Beyond Industry 4.0 - seeking for the philosopher's stone

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Abstract

Purpose: The purpose of this paper is to explore collaborative innovation practice in the context of industrial renewal that is framed by ideological setting of the future based on sustainable growth.

Design/methodology/approach: Our approach is founded on a practice-based school of innovating, where a researcher is part of what is being researched and the interplay between multiple actors is emphasized. Although, this is mainly a conceptual paper, a participatory roadmapping process has been utilized as a tool for engaging a large group of experts of industrial ecosystems in co-innovation around the topic.

Findings: Our research describes how many mission-oriented innovations, aiming at sustainable growth, call for ideological compromises between private and social goals. Therefore, actors' engagement to the vision building is crucial.

Originality/value: This paper emphasizes that crossing the theoretical and paradigmatic borders enables actors to build shared meanings and gain better understanding of the multifaceted nature of business reality.

Practical implications: For managers, the core practical implication of the study is related to (eco)system thinking. The outcomes of the study highlight that going beyond industry 4.0 requires interaction with key players, as the resources, roles and offerings of industrial ecosystem actors are interconnected. In addition, through the identified emerging research themes of looking *beyond Industry 4.0*, we call researchers to co-innovating and creating a multilevel movement of challenge driven research looking beyond Industry 4.0

Introduction

The purpose of this paper is to explore collaborative innovation practice in the context of industrial renewal that is framed by ideological setting of the future based on sustainable growth. We will focus on industrial service ecosystems, where various different organizations and individuals work together with common objectives based on a non-hierarchical form of collaboration, in the context of manufacturing industry. Currently, complex global challenges are defying industrial service ecosystems. To begin with, climate change, scarcity of natural resources and population growth are strengthening the need to find profound and wide spread solutions in order to reach sustainable value creation - in terms of socially, ecologically and economically. All United Nations Member States adopted the 2030 Agenda for Sustainable Development in 2015 and it delivers a shared blueprint for peace and prosperity for people and the planet, now and into the future. The increasing concern and efforts to build shared agendas are more and more influencing the whole innovation system, from mission-oriented innovation policy to challenge driven ways of collaborating as far as to the content of shared visions. Mission-oriented policies are systemic public policies that appeal on frontier knowledge to reach specific goals or "big science deployed to meet big problems" (Ergas, 1987). Whereas challenge driven research is targeted to accelerate traditional innovation outcomes by leveraging co-innovation practices (Lee, S. M., Olson, D. L. and Trimi, 2012).

Vision can be described as a desired future state, it can be like a shared road map, a statement indicating what a group want to become or achieve by setting a defined direction for the actions. We see manufacturing industry framed by three settings of the future expressing different levels of shared agendas from the general mission of ensuring sustainable European competitiveness, to the challenge of digital transformation and finally to the attempts of reach shared vision of what that means as new logic, i.e. industry 4.0. Therefore, a participatory roadmapping process has been utilized as a tool for engaging a large group of experts of industrial ecosystems in co-innovation around the topic.

Within the industrial ecosystems, disruption is driven by servitisation and digitalization, i.e. the shift from goods/services differences to goods/service interdependencies and the emergence of data-enabled service systems as dynamic configurations of resources (people, technology, organizations, information). In these service ecosystems intangible assets, such as knowledge and skills, exchanges through interactions (Barile and Polese, 2010). Thus, practical research questions in this paper is: "How can the visions for the better future be best designed to enable participation across different actors and collaborative innovation practices for system-wide innovation?"

In this paper, we aim to explore the collaborative innovation practices required to go beyond Industry 4.0. Looking "beyond" refers to our mission-oriented enthusiasm to elaborate the fundamentals or crucial elements of collaborative innovation in the technology enabled renewal of industry. For this purpose, the paper integrates three key pillars (S -D logic, Service Science and Systems Theory) in order to have a comprehensive view on the digital transformation of manufacturing industry. We build on the service science approach with the aim of applying scientific knowledge to the design and improvements of service systems for economic, environmental and societal purposes enhancing the sustainable growth.

