Industrial Challenges

2

Christian Stary and Matthias Neubauer

Abstract

Recently, the German "Industry 4.0" initiative gained momentum, and sketches a vision for future production industries. This chapter reviews industrial challenges in the area of "Industry 4.0". The findings are structured along the fundamental understanding of production companies as socio-technical systems. Socio-technical systems consist of three important aspects—(i) human, (ii) organizational structures and technology—and, most importantly their mutual relations, and thus, the interdependencies of these aspects. The review reveals that humans need to remain a vital element of future production and need to drive organizational development efforts and continuous workplace improvement. Organizational structures are challenged by changing business models of production companies. Enabling organizational change requires an open organizational culture (e.g., in terms of digital readiness), learning support and digital literacy of all involved stakeholders. In order to create value from Industry 4.0 developments, still technical challenges, in particular vertical and horizontal process integration need be resolved.

2.1 Introduction

Today's industry needs to survive in a volatile environment. Changing customer demands, high degree of product individualization, increasing digitalization and system integration, effective and efficient manufacturing operations to meet high

C. Stary (✉) · M. Neubauer
Department of Business Information Systems Communications Engineering, Johannes Kepler University Linz, Linz, Austria
e-mail: christian.stary@jku.at

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quality at low cost, well-being of employees, etc., are just some factors that challenge daily work in industry. In general, an **industry** refers to the production of certain goods or services within an economy (e.g., automotive industry in Germany). Different Industry classification systems like the ISIC (2008), NAICS (2012) or NACE exist that organize companies with respect to production processes or similar products. (cf. https://en.wikipedia.org/wiki/Industry_classification). According to the NAICS (2012) **Manufacturing** "*comprises establishments primarily engaged in the chemical, mechanical or physical transformation of materials or substances into new products. These products may be finished, in the sense that they are ready to be used or consumed, or semi-finished, in the sense of becoming a raw material for an establishment to use in further manufacturing. Related activities, such as the assembly of the component parts of manufactured goods; the blending of materials; and the finishing of manufactured products by dyeing, heat-treating, plating and similar operations are also treated as manufacturing activities. Manufacturing establishments are known by a variety of trade designations, such as plants, factories or mills*". Compared to the definition of manufacturing, the understanding of "**Production**" is more generic in terms of any conversion from input to output. This also includes intangible products like the delivery of services in areas as government and health care or even knowledge production.

In this book, production companies are understood as complex, socio-technical systems of people, processes and machines that flexibly interact within a certain context when generating goods. A "workplace" is defined as a physically or conceptually distinguishable set of interactions between people, machines and processes within their contexts. For example, workplaces may include the interactions of individual workers in their immediate physical surroundings, and the interactions of teams of workers that are distributed across different departments. Taking a socio-technical systems point of view includes the consideration of three different perspectives—human, organization and technology—as well as their interdependencies (cf. Botthof and Hartmann 2015—Industry 4.0 as socio-technical system). In the subsequent section, industrial challenges for each of the given perspectives are identified. They form the basis for describing the S-BPM potential to support Industry 4.0 designs and implementation in Chap. 3.

2.2 The Vital Role of Humans in Production Industries

With the advent of initiatives like Industry 4.0, industrial internet, internet of things, cyber-physical systems or smart factories a vision of a tightly connected real and digital world has been evangelized in order to open new avenues for production and workplace design. In addition to the development of technological enablers, the vital role of the human beings for factories of the future has been emphasized by research and industry (cf. EFFRA 2013). Humans remain an integral and essential part of future production, since humans are of utmost importance for the overall production system flexibility and intelligence (Kärcher 2015, p. 49). However, the range of activity will change for people in future production situations. Human-centred workplace design has been an important aspect since the beginning of the "Industry 4.0" project development. Fundamental design issues refer to the elements of socio-technical systems and comprise aspects such as:

- Central or decentral decision-making; process and information transparency across organizational layers [Organization]
- The role of humans and technology—does technology serve humans as support means? Or do humans merely represent machine operators? [Human]
- Technology design—will technology substitute or support human work? [Technology]

(cf. Kärcher 2015, p. 50).

