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Smart Factories: South Korean and Swedish examples on manufacturing settings

Magnus Wiktorsson[a]*, Sang Do Noh[b], Monica Bellgran[a], Lars Hanson[c d]

[a]*KTH Royal Insitute of Technology. Dept of Sustainable Production Development, Södertälje, Sweden*
[b]*Sungkyunkwan University, Dept of Industrial Engineering. Suwon, South Korea*
[c]*Scania CV. Global Industrial Development. Södertälje, Sweden*
[d]*University of Skövde. School of Engineering Science, Skövde, Sweden*

Abstract

What constitutes a company's capabilities to develop a Smart Factory? South Korean and Swedish perspectives are here illustrated by company examples of smart factory solutions and related strategic aspects of their digitalization. It is concluded that the "smart-factory-capability" of a manufacturing company is integrated with its corporate production systems and includes perspectives on application areas, value adding processes as well as enabling technologies. It is furthermore challenged by the transformational inabilities of legacy systems. By its concrete examples is use and financial benefits, the paper contributes to the definition of *the smart factory* and its corresponding development scheme.

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Keywords: smart factory; smart manufacturing; digitalisation maturity; capability; manufacturing industry; transformation; South Korea; Sweden.

1. Introduction

Manufacturing is undergoing major changes in terms of digitalization, technology development and environmental concern, driving a renewal of industrialized countries such as Sweden and South Korea, but also challenging the traditional role and scope of manufacturing. Recently, the advances in ICT (Information and Communications Technologies) have progressed in various fields, including hardware and software, bringing a

* Corresponding author. Tel.: +46-8-790 94 28.
E-mail address: magwik@kth.se

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renaissance to the manufacturing industry. This ongoing paradigmatic shift is enhanced by the German-initiated 'Industrie 4.0' concept launched 2011 [1]. The enablers of Smart Manufacturing and/or the Smart Factory are a collection of various technologies that can promote a strategic innovation of the existing product development and production in manufacturing industry through the convergence of humans, processes, technology, and information.

Since the field of Smart Manufacturing is still in a rather immature phase, there are no fully established definitions. However, one example of definition of Smart Manufacturing could be: *"a (fully)-integrated and collaborative manufacturing system that responds in real time to meet the changing demands and conditions in the factory, supply network, and customer needs"* [2]. It means that the active manufacture-based technologies and systems can respond in real time to internal and external changes, thus by getting more adaptive and diversified.

From an international perspective, initiatives within the EU's *Digitising European Industry*, German *Industrie 4.0*, the US initiatives *Advanced Manufacturing Partnership* and *Smart Manufacturing*, China's initiative *Made in China 2025*, South Korean *Manufacturing Innovation Strategy 3.0* and UK's *Catapults*, emphasize the use of information technologies and automation in manufacturing and the realization of smart industries by cyber-physical systems. These national and multinational initiatives have initiated a multitude of research programs, testbeds and projects in order to develop new knowledge and applications for the manufacturing industry. It is argued that smart manufacturing is difficult to achieve (at least at the level of performance and value it potential can provide) if coordinated efforts are not taken, no matter how large a single manufacturer is [3]; uncoordinated initiatives would mean replication of efforts and very high investments that is against the intention of smart factories.

South Korea and Sweden are two interesting examples of being a manufacturing-oriented country, sharing the similar industrial structures regarding size and sectors, as well as typical manufacturing challenges and opportunities. For example, automotive companies cooperate and often share supply networks globally. Manufacturing companies in South Korea and Sweden are currently developing and testing concepts and applications of Smart Factory technologies. The development and modernizing of manufacturing industry in both countries is supported by extensive governmental investments with the overall purpose of creating a world class manufacturing sector.

In this paper, an attempt is made to bring high level concepts of smart manufacturing to the concrete, using examples from South Korean and Swedish SMEs and large companies. It aims to contribute to the definition of smart factory and its corresponding development scheme by discussing key enabling and hindering dimensions for building the "smart-factory-capability" of a company. Areas specifically discussed are; the need of integrating the technology-driven smart factory initiatives with the operative production systems, different perspectives on initial quick-win application areas, challenges of introducing new processes and technologies in an industrial structure inhibited by its legacy systems, and the contribution of 'smart manufacturing' in becoming also sustainable. The base for the smart factory discussions is active participation in national initiatives and discussions in South Korea and Sweden, as well as active participation and observations of specification, development and implementation of smart factory cases in South Korean and Swedish companies.

2. Smart Factory from a South Korean perspective

Today, most manufacturing companies in South Korea are facing a period of big challenges, trying to improve their competitiveness by its convergence of ICT. The concept of *Smart Factory* could be considered as the collection of cutting-edge technologies that supports effective and accurate decision-making in real time by the convergence of ICT with existing strategies and technologies in design, engineering and production operation. 'The Manufacturing Innovation Strategy 3.0 (Strategy 3.0)' is an initiative to comprehensively upgrade manufacturing industry of South Korea. It started in June 2014, and is based on direct inspiration from Germany's 'Industry 4.0' plan.

