Accelerating Technological Advancement and Adoption of Industry 4.0 Technologies: Smart-Factory Labs, Digital Capability Centers and Lighthouses Networks

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Abstract

The Future of Production is smart and connected, being showcased at factory level by “cyber-physical production systems” converging the digital and physical worlds, and networking all levels of production from the field level to the ERP level (i.e., vertical integration), and across the production line from raw materials to finished products (i.e., horizontal integration); and by “glocal production networks” interconnecting manufacturing and logistics systems. Furthermore, production intelligence addresses a dynamic market that calls for different lot-sizes and quick responses to customer’s individual demands by leveraging the advances in information, operational and engineering technologies. In this paper, we focus on how to accelerate technological advancement and adoption of Industry 4.0 technologies in order to aid the digital transformation of today’s factories. We highlight the value created by smart-factory labs, digital capability centers, and (digital) lighthouse. We mention how these entities facilitate the implementation of Industry 4.0 technologies globally by: contributing towards awareness, education and training; assisting SMEs in digital/smart technologies adoption; promoting best practices; and creating a global innovation network of smart industries.

Keywords – Industry 4.0, Smart Manufacturing, Smart Factory-Labs, Technology Test-Beds, Digital Capability Centers, Industrial Showcase-Sites, Digital Lighthouses.

1 An Industry 4.0 Vision

In the near future, all factory objects will be integrated into decentralized and self-organizing industrial networks known as: “Cyber-Physical Production Systems” [1]. At factory level, vertical integration will allow to directly access every machine tool and device on the shop-floor through edge/fog/cloud computing. This will be achieved through an industrial network of smart sensors, actuators and controllers of – “intelligent production resources” – with sensing, processing, communication, and actuation capabilities. Moreover, big data analytics and other data-driven services will enable exact forecasting and closed-loop automatic controls of manufacturing and logistics processes. Information can now be provided in real-time to the smart operator using intelligent user interfaces based on augmented and virtual reality [2].

Figure 1. Digitalization and Industry 4.0 Overview

Owing to a horizontal integration, very small batch size production will be possible. This can be achieved with cost-efficiency and Just-in-Time (JIT) manufacturing to customer’s individual demands. Before long, customers will co-design and order their products at the click of a mouse, and expect their personalized products to be delivered to their home within a few days or even hours by a drone or AGV (Automated Guided Vehicle) [2].

The digitalization of production planning and control through digital twins and digital object memories [3] can provide enhanced visibility, traceability, and real-time synchronization and adaptation of distributed work and material flows [2].

2 I4.0 Technologies Adoption Challenges

Despite the huge potential of Digital Transformation for industry, the adoption of Industry (I) 4.0 technologies is a complex “socio-technical” and “financial” challenge for companies, and particularly for SMEs. Nevertheless,
the digitalization of SMEs is essential in order to avoid a “digital divide” of current global production networks, as companies evolve from the Industry 2.0 or Industry 3.0 to the Industry 4.0 due to their limited access to, use of I4.0 technologies. The following typical problem areas or challenges have been identified for companies based on a literature review and discussion-based interviews with academic and industrial experts on CPPSs (cyber-physical production systems), and smart supply and logistics chains:

- **Lack of Awareness**: Companies, particularly SMEs, have no or only little awareness about the on-going digital transformation and Industry 4.0 Revolution – or they underestimate its potential to disrupt their own production technology and business model.

- **Lack of Corporate Courage and Digital Leadership**: Companies may be aware of the on-going Fourth Industrial Revolution or Industry 4.0, but they do not have the courage, authority and/or control to push through the needed digital transformations within their own organization, which are part of global production networks that are currently being digitalize [4].

- **Lack of Practical Knowledge**: Companies are aware of their digital transformation strategic/operational needs, and have the courage to undergo through the digital journey for their operating and/or business models. However, they are lacking of the methods, tools and practical guidance as well as best practices in defining their focus area, and extending their digital transformation [5].

- **Lack of Rightly Skilled Talents**: Ultimately, the lack of rightly skilled digital talents to implement and maintain the modern information, operational and engineering technologies arriving and disrupting the shop-floors and value chains/networks, restrain companies from adopting Industry 4.0 solutions and becoming a – “relevant-player” – in their digitalized global production networks [6] [7].