Although this is mainly a conceptual paper, the authors have active interactive relationships with the practitioners and through these interactions we aim to understand the studied phenomenon, digital disruption in Finnish industrial ecosystems, from the inside rather than the outside. As an example of a vision driven collaborative innovation effort, one of the leading technology research companies in Europe, VTT Technical Research Center of Finland Ltd., has taken an active role in tackling complex challenges (Hyytinen et. al. 2018) and boosting innovation ecosystems. They (ibid) build on the aim of turning global challenges into opportunities for the sustainable growth and renewal of industries through research-industry co-innovating. We will explore the first steps of an initiative focusing on the manufacturing industry with the vision of "Beyond Industry 4.0".

Our approach is founded on the practice-based school of innovating, where a researcher is part of what is being researched and the interplay of multiple actors is emphasized (Mele *et al.*, 2016). We perceive service as a fundamental approach to "apply knowledge for the benefit of another" (Vargo and Lusch, 2004), and thus adopt the S-D logic as a starting point. In line with the service ecosystem view (Vargo and Lusch, 2011), we broaden the level of analysis from firm's activities to network level continual co-creation involving a variety of actors within different roles. Moreover, in line with the current literature of innovation, we perceive innovating as collaboration beyond organisational boundaries rather than intra-organisation action ((Lee, S. M., Olson, D. L. and Trimi, 2012); (Valkokari, Paasi and Rantala, 2012).

Building the scene for Industry 4.0 co-innovations

Industry 4.0 is a concept already adopted in the interplay between research and industry to envisage the brighter future of manufacturing. Growing exports and high-value employment are strived through fully taking advantage of digitalization and its potential. According to Gartner, Industry 4.0 is a framework for

addressing the digitalisation of complex value chains and the efficient collaboration between businesses, IoT, technology providers and consumers. In other words, Industry 4.0 extends beyond the digitisation of physical assets, with the vision of a digitally enabled industrial economy that integrates business processes and data across multiple supply chains and their participants. The discussion has been extremely active and ended up to different interpretations. It is closely linked also to the concept of industrial internet of things (see (KIEL *et al*>, 2017) and grounded to many technological enablers. Such disruptive technologies, by definition, disrupt existing social institutional arrangements as they challenge and revolutionize the way business is conducted, competition in the market place as well as human interaction in a society. In other words, their diffusion requires a systemic change from macro to micro level (Geels, 2004); (Valkokari, Paasi and Rantala, 2012). On the other hand, it has been highlighted that the micro level implementation in industrial companies is still far away from the vision, i.e. companies are still at the phase of Industry 2 (Qin, Liu and Grosvenor, 2016) .

As pointed out above, currently the concept of Industry 4.0 has settled on being more a buzzword with the promises of the brighter future than a careful conceptualization that is generating cumulative knowledge based on the empirical research. (For which purpose it is not recommended here either). Thus, the economic, environmental as well as social opportunities related to Industry 4.0 can be identified (Kagermann H., 2015);

- flexibility and resilience of manufacturing increases and smart solutions provide platforms for new services and innovative business models,
- a wide range of real and virtual data offers full transparency with regard to products' resource consumption and enhances the optimization of product life cycles and even the move towards a circular economy
- quality of work will be improve, i.e. work will be more varied and interesting, workers will increasingly act as experts, decision-makers and coordinators.