Lüdtke (2015, p. 125) highlights the explicit and systematic recognition of humans when designing and implementing automation support. He stresses that automation may not be successful in cases where humans are neglected and argues for a flexible assignment of tasks either to machines or humans. In his vision, the optimal task sharing should not be determined a priori. Instead, at each point in time task sharing shall be evaluated based on distribution strategies and situated requirements. Thereby, Lüdtke (2015) takes a "**H**uman-**M**achine **T**eam" (HMT) perspective leading to a collaborative task solving attempt between humans and machines. Taking such a perspective requires shifting focus to a team perspective rather than to the mere automation perspective. Thus, aspects such as communication among team members (H2H, H2 M, M2H, M2 M), knowledge about abilities, skills, activities, roles and plans of team members are vital for situation awareness and alignment between the team members.

Lüdtke (2015) proposes a procedural model for developing human-machine teams. This model structures development activities along four human-machine team dimensions:

- ***Composition***
  describes the purpose of a HMT, the typical number and types of involved actors as well as the number and types of required resources.
- ***Cooperation***
  describes who works with whom on a certain task and who might substitute the required behaviour; also defines handover behaviour between machines and humans vice versa.
- ***Interaction***
  defines the communication and modality among actors.
- ***Interface***
  defines the dedicated user interface for humans.

For each dimension Lüdtke (2015) suggests to follow the traditional development phases (1) requirements definition, (2) specification, (3) implementation and (4) evaluation. However, he stresses the importance of people involvement by participatory design techniques to meet human expectations and requirements. Furthermore, Lüdtke (2015) recommends a model-based approach to support these phases. Thereby, he proposes to apply different kinds of models which cover tasks, the work domain, humans, machines and user interfaces.

The **Involvement of people in the development of human–system interactions** represents an important aspect for any development attempt. System design always serves a certain purpose, aims to reach certain objectives and addresses actual user groups. Research and developments in the field of **h**uman **c**omputer **i**nteraction (HCI) promote human-centric design processes to meet user's expectations and requirements. Standards such as ISO 9241-210:2010 promote approaches and guidelines to integrate users in the design and evaluation of IT solutions in order to improve adequate system design and adaptation. ISO 9241-210:2010 Ergonomics of human–system interaction—Part 210: Human-centred design for interactive systems promotes the following key principles:

- The design is based upon an explicit understanding of users, tasks and environments
- Users are involved throughout design and development
- The design is driven and refined by user-centred evaluation
- The process is iterative
- The design addresses the whole user experience
- The design team includes multidisciplinary skills and perspectives

Besides the explicit recognition of humans in design specifications and their active involvement in development initiatives, **humans** themselves represent an essential **enabler for organizational improvement**. Employees are considered to be domain experts in their field of activity within a company. As such, employees pose a valuable source for improvement ideas (Setiawan et al. 2011; Fairbank and Williams 2001). Nevertheless, employees are often not involved in the innovation process (Setiawan et al. 2011; Fairbank and Williams 2001). The idea of employee participation in innovation processes is well-proven. Since the late eighteenth century employee suggestion systems (ESS) provide means for *employee engagement* and have been used to collect suggestions and ideas for improvements (Fairbank and Williams 2001). Integrating employees in the innovation process has the potential to lead to important improvements and financial benefits (Fairbank and Williams 2001). However, empowering employees to take part in innovation and improvement processes requires *organizational structures* facilitating employee involvement as well as *adequate tools* supporting employee commitment (Fairbank and Williams 2001). Considering the design of organizational structures enabling employee involvement, requirements and principles have already been defined (cf. Lawler 1986). Taking into account such design principles for organizational structures, the provision of adequate tool support to facilitate employee empowerment is still challenging organizational development.

Basically, two complementary views on empowerment at work and employee involvement have emerged in literature: a *sociostructural* and *psychological* perspective (Liden et al. 2000; Spreitzer 2007). The *sociostructural* perspective focuses on "conditions that enable empowerment in the workplace", whereas the *psychological* perspective focuses "on the psychological experience of empowerment at work" (Spreitzer 2007, p. 54). In general, sociostructural empowerment can be subsumed as the sharing of decision-making power between superiors and subordinates (Liden et al. 2000; Spreitzer 2007).

