reflection about the risk of raise of wage inequalities.

On the background remains the unsolved paradox of innovation 4.0: on one side the organizational need to return to shared spaces and time and, on the other side, the increase of digitization and diffusion of smart working that risk to weaken and de-power this trend.

Cecez-Kecmanovic, D., Galliers, R. D., Henfridsson, O., Newell, S., & Vidgen, R. (2014). The sociomateriality of information systems: current status, future directions. *Mis Quarterly*, 38(3), 809-830.

Colbert, A., Yee, N., & George, G. (2016). The digital workforce and the workplace of the future. *Academy of Management Journal*, 59(3), 731-739.

Kunze, F., & Menges, J. I. (2017). Younger supervisors, older subordinates: An organizational-level study of age differences, emotions, and performance. *Journal of Organizational Behavior*, 38(4), 461-486.

Orlikowski, W. J., Scott, S. V. (2008) Sociomateriality: Challenging the Separation of Technology, Work and Organization, *The Academy of Managem*

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Part I

# OVERVIEW

Chapter 1

# UNLOCKING THE IOT POTENTIAL IN MANUFACTURING: AN ORGANIZATIONAL ANALYSIS AND RESEARCH AGENDA [1]

**Cristiano Ghiringhelli-Francesco Virili**



## 1.1. Introduction

The basic concept underpinning the Internet of Things (IoT) is the possibility of connecting objects to the Internet, typically by means of a small and inexpensive "smart label". The transition from a world of objects to a world of smart objects connected, identified, and monitored in real time paves the way for radical innovations in the field of manufacturing: a development known as Smart Manufacturing (also referred to as Industry 4.0, Factory 4.0, Smart Enterprise, Industrial IoT). Over the past five years, Smart Manufacturing has gained significant momentum in terms of market diffusion, levels of investment, and productivity gains, as reported by a body of analytical studies (McKinsey & Co, 2015; GE & Accenture, 2014; DHL & Cisco, 2015; PWC, 2014).

*Market diffusion*. For example, one study indicates that the deployment of IoT by businesses has grown by 333% since 2012, reporting that 65% of companies sampled deployed IoT technologies in 2014 (compared to 15% in 2012) (Forrester Research, 2014). A survey of 235 German industrial companies conducted by the market research institution TNS Emnid found that "*while today only one fifth of the industrial companies have digitized their key processes along the value chain, in five years' time, 85% of companies will have implemented Industry 4.0 solutions in all important business divisions*" (PWC, 2014:7)

[1] A previous version of this research was presented at ItAIS 2016, the annual conference of the Italian chapter of the Association for Information Systems, Verona, October 7-8, 2016.

*Investment levels*. Furthermore, investments in Industry 4.0 solutions are forecast to account for over 50% of planned capital investment over the next five years (PWC, 2014). German industry will thus invest a total of €40 billion in Industry 4.0 every year by 2020. Applying the same investment level to the European industrial sector, the annual investments will be as high as €140 billion per annum" (PWC, 2014:7). In Italy, "Industria 4.0 National Plan 2017-2020" – recently promoted by the Italian Government – provides for a wide array of initiatives aimed at promoting investment in innovation and competitiveness according to the Industry 4.0 approach.

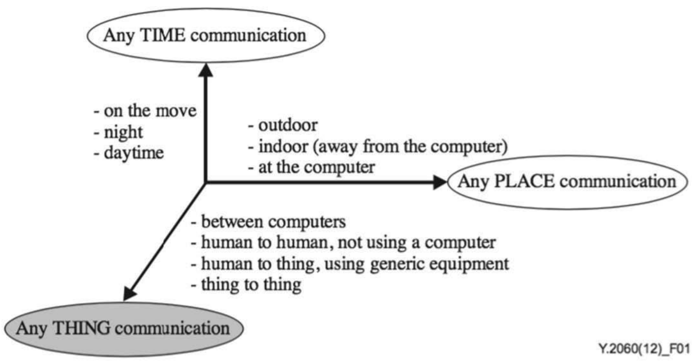
*Productivity gains*. Again, IoT is predicted to generate productivity gains of over 18% over the next five years, with estimated additional revenues averaging between 2% and 3% per annum (PWC, 2014). However, it should be frankly acknowledged that the long-term impact of IoT is currently difficult to estimate. Early ongoing projects show that the potential of IoT for manufacturing may only be unlocked by adopting new, and still largely unexplored, organizational solutions at a range of levels, including new organizational structures, systems, processes, and relationships. Innovative people management and HR development approaches are likely to be key success factors in Smart Manufacturing initiatives, and this generates novel research requirements in the field of organizational studies.