Although, the industrial practice has not yet challenged the previous phases, a new stage is already introduced, Industry 5.0. in line with the Society 5.0 , see (Skobelev and Borovik, 2017). Society 5.0. seeks the full benefit of the technology potential in terms of creating better for human and the whole society. When the sustainable growth is more on a side role in Industry 4.0, it is more at the center in Society 5.0. Society 5.0.is defined by the Cabinet Office of Japan as a new economic society following the information society. The initiative describes the idea of super smart society that is human-centered, offering customised services that support higher quality of life by fully incorporating the technological innovations e.g. from the areas of robotics, censoring, AI and platforms. It brings digitalization across all levels of the society. The Society 5.0. includes a clear ideological statement with a strong motive to accelerate solving the most crucial sustainability challenges of the society (in Japan). It has already raised global interest and rose debate concerning the role of big government approaches (e.g. Fiorini, 2017).

In line with the Manufacturing Service Ecosystem concept (Wiesner, Thoben and Westphal, 2013), we define these industrial service ecosystems as a non-hierarchical form of collaboration where various different organizations and individuals work together with common or complementary objectives on the new value added combinations of manufactured products and product-related services. Anyhow, our focus, vision driven collaborative innovation, is broader than the products and/or services of one business ecosystem. In other words, we focus on collaborative innovation practices that may renew or even disrupt the current industrial service ecosystems. Therefore, we highlight the layered and a more loosely-coupled structure of ecosystems. As Vargo and Lusch, 2011, has defined service ecosystems as a "spontaneously sensing and responding to spatial and temporal structure of largely loosely coupled, value-proposing social and economic actors interacting through institutions, technology, and language (Vargo and Lusch, 2011). Within the service-ecosystems approach, "service flow emphasizes the continuous, dynamic and adaptive flow of service (i.e. intangible assets such as knowledge and skills) exchanges through interactions among networks of actors reciprocally engaged in value co-creation through complex relationships" (Barile and Polese, 2010).

Building on the 5 axioms of S-D logic, we suggest the vision created can serve as a tentative future value proposition, thus guiding the future oriented resource-integration intentions of actors needed in realizing the value in use. The innovation ecosystem activities can serve as a pre-form for institutional arrangements for future service ecosystems and involve both social and economic actors need for value co-creation that realizes the sustainability target in a specific use context.

The three perspectives of co-innovation towards industry 4.0

Challenge driven research can be defined as an innovation framework that accelerates traditional innovation outcomes by leveraging open innovation and crowdsourcing along with defined methodology, a process and tools for helping organisations develop and implement actionable solutions to their key problems, opportunities and challenges (Bonadio, 2011). Further, the approach *highlights the practical processes and tools for co-innovation.* In line with the practice based view to innovations, it pursues to understand innovating as a system of ongoing activities, emerging from actors networking and socializing, something that is a value co-creation matter and socially constructed (Russo-Spena, Mele and Nuutinen, 2017).

The literature of innovation highlights that disruptive as well as radical innovations are architectural and system-level in their nature. They are new to the firm, its customers and suppliers, industry and/or the world. Therefore, such innovations can be competence destroying or destructive, when reflecting their impact on markets, firms, and industries (Schilling, 2013) and the whole processes of value creation (Christensen, 1997). Thus, a conceptual framing of management within such system-wide innovations within industrial systems, i.e. shaping new markets and changing the whole processes of value creation in industrial service ecosystems, is recognized as a rather neglected area of research in prior studies. However, in practice, the incremental and sustainable innovations are more typical and desired although these different kinds of innovations occurred within natural and repeatable cycles.

Within industrial ecosystems, three types of innovation can be identified: 1) efficiency innovations, which reduce or simplify the delivery of something focus often on production systems, 2) renewing innovations, which replace older models with new ones are connected with design approaches and 3) disruptive innovations, which transform industrial ecosystems and can enable significant opportunities for growth. These three types of innovation difference in their focus, practices as well as outcome. The figure 1 emphasis this, i.e. how efficiency innovations typically aim to increase of profit, renewing innovations target on designing new products or services (value for customers) and disruptive innovations are intentionally looking for changing the game within industrial ecosystems.