Parallel aspects of structural empowerment can be found in *high-involvement management* (cf. Spreitzer 2007; Konrad 2006; Lawler 1986). High-involvement management as well as structural empowerment focus on the sharing of decision-making power within different levels in the organizational hierarchy. Lawler (1986) identified that by providing *power*, *information*, *knowledge* and *rewards* the building of a high-involvement work system is enabled. These enablers are in line with Spreitzers' understanding of facilitators for structural empowerment (cf. Spreitzer 2007).

Providing *power* refers to sharing decision-making power between superiors and subordinates (Konrad 2006; Lawler 1986; Spreitzer 2007). Sharing decision-making power is not exclusively limited to granting final authority and accountability for decisions but already starts at giving employees the possibility to provide input and contribute to decision-making processes (Konrad 2006; Lawler 1986).

As Spreitzer (2007, p. 55) states: "*relevance is key*", *the focus lies on enabling employees to make and influence decisions concerning their day-to-day work*. Transferred to the context of workplace improvement, the goal is to enable employees to take part in improving processes, tools and artefacts and interactions in which they are involved in their everyday work (Lawler 2008).

Sharing decision-making power is necessary but not sufficient to facilitate employee involvement (Lawler 2008; Macduffie 1995). In order to contribute to improvement and innovation processes, employees need to know how their actions influence their environment and affect the organization's performance (Gibson et al. 2007; Konrad 2006; Spreitzer 2007). This can be done by explicitly providing *information* on performance indicators (e.g., output/throughput, revenues, costs) relevant for the particular work process (Konrad 2006). This information allows employees to reveal how their actions or planned changes in their workplace affect the organization. Furthermore, the provision of additional information supports employees when making decisions and suggestions (Spreitzer 2007).

Knowledge, in terms of an employee's skills and abilities, is essential when it comes to making right decisions and taking action (Lawler 2008; Konrad 2006). This includes not only knowledge about a certain work task but also interdependences and economical aspects within the organization (Lawler 2008).

Additionally, financial *rewards* are seen as a compensation for additional involvement beside the day-to-day work (Spreitzer 2007) and, furthermore, are seen as a method to ensure that employees use the given power and information for the organization's advantage (Konrad 2006).

Taking into account the importance of humans within socio-technical development as well as their empowerment in organizations, a context sensitive understanding of workplaces is essential. There has been considerable research in the notion of context in business processes and context awareness of business process management systems (Rosemann et al. 2008; Saidani and Nurcan 2007; Wieland et al. 2007). Context can be generally defined as "any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" (Dey 2001). Context in the domain of business processes has been more narrowly defined as "the minimum set of variables containing all relevant information that impact the design and execution of a business process" (Rosemann et al. 2008). In accordance with this definition, most work on developing context-aware systems in business process management focuses on the adaptation of processes to changes in the context (Rosemann et al. 2008; Saidani and Nurcan 2007). This aims at increasing the effectiveness and efficiency of processes, by reducing the gap between desired process behaviour and the workers' interactions afforded by specific contextual conditions.

Including the views of human workers in context-aware systems requires a dynamic, people-centred notion of context. Based on Dourish (2004), Kannengiesser et al. (2014) define interactional context as "a process that generates subjective views of a workplace. The workplace is the environment a process participant interacts with; it can include the technophysical environment (tools, business objects, physical layout, etc.) and the sociocultural environment (values, norms, organizational structures, etc.)". The subjective perspective of interactional context provides a suitable basis for developing context-aware process applications that are adaptive to the individual psychological and physiological needs of human actors. For context-aware processes to be labelled people-centred, it is not so much the specific information dimensions (e.g., technophysical, sociocultural etc.) of context that matter but the way in which context information is captured and used for the benefit of workers.