The aim of this chapter is to examine these requirements, contributing to the development of an organizational research agenda. More specifically, we first provide a brief macro overview of IoT innovations, emphasizing the factors underpinning their development as well as currently unresolved problem areas. Second, we outline the potential of IoT to enhance manufacturing via new business models and production paradigms. Third, we discuss the critical challenges associated with implementing IoT models, in terms of the organizational traits, work organization, workforce characteristics, change management, and organizational relationships required for their potential to be fully realised. Finally, we describe promising lines of enquiry and theoretical frameworks for future research programmes, with a view to defining an organizational research agenda with the power to assess emerging opportunities for smart manufacturing and analyse the related organizational issues.

## 1.2. Background

*IoT definition.* The IoT has been defined as "*a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information* *and communication technologies (ICT)*" (Recommendation ITU-T Y.2060, 2012:2). A key aspect of IoT is that it adds an "Any THING" dimension of communication to ICT. This expands opportunities for things and systems to be controlled remotely, but more importantly enables direct – thing-thing, human-thing, human-human (non-computer-mediated), thing-computer and computer-computer – interaction while continuing to exploit the existing network infrastructure (fig. 1).

Figure 1. The new dimension introduced in the IoT (Recommendation ITU-T Y.2060, 2012).




All these forms of interactions are driven by data and, at the same time, also produce data that may be processed by advanced systems (using, for example, algorithms) designed to support (or substitute – (Rifkin, 2014)) sophisticated human decision-making processes. Such "cyber-physical systems" – i.e., engineered systems that are built from, and depend on, the seamless integration of computational algorithms and physical components (National Science Foundation, 2016) – include smart firms, smart homes, and even smart cities, and offer enhanced efficiency, efficacy, accuracy, flexibility and economic benefits.

*A macro-economic overview of IoT.* It has been observed that the IoT reconfigures the communication-energy-logistics circle in such a way that productivity is dramatically increased and marginal costs reduced. Consequently, IoT has the potential to boost a hybrid economy based on both the capitalistic and "Global Collaborative Commons" paradigms (Rifkin, 2014). In particular, Rifkin states that IoT could reconfigure the Communication-Energy-Logistic circle in such a way that the productivity dramatically grows and, at the same time, marginal costs fall down to near zero, in perspective making goods and services priceless, nearly free, and abundant.

Shortly, no longer subject to market forces. The new hybrid economy boosted by IoT is seen by Rifkin as based partially on the rules of the capitalistic paradigm (exchange value, financial capital, ownership, consumerist approach, competition), and partially on the new rules of the Global Collaborative Commons (sharing value, social capital, access, sustainability, cooperation) (Rifkin, 2014).

The recent growth in the IoT, privacy issues and further barriers. Even if the term "IoT" has been introduced in the 1995 by Kevin Ashton, a co-founder of the Massachusetts Institute of Technology Auto-ID Center (that created a global standard system for RFID), the IoT has only expanded significantly in the past five years (Rifkin, 2014; Lee & Lee, 2015). Up to 2010, many barriers hindered the growth of IoT, including the cost of sensors (such as tags and chips), gyroscopes and accelerometers, and the limited address space allowed by the IPv4 Internet protocol. However, as the cost of these components has decreased and the IPv4 Internet protocol has been substituted by IPv6, the IoT has seen major expansion. However, a highly critical aspect of the spread of IoT is privacy (Weber, 2010; Sicari et al., 2015).

Research has examined the complex challenges posed by personal security, technical security, and data protection issues, as well as by the current legal and standardization guidelines, all of which continue to slow down the broader diffusion of IoT (Rifkin, 2014; Lee & Lee, 2015; Weber, 2010; Sicari et al., 2015). Policy makers are now developing a common security framework (see AIOTI, launched by the European Commission in 2015).

Finally, two further aspects are currently working against IoT in manufacturing: first, a growing but still limited awareness, both in Italy and elsewhere (Staufen, 2015); second, a limited understanding of the organizational issues raised by IoT.