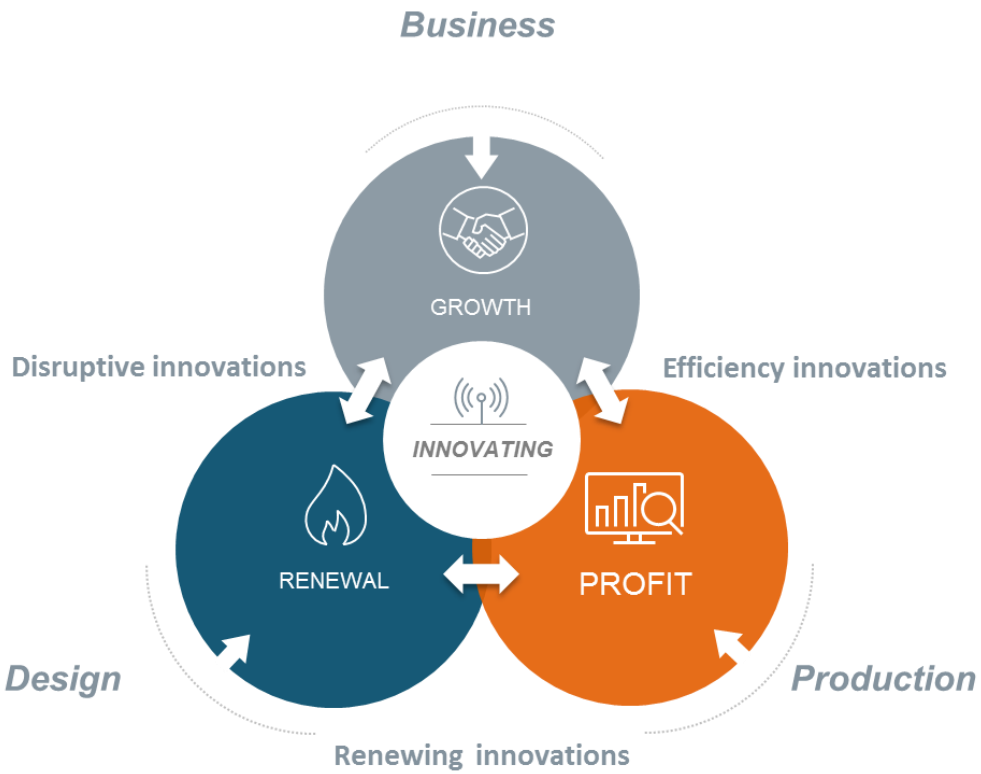

Figure 1. Innovating in Industrial ecosystems - conceptual framework

Our conceptual framework (Figure 1) approaches the Industry 4.0 phenomenon from the meso-level, that is, from the viewpoint of the managers of industrial companies and research organisations. The framework highlights that in order to be able to enhance the digital transformation, actors need to understand the mechanisms to shape industrial systems in order to be able to plan and reflect their own actions. In our framework, we suggest the three types of (co)-innovation as a mechanism that shapes industrial ecosystems towards the vision of "Beyond Industry 4.0".

From business strategy perspective, we emphasized the need to create the sustainable growth that is based on the Finnish (and European) strengths as well as urges to solve societal challenges with human in the focus with exploiting technology (in line with the idea of Society 5.0.). Strategies of that kind put into the design of services and products as well as guiding the new logic of production might reach systemic innovation and emerge of new service ecosystems.

Exploring Beyond Industry 4.0 - our roadmapping process

Science and technology foresight, including roadmaps, is regularly used at macro-level long-range planning for economic and social policy development by national governments ((Valkokari *et al*>, 2014). Thus, road-mapping can be used at meso or micro level to integrate technology and business approaches to vision-building ((Phaal, Farrukh and Probert, 2001); (Ah*lqvist et al*>, 2010)). While this paper, aims to explore the collaborative innovation practices required to go beyond Industry 4.0., the participatory roadmapping process has been utilized as a tool for co-innovating. The strength of the road-mapping approach is in the

identification of barriers, as well as enablers addressed with these barriers, and in the generation of shared targets - i.e., creating a multilevel movement of challenge driven research looking beyond Industry 4.0