In this book *people-centred context awareness* is understood as the ability to adapt workplaces to the workers' needs so that the changes are perceived as beneficial by the workers. Thereby two important aspects are differentiated:

- Capturing context
  - Direct sensing by workers
  - Indirect sensing via facilitators (Observer, Contextual Inquiry, Contextual Design)
  - Physiological Sensor systems

- Adapting Processes to context:
  - Process instances
  - Process models

Summarizing, requires a novel, integrative perspective on system design. Although the fundamental understanding of can be applied, the constituents, relations and contextual factors of these systems need to be revisited. In particular, the roles need to be redefined in terms of active actors operating on concrete work tasks as well while at the same time rethink the structure and arrangement of these work tasks. Dynamic development of processes seems to be crucial for meeting the demands of today's production companies. Since management can only represent regulative power in terms of standards and legal frameworks, workers need to be empowered to develop design force. Adapting and designing production and business processes across organizational layers requires interactive tool support. It needs aligning previously isolated areas to enable novel concepts such as servitization delivering value to customers.

2.3 Organizational Challenges of Future Production—"Servitization"

Digitization is driving many organizations, both in service and manufacturing industry. The impact of digital technologies on services and products are so severe that organizations in all sectors have started revisiting their business models and production processes. In manufacturing industries, traditionally developing and producing tangible goods, providing customers with services such as maintenance and repair, have not played a significant role in business strategies. When taking them into account these services as part of value-driven operation, "servitization" conceptualizes the idea of manufacturers becoming service providers (Lay et al. 2014). Thereby, the role of IT as an enabler for digitization has to be recognized (Abolhassan 2016). Since the integrated digitization of manufacturing and service industries is likely to have similarly far-reaching impact as the industrial revolution in the nineteenth century, a crucial question for manufacturing companies is not only how products are going to change in a digital world, but also what challenges arise from those developments for organizing work and production processes (Baines et al. 2013).

Products in a digital world are likely to become hybrid as physical goods increasingly integrate digital elements. Entire sectors, such as automotive heavily rely on digital components embedded in physical products. The benefit of such a shift are intelligent functions for customers affecting essential areas of human living, such as in case of healthcare through networked medical devices. Digital systems facilitate the development of hybrid products, so-called "digicals". Their effective use depends on high connectivity and real-time data processing capabilities enabling situation awareness.

Although digital information systems have formed the backbone of business operations now over several decades, many manufacturing and production organizations are still reluctant to digital integration tasks (see also two of the case studies in this volume—Chaps. 4 and 6). However, such an endeavour requires rethinking their organizational structure and processes (cf. Rigby 2014). While customers increasingly become digitally literate, organizations still are trying to cope with transformation tasks due to the socio-technical nature of that process and its adjacent challenges (cf. Rigby et al. 2015).

2.3.1 Changing the Business Model

For organizations a chance to compete in the realm of increasing digitization is cooperation with customers and companies outside the sector, and competition, as it brings about opportunities for them to design a digital business model in the realm of innovating it (cf. Roos 2015). Business indicators reveal growing technology sectors, see, e.g. TechCity et al. (2016) for the UK. Stakeholders are interacting with multi-sided platforms going beyond B2B and B2C, and proliferated rapidly with the Internet. They lead to the development of new business models to monetize innovative value propositions in digital markets. Internet intermediaries are considered as resource integrators, involving consumers and business partners in a process of co-creation of value, thus establishing an integrated, two-sided business model (Muzellec et al. 2015). Business models of respective Internet ventures reveal a clear pattern of evolution from inception to an integrated combination, B2B&C and B2C&B. This development can be accounted to a shift in the relative influence of different business stakeholders (ibid.).

The emerging concept of servitization has been recognized as trigger for changing business models of production companies. However, the expected benefits from servitization have not been measured so far on the business model level. As Cai et al. (2014) point out when analysing empirical evidence, manufacturing companies still encounter challenges when implementing servitization concepts. They could identify risks for each element of the business mode, in particular service strategy, -offering, -process and a variety of environmental factors. Today's managers still need guidance for service business development, in order to handle the process of introducing servitization and to develop respective organizational capabilities (cf. Paiola et al. 2012). For instance, organizations selling through distributors (indirectly) to customers, with functional structuring, are likely to achieve servitization "through four distinct phases: (1) rearranging collaboration with distributors, (2) enlarging the service competence of distributors, (3) modifying potential distributors into subsidiaries and (4) job enlargements in subsidiaries" (ibid.).