With regard the first issue, the awareness and/or knowledge of the IoT approach differs among countries. In a general view, it is higher in the German area (where the Industry 4.0 label has been introduced and developed), high in USA (where the same approach is known as Smart Manufacturing) and very low in Italy, as confirmed by a recent research which found that almost 70% of the Italian companies surveyed haven't started yet initiatives in the Industry 4.0. Only 20% have experienced Industry 4.0 (Staufen, 2015). Not surprisingly, in Italy the departments perceived as most involved are operations and logistics but – more than in Germany – sales are seen as a key application field. Moreover, very high organizational impacts are expected by Italian companies from Industry 4.0: approximately the 70% of companies surveyed expect benefits in areas such as business model, R&D, human resources qualities, improving overall organizational performance (above all quality of service).

In general, these data confirm that, at the moment, in Italy the Industry 4.0 approach is still a relatively new phenomenon, and this may still represent a serious barrier to its diffusion and experimentation. The Italian "Industria 4.0 National Plan" paves the way towards a wider adoption of the Industry 4.0 model by the Italian companies supporting the digitalization of industrial processes, the improvement in workers' productivity, as well as the development of new skills, new products and new processes (Minister of Economic Development, 2007).

## 1.3. Exploring the potential of IoT: from data to action, via decisions

IoT technologies help to develop "agile decision-making processes" for descriptive, diagnostic, prescriptive and predictive purposes at three different levels: 1) at the operational level, with a view to running and managing formal procedures; 2) at the continuous improvement level, in terms of designing formal procedures to enhance efficiency, productivity, flexibility, and adaptation; 3) at the organizational development level, with the aim of fostering organizational learning and the development of new business models and markets. The case of DHL provides one of the clearest available examples of these diverse functions of IoT.

*An illustrative case study.* In Europe as well as in the United States, logistics has been one of the first industries to start experiments on IoT for operations. In this field, the experience of DHL represents a very well-defined case study showing how the organizational structure, systems and processes have to be redesigned in order to unlock the potential embedded in the IoT technologies. DHL has conducted wide-scale experimentation in applying the IoT to its logistics operations. As result, DHL's most sophisticated operating sites currently apply IoT systems in all three main areas of the logistics value chain: Warehousing, Freight Transportation, and Last-Mile Delivery Operations (DHL & Cisco, 2015). This allows to appreciate, in particular, the cycle descriptive-diagnostic-prescriptive-predictive organizational decision-making process above introduced.

*DHL Warehousing Operations and IoT*: operation automation and optimization. With regard to Warehousing Operations, DHL has developed an IoT-enabled smart-inventory management system based on pallet or item-level tagging. This involves the use of devices such as RFID, wireless readers that receive, aggregate and send data (gathered from each pallet as it arrives through inbound gateways) to the WMS for processing, as well as cameras attached to warehouse gateways that can also be used for damage detection (by scanning pallets for imperfections). Each movement of a pallet generates a tag transmission report that is sent to the WMS and, in the case of misplacement or compromised temperature / humidity conditions, an automatic alert enables the warehouse manager to take corrective action. During the outbound delivery phase, pallets are scanned as they pass through an outbound gateway to ensure that the correct items are being shipped (in the optimal order of delivery), and stock levels are automatically updated in the WMS. In addition, warehouse vehicles (forklifts) and equipment are connected, with a view to preventing collisions among them or with warehouse staff (in the next section, we discuss the organizational effects of the "augmented workforce"), monitoring their movements, position and operating conditions, and predicting maintenance needs.

*Freight Transportation Operations and IoT*: better tracking, SC risk management, capacity optimization and predictive maintenance. The opportunity to tag individual goods and items (not just the whole container) opens up new possibilities for Freight Transportation Operations also. Connected sensors on board trucks, and multi-sensor tags on individual goods, transmit data concerning items' location/condition, generating an alert if a package is opened (possible theft). By tagging each good, logistics providers not only maintain real-time and highly precise (metre by metre, second by second) visibility of the movement and condition of goods at the item level, guaranteeing a higher level of transport visibility and security (and reducing theft and acting against the organized crime that affects ports and rest areas). Moreover, IoT data integration is of value in handling natural disasters, conflict, economic uncertainty, and market volatility. For example, referring to the DHL Resilience360 project for supply chain risk management, DHL declares that "in the future, Resilience360 could integrate all the data transmitted from assets and respond when a truck carrying urgent cargo is about to break down or when a warehouse has been flooded from a storm. It could also move a shipment from air freight to road freight to compensate for an airline strike" (DHL & Cisco, 2015:21). Sensors can monitor how often a truck, container or ULD is in use or idle and transmit this data to a central dashboard for optimal utilization analysis designed to identify spare capacity along fixed routes and solutions for consolidating and optimizing routes. Finally, an electronically-connected fleet can also enable predictive asset lifecycle management (see MoDe project): this involves the transmission of data (via a wireless network) from a maintenance platform to a central unit in the truck, and then back to the maintenance platform for analysis. This means that the driver and/or maintenance crew may be alerted of potential problems in advance.