The roadmapping process involved a smaller core group and the expert group. Figure 2 presents the activities of both the core group and the expert group within these phases. The authors of this paper formed the core group. The cross-disciplinary expert group consisted of researchers with different backgrounds. Each had several years of experience with the manufacturing industry and its current development challenges. In addition, these experts are actively participating in strategic agenda formation within European research and innovation policy networks around the topic, for instance Big Data Value Association (BDVA), The European Factories of the Future Research Association (EFFRA), and Sustainable Process Industry (SPIRE).

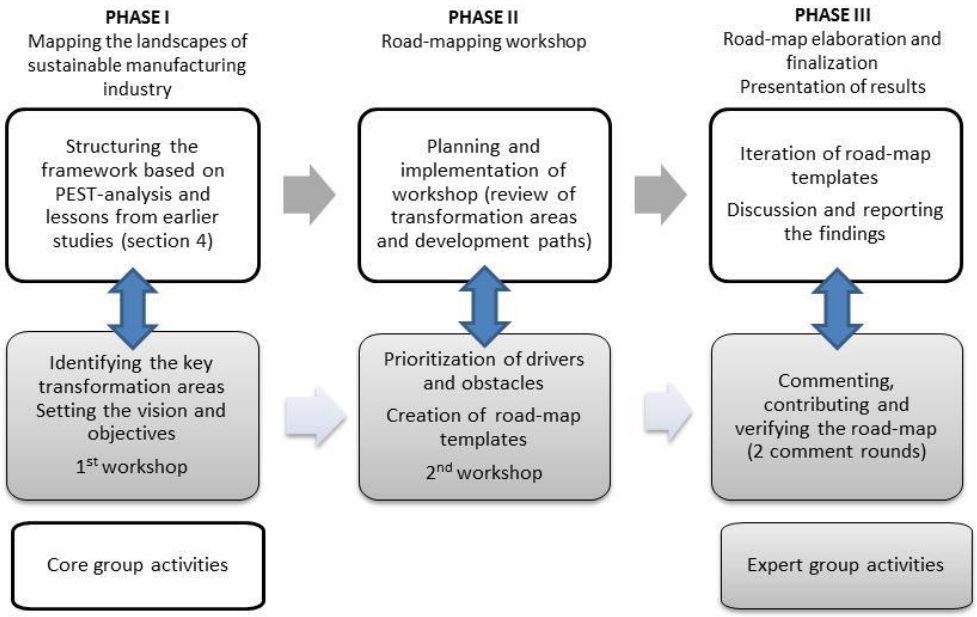

Figure 2. Roadmapping process

The road-mapping process was completed in three phases: mapping of the landscapes of sustainable manufacturing, road-mapping workshops with experts, and the roadmap elaboration and finalisation. First, the core group mapped and positioned the relevant literature, including existing roadmaps and scenarios formed by above-mentioned organisations. The previous sections summarize the results of this phase. The aim of the first workshop with the broader expert group's was to brainstorm the future scenarios and identify novel opportunities emerging, when complex global challenges are defying industrial service ecosystems. In all, over 50 people participated in the first workshop and were physically present. Thus, in order to allow reflection on the changes that are needed for an industry's development, it is important to know what we want to reach and where we wish to end up. Therefore, the next two workshops with smaller expert group (around 20 participants) focus on creating more dedicated roadmaps for different industrial ecosystems.

Finally, workshops were followed by project core group iterations and the commenting rounds organised in the spring of 2019. At this phase, the results were also reflected with company representatives. This was done in line with the aims of the practice based view to innovation, which emphasize the interplay of multiple different actors. This phase's aim was in identify the change directions in the key areas of digital transformation beyond Industry 4.0 and crystallise the connections between the various roadmaps. The results of this work are presented at the findings section.