Recently, Tsou et al. (2015) could show that openness of organizations accelerates changes of business models. It concerns (i) the technological context (openness of technology) when adopting systems, (ii) the organizational context (i.e., openness of corporate culture) triggering innovation, and (iii) the environmental context (i.e., openness to the external environment) when opening boundaries to the external environment. In particular, openness to service co-production fosters organizational performance. In addition, knowledge reach/richness, and also process reach/richness plays a crucial role (see Fig. 2.1). Greater process reach/richness significantly increases the effects of service co-production on organizational performance. Process reach/richness is an explanatory variable that accounts for important differences in organizational performance. The latter clearly indicate that the process design is crucial for implementing servitization in manufacturing industries Fig. 2.2.

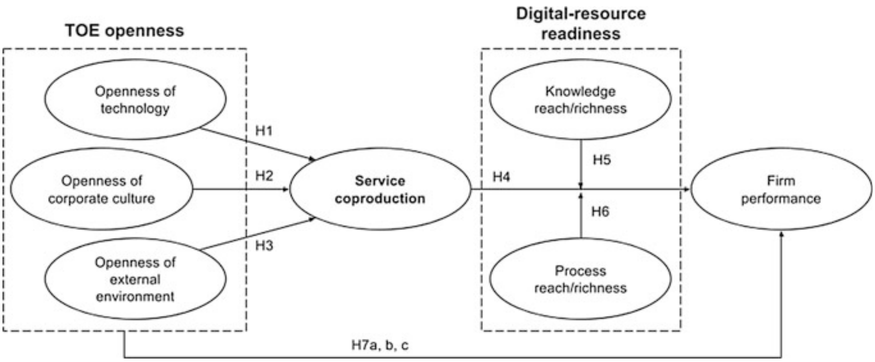

Fig. 2.1 Service co-production increasing organizational performance (adapted from Tsou et al. 2015, © Elsevier Ltd. All rights reserved)

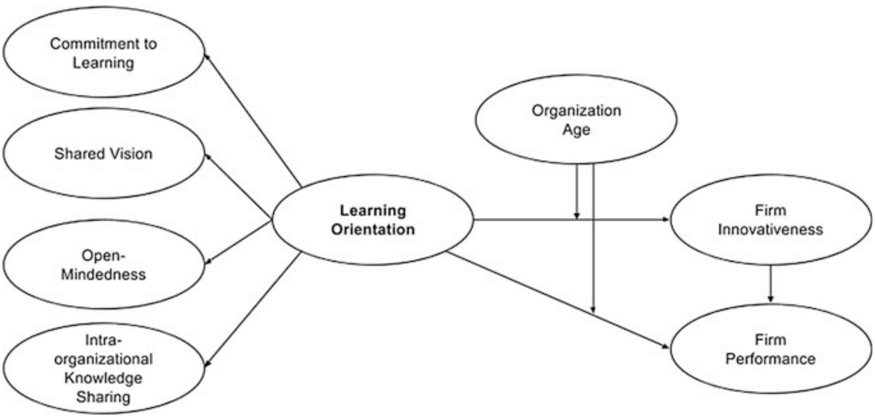

Fig. 2.2 Learning orientation (adapted from Calantone et al. 2002, © 2002 Elsevier Science Inc. All rights reserved)

The study has revealed several practical implications for managing business models:

- Top management needs to actively transform an organization's business models to an open model, in order to stimulate its ability to manage collaboration.
- Managers should remain highly sensitive to competition and the macro-environment while encouraging service co-production with partners.
- "With regard to IT service co-production project managers need to ensure that (1) project objectives are clearly defined in terms of openness aspects from both the market (i.e., external environment) and the organization's (corporate culture) perspectives, (2) the involvement and support of top management (i.e., the chief executive officer) are secured, (3) standard project management processes are used to mitigate the failure of service co-production practices, and (4) sufficient technological resources and capacity (i.e., digital resources) are dedicated to completing the service co-production project in the time allotted. This sequence of resource picking and capability building may serve as an effective roadmap for IT firms that are contemplating service co-production implementation" (ibid., p. 11).
- Digital process management for service operation is crucial, in particular when managing the increased amount and flow of knowledge related to customers. Moreover, "customers demand more information and knowledge about organizations with which they co-produce products or services". Digital process management is thus necessary to ensure that this need can be fulfilled (ibid., p. 12).
- Open collaboration channels are required for value networks supporting digital innovation. They are essential membranes for knowledge diffusion to partners and customers and vice versa.