*Last-Mile Delivery operations and IoT*: optimization of daily collection routes, enhanced tracking, temperature sensing and return trip optimization. DHL has made major changes to its Last-Mile Delivery operations thanks to IoT technologies. These are the operations that take place during the final leg of the delivery journey, which is strongly labour dependent and characterized by high consumer expectations. In light of these features, IoT technologies can enable the logistics provider to develop a cost-effective solution. For example, DHL delivery operators can optimize their daily collection routes by skipping empty mailboxes (thanks to sensors placed in individual boxes). In the interest of offering a flexible delivery address service, tagged parcels provide recipients with more detailed information about when their parcel is expected to arrive, giving them the opportunity to specify the delivery address at the last minute. In addition (although currently only in Germany), temperature-controlled smart lockers can replace traditional mailboxes and ensure "first-time every-time" delivery of parcels, groceries, and other environmentally sensitive goods. A similar scenario will apply to "smart home" products, which consumers are beginning to adopt. Finally, DHL is testing new business models for monetizing and optimizing the return trip, possibly by using IoT to connect delivery staff with surrounding vehicles and individuals.

The case reported gives a clear example of how the development of an organizational capability, in terms of flexibility and responsiveness in decision-making, actual as well as predictive, is a key point introduced by IoT.

While the first two levels (Warehousing Operations and Freight Transportation Operations) mostly refer to intra-organizational decision-making processes, the third level (Last-Mile Delivery operations) is mainly focused on inter-organizational relationships and new business model development.

*IoT potential: improved productivity and quality, new production systems, value chain management, and new business models.* As outlined above, the IoT approach enables agile decision-making processes by sustaining: operational tasks (in the case of DHL: the optimization of fleet and asset management; the real-time updating of inventory level data; and the real-time monitoring of a shipment's location-condition-security); continuous improvement (in the case of DHL: the elimination of time-consuming manual activities; optimized inventory and asset management, preventing costly out-of-stock scenarios; optimized energy consumption); and organizational development (in the case of DHL: temperature-controlled smart lockers enabled by e-commerce and developments in the smart home sector). From a broader perspective, such agile decision-making processes can potentially produce substantial added value for organizations at multiple levels.

*Improved productivity and quality*. The marked improvements in productivity and quality discussed in the DHL case study are just an illustration of a wide range of potential IoT-based innovations that may be implemented at any point along the value chain. In product development, for example, IoT technologies can help to achieve low-cost variability, evergreen design, new user interfaces and augmented reality, ongoing quality management, connected service, and system interoperability. In marketing and sales, they can support new ways of segmenting and customizing, and new customer relationships. In terms of after-sale service, they can enable the provision of remote service, preventive service and augmented-reality-supported service, and the gathering of valuable data from product users (Porter & Heppelmann, 2015).

*New production paradigms*. IoT innovation in production gives rise to five main developments (Porter & Heppelmann, 2015). The first of these is the smart factory concept. A smart factory is a flexible network of cyber-physical systems that automatically supervise production processes and adapt their own functioning in real-time, in response to operating conditions. The connectivity and data-processing capacity of networked machines allow production processes to be radically optimized, minimizing downtime, costs and waste, and maximizing productivity, efficiency and security. The second outcome is simplified components: "the physical complexity of products often diminishes as functionality moves from mechanical parts to software" (Porter & Heppelmann, 2015:104). In the automotive industry, for example, the Volkswagen Group is moving towards the introduction of the virtual cockpit, in which car data may be viewed on a high-tech display. The third development concerns reconfigured assembly processes: the use of standardized platforms secures economies of scale and lowers inventory. The fourth benefit is continuous product operations: smart and connected products include a cloud-based technology stack, which is a component that the manufacturer can improve throughout the life cycle of the product. Finally, a fifth spin-off of IoT technologies may be labelled "the new lean" (Porter & Heppelmann, 2015; Staufen, 2015): potentially, the data transmitted by connected products can facilitate the rationalization of product use and activities across the value chain, by reducing or eliminating waste, pre-empting the need for service prior to a failure, revealing that maintenance may be deferred, and reducing downtime.