Findings

Our findings present the co-innovation practices that enable different actors, researchers with multidisciplinary backgrounds, to resolve (together) the contradictions and inconsistences of the current logic of action within manufacturing industry ecosystems. Linkages between various levels (micro, meso and macro) are important in roadmapping beyond Industry 4.0. During the roadmapping process, the future research themes were identified and they were summarized to the Figure 3. At the phase III, the concept "Beyond Industry 4.0" was approached in the interconnection with the Society 5.0 in order to enhance the participants in for a broader vision of change in longer run.

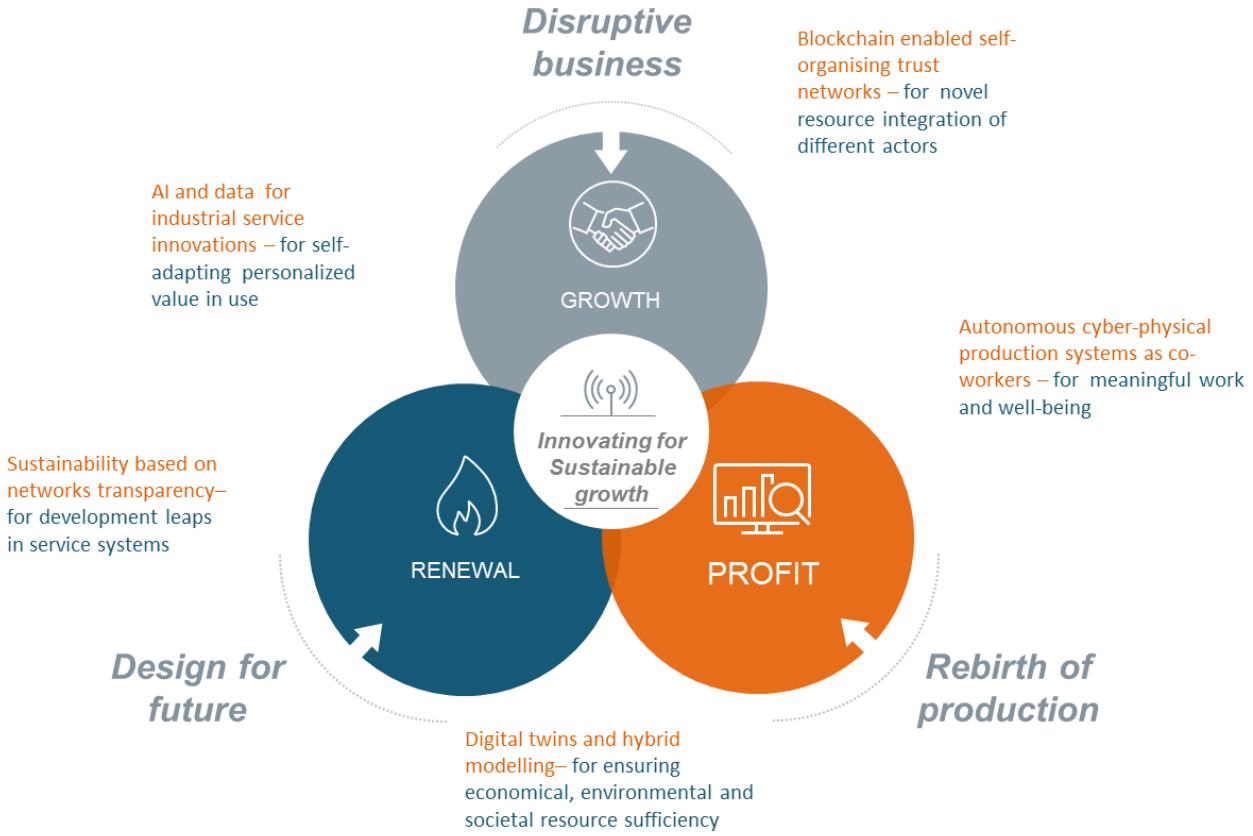

Figure 3. Emerging research themes beyond Industry 4.0

Many mission-oriented innovations, aiming to the sustainable growth, call for ideological compromises between private and social goals as well as balancing between ecological, economic and social impacts. It will be necessary to support processes for envisaging and then negotiating these goals right from the outset. Collaboration between the many heterogeneous actors and industries will thus be crucial. Therefore, ecosystems have been identified as the promising way and vehicle to solve complex global challenges within the multilevel self-organising network of independent actors. The promise of multifaceted value embedded in the shared vision serves as a motive for actors of different kind to develop value propositions for resources to be integrated into the future service ecosystem. Key for ecosystem composing and orchestration is to generate shared meanings together with key actors. So, when parties have different interests and those interests collide the need for effective boundary spanning is highlighted. The institutionalized set of present rules, roles and beliefs tend to remain even when actors develop new value propositions. For instance, blockchain enabled trust networks could provide a way to overcome these and create novel means to

integrate resources that exceed the present logic of business for example according to the ideological aims. In addition, the central role of ecosystem orchestrators has also been noted and can serve as an entity that support new visions, practices and roles to emerge (and thus breaking institutional arrangements preventing the mission-oriented innovation, cf.(Wieland, Vargo and Akaka, 2016). However, research and technology organizations (RTO's) can have a central role in building dynamic and open ecosystems with a variety of partners that can recognize the challenge with new service ecosystem potential of the digital transformation of industry. And therefore, challenge driven research provide new means for looking beyond the state-of-the-art and identifying obstacles as pointed out by Hyytinen et al 2018.

Conclusions