As Raja et al. (2015) have found, value from servitized offerings will be derived differently by buyers and users. Buyers tend to value cost savings and innovation as key attributes, whilst users tend to value control over working processes. Hence, manufacturing management has to tackle attributes according to stakeholder roles, focusing internally on control issues organizing work processes.

2.3.2 Focusing on People and Learning

Continuous growth of digital tech work force has been identified in traditional industries. For instance, for UK TechCity et al. (2016) found that, of the 1.56 million jobs in the so-called digital tech economy, 41 %—representing 648,000 digital jobs—are in traditional industries. Between 2012 and 2015, the number of adverts for digital jobs across traditional industries grew 34 %. The skills it needs are not coming from traditional education, even when recognizing that educational triggers are required. It will take another generation of scholars to regain these skills. For instance, the recent "Computer Science for All" initiative in the US, enacted by the Every Student Succeeds Act (ESSA) into law, is a fundamental step forward for K-12 education, as computer science needs to be considered a new basic skill required for economic opportunity and social mobility.

In addition, there is the need to link technical skills with business skills. In particular, for product and service innovation, up-to-date technical skills need to be complemented with business know-how (TechCity et al. 2016). Technical skill development to that respect may require dedicated learning formats (cf. Willett 2007), as industrial product-service systems for lasting customer retention require new development methods). Herzog et al. (2013) identified cross-domain thinking to be essential for the developer's mind setting. Thereby, gamification can help engineers not to think in separate service and product domains.

Calantone et al. (2002) findings revealed, based on in-depth interviews with senior executives and a review of the literature, four components relevant for learning orientation: commitment to learning, shared vision, open-mindedness and intra-organizational knowledge sharing. Learning orientation affects the innovativeness of organizations, which in turn affects their performance.

Picot et al. (2013) have detailed skills required for organizing work in digitized societies. According to their findings the potential of digitization can only be leveraged when content, process, organization of work and collaboration are considered as design entities. Such an understanding goes beyond the provision of digital systems for organizations and their stakeholders. It requires rethinking processes and the technological infrastructure. They lay ground for increasing flexibility in work design, with respect to locality, time, connectivity and distribution of knowledge. The authors identified a set of competences that need to become part of qualification schemes:

- Networking skills to form communities and units in a more self-organized way
- Leadership based on social skills, such as conflict resolution in real time
- Comprehensive digital literacy, even leading to first time users
- Dynamic adaptation of regulations including business rules and decision-making procedures, in order to meet requirements from an organizational perspective, such as letting robots control production lines, and letting customers change orders up to production time
- Value responsiveness revisiting work-life balance

Finally, the involvement of employees in digital workflows leads to a higher visibility of the work activities. A flood of employee-related data needs to be screened with respect to preserving workforce protection. Transmitting workforce data requires approval when measuring performance or dispatching resources in real time. A gain in flexibility can be accompanied with the trade-off of self-control for workers.

2.3.3 Digital Service Provision

Traditionally, manufacturers use services to differentiate their products and trigger sales. Although they have different service strategies, three categories of service offerings were identified by Raddats et al. (2014): product-attached services, operations services on own products, and vendor independent operations services. Consequently, manufacturers follow different service strategies. The service offerings refer either to customers, products or services themselves, and can be differentiated further (ibid.):

- Services supporting the supplier's product versus services supporting the customer's processes
- Transactional services versus relational services
- Individual services versus bundled and/or integrated services
- Standardized offerings versus customized offerings
- Input-based services versus output-based services
- Product-attached services versus product-independent services
- Services on own products versus services on multivendor products

The relationships between categories of services are additionally depicted in Fig. 2.3.

Of particular interest for process design are all links to operational issues on the organization's value creation activities. "Despite the high level of interest in how organizational structures facilitate service orientation in capital goods manufacturing companies, researchers have neglected this field" (Gebauer et al. 2009). They have explored distinct categories of organizational approaches contributing to service orientation:

- Product-strategic business unit
- Product-service strategic business unit
- Service-product strategic business unit
- Service strategic business unit and product strategic business unit

Although each organizational approach reflects a unique degree of service orientation and thus, leads to different levels of performance outcome, it can be noted that of main interest has been the static anchoring of service orientation rather than the dynamics of business operation in relation to organizational structuring.