For accelerating the technological advancement and wide-adoption of Industry 4.0 technologies, certain Digital Ecosystem stakeholders are required in order to facilitate R&D, technology transfer, and knowledge sharing (i.e., awareness, education, and training) across industry:

1. **Smart-Factory Labs** – focus on applied research, technological development, and trial of Industry 4.0 technologies towards innovative use-cases (e.g. [8] [9] [10]).

2. **Technology Test-Beds** – focus on experimenting and running first industrial pilots of mature Industry 4.0 technologies towards use-cases validation [11].

3. **Digital Capability Centers** – focus on education and training of the future production workforce by cross-skilling, up-skilling, re-skilling and/or expert-skilling it in digital skills with practical knowledge and hands-on experience on the strategic/operative use of Industry 4.0 technologies [12].

4. **Industrial Showcase-Sites** – focus on offering a go-and-see experience of companies leading the way on digital transformation of their operating and/or business models. These showcase-sites may feature the successful adoption of one or more Industry 4.0 technologies [13].

5. **Digital Lighthouses** – focus on being the world-class best practice for their industrial sector [13].

### 3 A Global Digital Innovation Ecosystem for the Future of Production

We propose a Global Digital Innovation Ecosystem for the Future of Production combining and networking three different types of stakeholders, and their tangible and intangible assets, following two main strategies for value creation: (i) smart-factory labs and technology test-beds, (ii) digital capability centers, and (iii) industrial showcase-sites and (digital) lighthouses.

The main objectives of this global digital innovation ecosystem are: (a) to accelerate the development of new industrial applications of Industry 4.0 technologies, thru collaborative R&D and open innovation practices among smart-factory labs + technology test-beds, (b) to facilitate the testing of the interoperability of 4.0 technologies use-cases across different industries and geographies, (c) to allow the “bench-marking” and “show-casing” of the Industry 4.0 technologies adoption, facilitating best practices by opening selected factories as showcase-sites and promoting them as (digital) lighthouses, and (d) to promote the co-development of education and training programs to help companies and their employees to acquire new digital capabilities and digital skills required for the successful adoption and strategic use of Industry 4.0 technologies.

#### 3.1 Horizontal Value Creation Strategies

The different stakeholders, and their assets, which are part of the ecosystem, could be connected horizontally via the following value creation options:

- **Smart-Factory Labs and Technology Test-Beds** – Accelerating the technological advancement and adoption of Industry 4.0 technologies by promoting controlled experiments to learn about their benefits as “digital levers” towards mature use-cases as well as for running pilots of innovative use-cases for the development of new digital competitive advantages, both involving “collaborative R&D” and/or “open innovation” projects focused on specific business and technology opportunities, as well as problems.

- **Digital Capability Centers** – Integrating a global education and training network targeting:
a) CEOs and Ministers in order to support them in the creation of a “digital vision”, and a “digital strategy”, based on what is possible now thanks to the Industry 4.0 technologies capabilities, so that through “smart industrial policies”, they will be able to drive their different industrial sectors towards the Fourth Industrial Revolution.

b) Sr. Executives and Sr. Officials envisioning the “digital future” of their industrial sectors and governments/societies and requiring of a “digital transformation roadmap” tailored to their businesses and government needs correspondingly.

c) Executives and Officials leading efforts in Industry 4.0 technology adoptions and digital transformations of their business and/or operating models.

- **Industrial Showcase-sites and Digital Lighthouses** – Different showcase-sites and lighthouses with a specific industry focus could share best practices and technology scale-up strategies across industries.

### 3.2 Vertical Value Creation Strategies

The different stakeholders and their assets, which are part of the ecosystem, could be connected vertically via the following value creation options:

- Driving “technology transfers” from smart factory-labs and technology test-beds to digital lighthouses, after successfully demonstrating the creation of one or more “digital levers” capable of offering new digital opportunities for firms and industries.

- Training top- and middle-management executives and officials on specific use-cases implementations of Industry 4.0 technologies by linking directly digital capability centers with smart factory-labs or technology test-beds, so their firms and industries as well as employees can acquire new digital capabilities and digital skills.