The purpose of this paper has been to look beyond the concept of Industry 4.0 as an example of collaborative innovation effort with an ideological aim and thereby envision the key aspects of challenge driven research within the manufacturing industry. While most of the current studies have focused either on business or technology perspectives, our study emphasised the need for a broader view of systemic change through the mission-oriented view. This means tackling complex global challenges but in a more focussed, problemsolving manner based on the European strengths (Mazzucato, 2018).

In a constantly changing world, the value of this paper is built on this approach, as a new way of doing things is proposed. Mission oriented/challenge driven research break the tradition of scientific disciplines. Hence, crossing the theoretical and paradigmatic borders enables actors to build shared meanings and gain better understanding of the multifaceted nature of business reality. On the other hand, it is more challenging to define the scientific contribution of such broad approach.

For managers, the core practical implication of the study is related to (eco)system thinking. The outcomes of the study highlight that going beyond industry 4.0 requires interaction with key players, as the resources, roles and offerings of industrial ecosystem actors are interconnected. Thus, ecosystem actors should build the digital transformation to their own strengths, such as BtoB service offering, understanding of value-in-use and engineering for project deliveries as well long tradition on industry-research collaboration. When seeking for the shared target, integrating the more societal and human focused topics into the vision of manufacturing industry competitiveness through Society 5.0 seemed promising. There are also examples that companies can initiate new approaches to realizing Society 5.0 with customer co-creation business on the basis of the S-D logic as a key strategy (Fujii et al. 2018).

This study has evident limitations, which at the same time yield opportunities for further research. Following the notion of Naples Forum on Services that service systems are enormously complex, we adopted several perspectives to this study, but somewhat failed to reach a coherent systemic view. To gain a broad perspective on the subject, the authors selected a multidimensional view through the three innovation types. During the roadmapping process the phenomenon were explored at three levels from macro to micro. Qualitative and or quantitative studies on industrial ecosystems could be conducted to check the reliability of the results at the micro level. The deeper analysis of the change items (i.e. barriers and enablers) and their significance is a company - as well as and industry-specific matter and, thereby it, should be handled at meso level with ecosystem actors considering their own context. Finally, mission oriented approach at macro level needs to be transparently connected with bottom- up experiments in order to build comprehensive understanding of the multi-layered outlines of possible futures.

Topic: Industry 4.0 and digital transformation

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