Organizational considerations so far seem to focus on either the integration or the separation of product and service business. However, manufacturing is shifted increasingly towards distribution and cloud-based services. Hence, not only core processes of production, but rather business model and architectures need to be revisited and restructured, emphasizing service orientation, high degree of collaboration, knowledge management, eco-efficiency. Current manufacturing involves all activities ranging from product design, production, fabrication, testing, maintenance and all other stages of a product life cycle (Li et al. 2010, 2011).

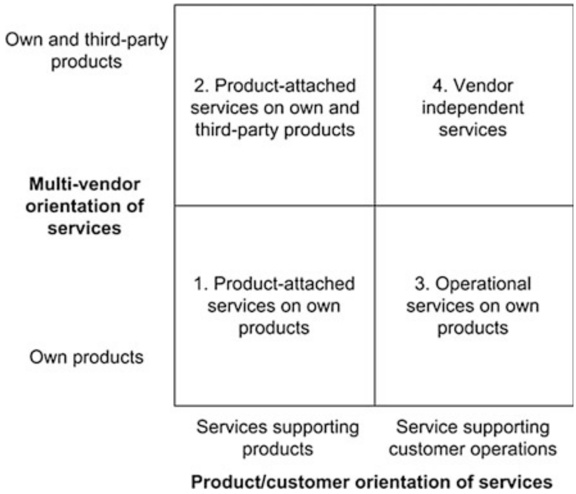

Fig. 2.3 Framework of service categories (adapted from Raddats et al. 2014, © Taylor & Francis Group)

While not evident from its beginning collaboration and service orientation are playing fundamental roles in becoming agile and stay in business (Tsou et al. 2015). From empirical evidence it can be concluded that is positively linked with increasing service networking activities of manufacturing companies (Bikfalvi et al. 2013), however, depending on the servitization strategy of an organization (see above). Consequently, interaction between organizations or business unit plays a crucial role in digital production. Manufacturers establish inter-firm collaboration for service operations. However, the results indicate that the mere existence of service networks does not guarantee success in servitizing (Bikfalvi et al. 2013) "Despite the existence of a parsimonious set of standardization efforts addressing product-related services, manufacturing firms have not reached a common understanding of the product-service system and the corresponding business processes and IT systems" (Neff et al. 2013, p. 1).

Servitization needs to rely on an intelligent and collaborative manufacturing service model. Distributed resources, such machines, computer-aided design and engineering tools, models repositories, and capabilities for design, fabrication, assembling, simulation, and testing need to be interconnected through process specifications and workflows for operation support (cf. Alexopoulos et al. 2011). They form a shared pool in servitized manufacturing, establishing a platform which can itself be considered as a service. Stakeholders (including customers) need access to services which are part cloud settings, in particular, encapsulating.

- Design as a service (Wu et al. 2012)
- Social networking as a service (Wu et al. 2013)
- Simulation as a service (Ren et al. 2011)
- Production, test and assembling as a service (Cohen et al. 2015)
- Logistics as a service (Holmborm et al. 2014)

Due to actor- or organization-specific requirements service manufacturing platforms need to provide intelligent service composition facilities. They allow customized settings including collaboration support. Finally, a service manufacturing platform should encapsulate not only a variety of physical resources but also knowledge categories in terms of operationalizing aggregated information, such as broker services or intelligent information agents (cf. Wu et al. 2013). Business processes could build the relevant boundary for building such platforms, as they provide operational procedures which can be embodied into various contexts relevant for an organization, including manufacturing and business model development.