- Accelerating 4.0 technologies adoptions at-large out of the smart factory-labs and technology test-beds thanks to the digital lighthouses actions as early-adopters and evangelists of the new technology.

### 4 First Int’l. Smart-Factories Labs Summit

As a first effort to network a group of smart-factory labs, the 1st International Smart Factory Summit took place at Biel, Switzerland from September 21 to 23, 2018. The summit theme was: “Towards a Global Network of Connected Smart Factories and Their Talents”.

Initiatives from across the world including: Germany, Romania, Sweden, UK, Mexico, USA, Korea, Japan, Malaysia, Vietnam, Indonesia, and Switzerland – were participating. During two intensive working days over 40 participants exchanged best practices and ideas to accelerating technological advancement and adoption of Industry 4.0 technologies on a global scale. Overall, the international summit hosted three working sessions.

#### 4.1 Session 1: Smart Factory Labs around the World – Concepts, Models & Best Practices

Session 1 investigated the requirements to coordinate international knowledge exchange and to support a global digital innovation ecosystem for the future of production. The session presented the learnings of aforementioned initiatives and identified new and/or emerging initiatives world-wide. Questions discussed in this session were:

- How can we learn from each other; exchange best practices and technologies in a world-wide network?
- Which challenges can only be addressed with a globally coordinated approach, and which ones need to be addressed on the local level?
- Do we need a quality check or brand for the world-wide initiatives?

The remarks of the session can summarized in a strong believe – by its attendees – that shared resources provide cost-effective solutions, global collaboration promotes “global” and “local” solutions, and new networks expand knowledge and current value creation chains’ capabilities.

#### 4.2 Session 2: Smart-Factory Labs and Digital Capability Centers in Training and Education

Session 2 investigated the changing roles, tasks and demands on the human worker in the Factories of the (near-)Future. Under the pressure of technological advancement, companies require to (re-)evaluate the education and training of their employees. Questions discussed in this session were:

- Which role(s) can smart-factory labs and digital capability centers play in the education and training of the future (digital) workforce?
- How can networked smart-factory labs and digital capability centers help each other w/ the preparation, execution, auditing, certification and evaluation of newly designed training and education programs?
- Which new education and training technologies can accelerate the pace of learning?
- How can we link smart-factory labs and digital capability centers with other education and training platforms throughout the world?

The remarks of the session can summarized in the need to accelerate the up- and re- skilling of the current and future production workforce thru innovative educational and training approaches, under a “renewed” life-long learning perspective, and taking advantage of course of the new educational technologies (i.e. Education 4.0).
4.3 Session 3: A Global Smart Factory System Architecture

Session 3 addressed the technical hurdles that mfg. systems must overcome to allow more customer-focused value creation. Smart Factories are seen as an integral building-block of a smart world – integrating seamlessly with smart logistics, smart cities, smart infrastructure, etc. In order to be able to react appropriately to current and future challenges, production facilities must become: highly-modular and reconfigurable; internally and externally networked; self-aware, self-descriptive, self-sensing and transparent; smart, intelligent, adaptive, proactive and self-optimizing; human-centered and flexibly automated, and finally capable of individualized mass-production. Questions discussed in this session were:

- What is the definition of a smart production facility?
- Which standards, technologies, and architectures require international awareness and collaboration?
- Do we require a “global” smart factory system architecture standard?
- Which regional and national aspects need to be considered, when developing a global smart factory architecture (e.g. regulations, skills, technology readiness levels, etc.)?
- How can we link smart factory systems throughout the world based on a “global” smart factory system architecture?

The remarks of the session can be summarized in the need for collaboration in international norms and standards, and their importance, for the emerging digitalized global production networks.

5 Conclusions

There are many research challenges in the road ahead for the “Factories of the Future” from the perspectives of human, machine, planning and control, operation and maintenance, and product design as shown in Figure 2, which require open international collaboration.

Overall, a Global Digital Ecosystem for the Future of Production is fundamental for the rapid technological advancement and adoption of Industry 4.0 technologies. Such innovation ecosystems must consist of horizontal and vertical networking and value creation strategies for their stakeholders. To facilitate this networking on a global scale, an international coordination approach is required in order to connect and apply local knowledge and best practices on Industry 4.0 across different and various geographies.

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