*Significant changes in the value chain management*. New data resources and new opportunities for Data Analytics introduced by IoT technologies allow for a wide range of opportunities capable of generating significant changes in the whole value chain. In the product development area, for example, in terms of low cost variability, evergreen design, new user interfaces and augmented reality, ongoing quality management, connected services, systems interoperability. In the marketing and sales area in terms of new ways to segment and customize, new customer relationships, new business models focused on systems (instead of discrete products). In the after-sale field, in terms of remote service, preventive service and augmented reality supported service and collection of data from users.

*New business models*. IoT innovation can prompt the adoption of radically new business models and frameworks (Dijkman et al., 2015). For example, according to one report (McKinsey & Co, 2015), it appears that four new types of business model are emerging in the field of manufacturing: a) platforms (on which products, services, and information may be exchanged via predefined communication streams), b) "as-a-service" business models (in which technology and automation providers move from selling machinery to a pay-by-usage model), c) Industrial Property Rights-based business models (introducing modes of recurring revenue generation in addition to – or instead of – a one-off asset sale) and d) data-driven business models (that introduce new ways of collecting and using data either for direct monetization – such as Google's search engine, or the crowd-sourcing of data whereby companies obtain services, ideas, or content via the contributions of a large group of people or online community – or for indirect monetization – using the insights obtained via IoT technologies to identify and target specific customer needs and characteristics).

## 1.4. Unlocking the potential of IoT: the organizational perspective

*Inside the corporation: organizational systems, processes and structure.* We believe that, in the IoT approach, a key source of competitive advantage is the organization's ability to fully exploit the potential value of the data generated during its operations. This requires conducting effective data analysis and using it to inform the decision-making processes governing organizational action and the management of uncertainty (Simon, 1957; Thompson, 1967). Data gathered, produced and shared by the machines, components, devices and products involved in organizational operations are only potentially useful. They remain meaningless if they are not appropriately selected, understood and processed. In other words, IoT technologies introduce the potential to enhance both current and predictive decision-making processes (Bosch IoT Lab White Paper, 2014), but this opportunity will only be realized if the company develops the specific organizational capability to use it to drive and regulate its operations. The experience of

IoT pioneers proves that the greatest challenges associated with the IoT approach are, first and foremost, organizational.

*Systems and processes*. The radical enhancing of production systems described above may only be attained if organizational decision-making processes are appropriately redesigned and well integrated with internal operations. In the case of DHL, for example, Warehousing, Freight Transportation and Last-Mile Operation – which comprise the entire life-cycle of the company's delivery service – have been closely integrated with one another: hence, the sharing of data among the three functions allows mutual regulation to take place. In other words, IoT requires a holistic enterprise management approach that breaks down traditional modes of organization and organizational silos. In manufacturing, the need for a global approach is particularly strong: here, for example, the IoT paradigm demands full integration among production systems and Enterprise Resource Planning (ERP) systems, Product Data Management (PDM) Systems, Product Lifecycle Management (PLM) systems, Supply Chain Management and Customer Relationship Management (CRM) systems. According to some analyses, the integration of systems that are usually managed independently of one another can facilitate gains in efficiency of up to 26% (McKinsey & Co, 2015).