2.4 Technological Challenges of Future Production Systems

With the advent of the Internet of Things (IoT) and its application in the industry sector (cf. Kagermann et al. 2012), not only the communication among technical IoT devices (e.g., sensors, actuators) and humans became vital to reach organizational goals but also the integration of different organizational levels (i.e., vertical integration of business processes with production planning systems and production control systems) has become an important aspect (cf. Meyer et al. 2013; Schüller and Elger 2013; Bassi et al. 2013; Kagermann et al. 2012). The vertical integration of business processes and technical manufacturing processes targets towards the need of production companies to be able to flexibly change requirements, reconfigure processes, get immediate feedback about the current state of production processes for the management, and to reach information integration between all process levels (Schüller and Elger 2013; Kannengiesser and Müller 2013). Accordingly, Haller et al. (2009) identify two paradigms from which business value out of IoT can be derived. First, real-world visibility which addresses the increased information on what is going on within the real world and thus allows to increase accuracy of timeliness of information and to support the identification of optimization opportunities. Second, business process decomposition is identified as a paradigm to gain added value out of IoT. The benefit of business process decomposition is described as following by Haller et al. (2009):

> The decomposition and decentralization of existing business processes increases scalability and performance, allows better decision making and could even lead to new revenue streams through entitlement management of software products deployed on smart items… Edge processing and business process decomposition allows applications to make (part of their) decisions locally in a decentralized manner and act accordingly. It thereby extends the real world visibility concept with real world interaction.

To implement such decomposed, distributed systems a design environment is required which allows to take into account “all business objects, business processes, services, as well as processing, sensing and communication capabilities of smart items" (Haller et al. 2009, p. 17). Such an environment should allow for modelling and executing organizational processes in an integrated and distributed way. Furthermore, it should support the adaptability of a model during deployment to support self-organization and optimization during runtime (Halleret al. 2009).

However, even if a vision of future production systems is well established, the design and implementation of such systems remains a challenging task. Subsequently, further characteristics, challenges and requirements related to future production systems are summarized based on literature findings.

Vogel-Heuser (2014, p. 37ff) describe the following fundamental technical characteristics of CPS:

- (Reference) Architectures allowing for the integration of diverse, heterogeneous system architectures
- Communication and integrated data flow among diverse stakeholders in terms of heterogeneous systems as well as different human target groups
- Intelligent products and production units, e.g. flexible units that may be adapted, products know where to go and consider changes in production environment, this typically requires a modular product structure and a model-based engineering approach which allows to adapt products at runtime. Thus, a specification of required (product) and offered (machine) capabilities is necessary
- Human-centred system design in terms of understandable data aggregation and integration and assistance.

In addition, Bauernhansl (2014, p. 26) envision a shift from the hierarchical automation pyramid to a service-oriented network. It will lead to encapsulating services within the different traditional automation layers and their provision in a service network. In such an environment, software, infrastructures, platforms may be offered as services which can be flexibly combined, e.g. software services to apps which may be used to support the value chain. In the context of modelling cyber-physical systems Derler et al. (2012) identify challenges like:

- Modelling interactions of functionality and implementation
- Modelling distributed behaviours
- System heterogeneity requiring the combination of multiple models
- Methodologies bridging the gaps between the disciplines involved (e.g., control engineering, software engineering, sensor networks) (Derler et al. 2013)
- Modelling service semantics

From the technological requirements given above, the following design challenges of future production systems can be derived:

- Handling the heterogeneity of system components
- Loose coupling of system components
- Case-based, flexible application composition
- Late binding of system components

- Providing means for modelling decomposed, distributed behaviours of organizational processes
- Modelling (message) semantics

2.5 Conclusive Summary Industrial Challenges

The aim of this chapter was to review industrial challenges in the area of "Industry 4.0". The review has been structured along the fundamental understanding of production companies as socio-technical systems. Socio-technical systems consist of three important aspects—(i) human, (ii) organizational structures and technology—and the interdependencies of these aspects.

The review reveals that humans will remain a vital element of future production situations and need to become involved in organizational development efforts and continuous workplace improvement. Organizational structures are challenged by changing business models of production companies. Enabling organizational change requires openness to adaptation and innovation, digital readiness), learning support and digital literacy of all involved stakeholders. In terms of adequate technology design for people in organizations, technical challenges have still to be tackled, in particular, developing adequate design and implementation environments for vertical and horizontal process integration to generate value from the Industry 4.0 concept.

The contents of this chapter frame the description of the S-BPM potential in the area of "Industry 4.0". In the following chapter this potential will be discussed and current developments from the S-BPM community will be summarized.

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