The purpose of the 'Strategy 3.0' is to introduce innovation to the manufacturing process, including expanding the use of smart factories and developing core technologies related to smart manufacturing. The aim is to foster the growth of segments combining manufacturing with information technology, examples of which include the incorporation of information technology into the energy management and industrial safety sectors. Given the discrepancy in innovation capacity between large companies and their secondary and tertiary subcontractors in South Korea, 'Strategy 3.0' puts emphasis on the following [4]:

- Setting up 10,000 smart factories by 2020 to facilitate convergence between software and hardware technologies raising about 972 million USD. Late 2016, the number of smart factories reached 2,800. In 2017, the plan set for 2025 was to expand to 30,000 smart factories with optimized operations by digital and analytic technologies.
- Training more than 40,000 skilled and smart workers for operation of smart factories by educational programs.
- Spreading innovation capacity and wealth, going beyond a mere focus on the enhanced automatization of manufacturing.

In terms of R&D, there are eight core technologies identified in 'Strategy3.0'; smart sensors, IoT, cloud, big data, CPS, 3D printing, hologram, energy saving, adding four action plans for smart factory as follows [4]:

- Spreading of smart manufacturing processes which include programs for dissemination and spread of smart factory, and development of core technologies strengthening the software power, and promotion of investing in enhanced R&D projects by supporting 189.3 million USD until 2020.
- Creating representative new industries including early visualization of converged facilities for smart factory, commercialization and development of intelligent materials and components, adding also promotion of private investment and R&D.
- Smart innovation in regional manufacturing industry with detailed plans such as activation of start-ups, utilization of local strategic points to become smart industrial regions, and development of the smart industry concept according to regional industrial strengths.
- Construction of innovation infrastructure and restructuring companies including promoting restructuring the business within the private sector, improving regulation and system of new technologies and cultivation of technology manpower in the smart factory.

In the South Korean 'Strategy 3.0', the smart factory is defined as "a manufacturing system which all business processes of planning, design, production, distribution and sales are automated, connected and integrated by various information and communication technologies. It can produce personalized products by customers with satisfactory time, cost and quality". [5] According to the main purpose, there are two directions in applying smart factory technologies: 'Operation Excellences in Manufacturing' and 'Personalized Manufacturing for Servitization'. [6]

Research and development related to intelligent and autonomous operation of the 'smart factory' have been conducted for analysis, prediction and proactive operation based on real-time data from a shop floor considering productivity, quality and logistics. CPS (Cyber Physical System) is considered one of the core technologies for designing and operating a smart factory based on the cyber model, DT (Digital Twin) [7]. It realizes an integrated system, monitoring and controlling changes in the shop floor autonomously by combining information and communication technologies with products, manufacturing processes & resources, workers, production cells and lines [8]. Figure 1 illustrates basic concepts and structure of a smart factory with CPS.

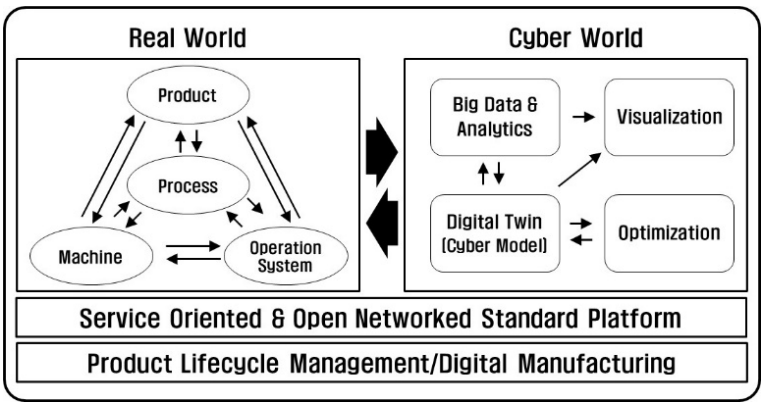

Fig. 1. Basic concepts and the structure of 'smart factory' with CPS. [6]

One smart factory case is a company which produces engine pistons of autos, and aims for ‘Operation Excellences in Manufacturing’. The major processes are melting/alloying, casting, machining and assembly. Due to characteristics of engine pistons, a permanent mold casting process with precise dimension control is used for mass production. Using smart sensors, IoT and big data analytics, a Digital Twin model which can evaluate and predict errors in productivity, logistics and quality is developed and implemented as shown in Figure 2. The data are gathered from furnaces, machines and MES (Manufacturing Execution System) in real time. Figure 3 shows snapshots of the implemented CPS dashboard on MES with results of data gathering, evaluation and prediction of productivity, quality and logistics. In 2017, quality problem decreased by 26% and net profits increased by 14%.