*Organizational Structures*. Nonetheless, this type of integration does not require replacing current systems with totally new systems. Rather, it implies redesigning organizational structure and operating systems in line with the holistic management perspective invoked above. The Candy corporation provides an interesting case study in the implementation of this crucial approach. Candy is known for its SimplyFi program, a wide range of smart home appliances that can communicate with the user via Internet (http://candysimplyfi.com). However, more saliently to our purposes in this paper, Candy has recently also changed its internal structure, introducing a new functional unit (labelled "Connect Unit") with the task of coordinating the entire IoT program. This unit collates and analyses marketing, IT, and Customer Relationship Management issues with a view to strengthening and coordinating R&D IoT programs. Similarly, the Bosch Group has created a specific unit (named "Bosch Software Innovations") charged with developing services for smart products by involving both internal product-based business units and customers (Bosch IoT Lab White Paper, 2014). More generally, it seems that at least three new types of organizational unit are emerging. First, Unified Data Organization Units. Porter observes that many companies are creating dedicated data groups with the function of consolidating data collection, aggregation and analytics. Such groups are responsible for making data and related insights available across functions and business units, and typically they are led by a C-level executive (the Chief Data Officer – CDO) who reports to the CEO (sometimes to the CFO or CIO). Ford Motor Company provides an example: it recently appointed a chief data and analytics officer to develop and implement an enterprise-wide data analysis strategy. Second, DEV-OPS Units, whose role is to manage and optimize the ongoing performance of connected products after they have left the factory. This type of unit brings together software-engineering experts from the traditional product-development organization (the "dev") with staff members from IT, manufacturing, and service who are responsible for product operation (the "ops"). Third, Customer Success Management Units are responsible for managing customer experience and ensuring that customers get the most from the product.

In conclusion, giving that each smart product can tell companies a lot about the customer experience, the product itself becomes a sensor that gauges the value customers are receiving. Importantly, Porter specifies that this new unit does not necessarily replace sales or service units, but assumes primary responsibility for customer relationships after the sale: consequently, it does not operate as a self-contained silo, but collaborates on an ongoing basis with marketing, sales, and service.

*Inside the corporation: HR and people management. – New work organization*. In an IoT-enabled work environment, it is likely that most of the people in an organization will use non-traditional interfaces to interact with networks of things in advanced ways. In the DHL case study, for example, significant changes have taken place in the role and the activities of logistics staff: the workers' actions are embedded in the IoT system, with warehouse staff connected to the Internet of things via scanners, smart devices and wearables that receive and send data in real-time. Similarly, Caterpillar have developed a suite of tools including cameras for human-operated vehicles, which monitor driver fatigue by tracking key indicators such as pupil size and blink frequency. Wearables, in particular, are likely to became the main way of interacting during operations: the smart glasses, for example, introduce the opportunity of interacting in a natural way within a work environment built on data-driven and collaborative workflows, meaningful integration of data and tools and hands/eyes-free interactions.

*Roles, competence and skills and the augmented employee concept*. As work organization and environment are transformed by the drivers described above, roles, competencies and skills will be required to change dramatically. In terms of competencies, for example, companies need to differentially adapt the capabilities and skills base of their employees across a wide range of functions. At the shop-floor staff level, basic process and IT systems know-how are required to ensure the connection between the digital and physical sides of the operation. At a more general level, in-depth overall understanding of corporate processes, systems, and data is prerequisite to developing new business models and operational improvements based on cross-functional information. Furthermore, companies need data and process experts who can operate at the interfaces between functions and systems and are able to work in close synergy with subject-specific experts, such as shop-floor managers, customer relationship managers, and supply chain managers. When developing new data-driven business models, such data experts are required to play a key coordinating role in new product design, given their broad overall knowledge of the production chain.

In short, as processes and business models become more agile and data-based, employees will require completely new skills and qualifications. At the moment, we know little about exactly what competences will be needed. Companies that have pioneered IoT technologies in manufacturing say less on this crucial issue than on other topics for which key insights have already emerged. Nonetheless, in line with our analysis so far, it is reasonable to posit that an effective IoT work environment will have three main traits: specifically, it is data-driven, exploits collaborative workflows and is based on hands/eyes-free interaction. These characteristics will likely lead to the development of the "augmented employee". This expression relies on a new employee profile that we need to explore and understand. "Today's products are designed so they can be assembled quickly by unskilled workers. 3D printing will introduce much more design freedom, allowing manufacturers to reduce their reliance on unskilled labour and also to create unique designs that could not be executed with traditional manufacturing", ABB Venture Capitals Managing Director Girish Nadkarni says (Deloitte, 2014:8). The role of humans will mainly concern data treatment and analysis, supervision and advanced decision-making. This will require a small number of highly skilled people focused on innovation and improvement; more generally, it will alter the workforce configuration required by the organization.

*HR management innovations*. From another perspective, the changes in the work environment and workforce profile just outlined, may only be obtained by transforming HR management accordingly. Bringing an IoT approach to bear on the HR function will include enhancing the performance management process and related compensation model, as well as agile working schemes, by drawing on data from IoT systems, while job design may take into account real workloads as measured via IoT data collection. In addition, HR Analytics solutions may be appropriately integrated with

IoT systems. Recruitment and Training & Development initiatives will need to take into account the new skills required by workers. Skills shortages will emerge in new areas (for example, in the availability of managers capable of leveraging Big Data analyses to make good decisions), and a new cultural mindset will be required to support collaborative data-driven work environments, enhanced leadership styles, agile working approaches, and virtual team collaboration. Nonetheless, the crucial issue at this point in time is that a Human Resources approach to the design and implementation of IoT systems has currently yet to be defined.

*Outside the corporation: inter-organizational relationships and value networks. – New inter-organizational relationships.* IoT introduces the opportunity to share and integrate data, not only within individual companies, but also across different organizations (Reaidy et al, 2015). This has key implications for both traditional and new business models. Closer integration among the companies in the value chain can generate a wide range of benefits, such as enhanced organizational flexibility, greater customer satisfaction, faster times to market, a more efficient division of labour, and higher rates of innovation and speed. The great complexity of the current competitive scenario and the intense innovation efforts that it demands justify the need for cooperation schemes among groups of companies with complementary know-how. In the automotive industry, for example, manufacturers have begun developing interdisciplinary partnerships with suppliers from other industries (such as component manufacturers, chemical companies and, recently, companies such as Apple and Google). In short, IoT technologies, by sustaining horizontal integration and the creation of value-added networks across the value chain, introduce opportunities not only to develop new business models, but also to enhance and/or upgrade traditional business models.

*The role of SMEs.* A further key development enabled by IoT technologies in terms of new inter-organizational relationships and business models is the opening created for SMEs to play a significant role in the newly emerging business scenario. Arguably, SMEs will enjoy increased opportunity to introduce their businesses into supply chains by leveraging IoT systems. On joining forces with larger value chains, they will no longer be mere suppliers within Smart Manufacturing scenarios, but will become stable partners in Open Innovation streams (Gershenhorn, 2016). SMEs have long been engaging with this challenge, but now have the opportunity to reinforce and accelerate the process of change (Faller & Feldmuller, 2015).

*Organizational change management concerns.* The IoT approach requires organizational change initiatives aimed at introducing a holistic enterprise management approach that can not only accomplish the integration of all internal processes, but also develop new relationships with external partners across the value chain. One of the most crucial challenges for organizational change management is the need to integrate staff with different work styles from highly diverse backgrounds and cultures (Porter & Heppelmann, 2015). A further challenge is the increase in complexity caused by the need to significantly revisit organizational structure, policies and norms. Finally, IoT will not only demand reconfiguration of the organization at the formal level, but also the appropriate culture, motivation, and level of engagement. These dimensions are a fundamental leverage in a work environment founded on advanced activity such as sense-making, interpretation, decision-making, flexibility and continuous improvement. Finally, seeing the lack of experience and competencies, traditional and new structures likely need to operate in parallel, and temporary solutions like hybrid or transitional structures will be required (Porter & Heppelmann, 2015).

## 1.5. A suggested research agenda

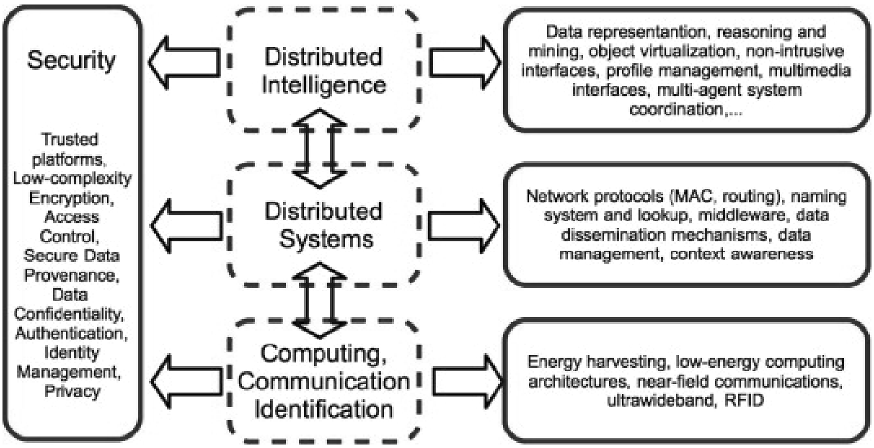
We have discussed some key IoT organizational challenges, including structures and systems, work organization, workforce qualities and change management strategies within Smart Manufacturing. The manufacturing sector is entering a new developmental stage with huge potential. However, this potential may only be fully harnessed by making significant changes at multiple levels of the organization in ways that are still largely unexplored. Thus, here below, we summarize the key areas of research and detailed research topics touched on in our analysis, also suggesting possible theoretical frameworks and a sample of bibliographical references.

The four promising research areas suggested here are spanning different disciplines: the IoT system area is related to the technical, computer science and engineering challenges of IoT development and evolution. The following three research areas are managerial and organizational, at different levels of analysis: interorganizational (area 2, organizational ecosystems) and intraorganizational with a focus on people and behaviours (area 4: HR and people management) or on organization redesign (area 3: structure, systems and processes).

*Research area 1: Enabling technologies.* In the ICT area, significant research challenges are emerging with the emergence and continuous evolution of the IoT system. An early systematic account is given in (Miorandi et al., 2012).

The research taxonomy proposed by the authors is based on the simple idea that in a smart objects world, 1) anything communicates; 2) anything is identified; 3) anything interacts. Each of these three basic aspects is related with a complex area of technical innovation and research, as depicted in the figure below.

Figure 2. Taxonomy of ICT research areas relevant to Internet-of-Things (Miorandi et al., 2012).




*Anything communicates* generates new needs in the research area depicted in the lower part of the picture, "Computing, Communication and Identification" technologies and their typical challenges related to the small size and low consumption needs of smart devices.

*Anything is identified* calls for research in the area of distributed network systems (middle part of the picture), with specific issues related to the enormous number of distinct but similar micro-devices actively operating in IoT networks.

*Anything interacts* raises even more advanced research challenges in the area of distributed intelligence (upper part of the picture), including new interfaces, new big data collection and analysis methods, new multi-agent coordination systems, and related issues with interesting intersection with the Artificial Intelligence research world, particularly in the areas of augmented and virtual work operators.

*Security*, depicted in the left part of the picture, cross-cuts and integrates the three ICT research areas illustrated above and urges for much needed and relevant research. The IoT system poses unprecedented security challenges: an enormous number of objects would produce detailed and potentially open confidential information. The controlled availability, monitoring and actual use of IoT data requires innovations in identification, confidentiality, authentication, and privacy technologies, standards and platforms that are urgently calling for new efforts in research and practice.

*Research area 2: Organizational ecosystems.* IoT innovations have a high potential of transformation or organizational relationships. We suggest here three major investigation areas, reflecting some of most important open issues in the business arena. Organizational and IS scholars may help to understand and shape IoT innovations at the interorganizational level by leveraging important conceptual tools: business models, value chain, and SME innovation network analyses.

*The business model research area* has developed a significant amount of conceptual analyses and frameworks, with an important impact in the business arena, particularly in the area of BM generation frameworks and tools, with international best sellers like (Osterwalder and Pigneur, 2013). It has been authoritatively recognized that BM transformation can originate organizational innovation at any level, raising complex issues (Chesbrough, 2010). The already rich organizational research agenda in the BM area (Zott et al., 2011), would therefore hopefully include future opportunities and challenges connected with IoT-enabled business models, like for example new services in the advanced logistics industry, illustrated earlier in this chapter.

*The value chain transformation* is a relevant instance of the wider phenomenon of IT-enabled interorganizational relationships. In their introduction to the special issue of Organization Science "Organizing for innovation in a digitized world" Yoo et al. (2012) show how distributed and combinatorial innovations are happening and diffusing through digital platforms. The IoT-enabled service innovations exemplified in this chapter typically show such characteristics. Value chains are classical loci of this type of digital innovation, which cannot be confined within a single organization. Organizational boundaries (re)definition is therefore a major area of analysis in this regard (Santos, and Eisenhardt, 2005), with specific applications and challenges in the vertical value chains (Jacobides, and Billinger 2006) an in the so called "netchains" (Lazzarini et al. 2001) integrating vertical supply chains and horizontal networks.

*The role of SMEs* in an IoT world could capture research attention for reasons indirectly related to the organizational boundaries redefinition. In an IoT world, more than in the past, business and process knowledge cannot be concentrated in a few large organizations, but tend to distribute among several actors including SMEs, according to a tendency already in act, discussed for example in (Chesbrough, 2006). Therefore, besides a growing