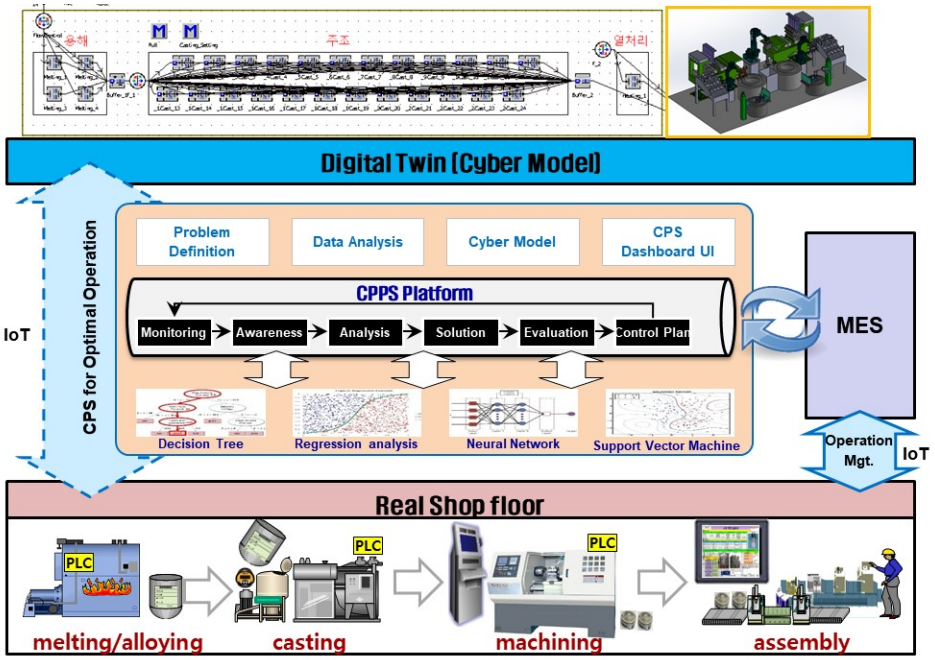

Fig. 2. CPS system for proactive operations in smart factory

Fig. 3. Examples of the CPS dashboard in a smart factory case in South Korea.

Another case is a micro smart factory for FaaS (Factory-as-a-Service), classified as an application of ‘Personalized Manufacturing for Servitization’. Figure 4 shows a concept of FaaS for mass personalization. The micro smart factory is a fully automated manufacturing system consisting of 3D printers, post-processing machines, assembly machines, robots for part handling and assembly operations to produce customized products in low volume for individual customers or start-up companies.

Figure 4 further illustrates a micro smart factory and its CPS system for FaaS implemented in South Korea. It was designed, evaluated, implemented and operated effectively using the digital twin model. The economic analysis shows that overall cost is decreased by 28% compared to traditional production.

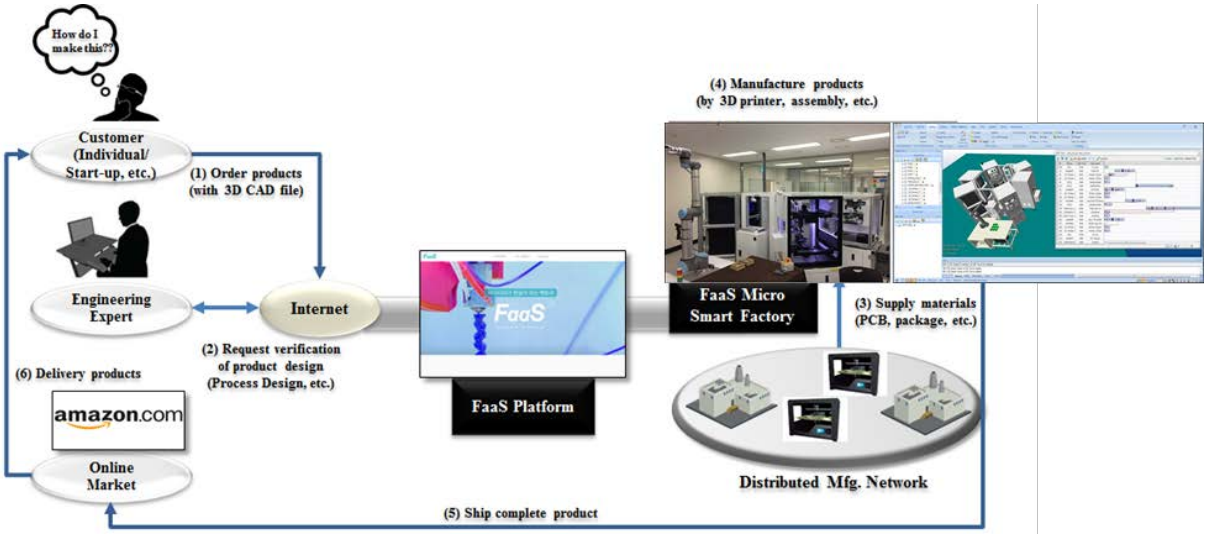

Fig. 4. Concept of FaaS for mass personalization, including its CPS system (top right). [9]

3. Smart Factory from Swedish perspectives

In Sweden, a national agenda on 'Smart industry' was launched by the Government in 2016 stating as preconditions that Sweden's prosperity is built on innovative export companies that have successfully renewed their products and production. The strategy for new industrialization comprises four areas: *Industry 4.0*, *Sustainable production*, *Industrial skills boost* and *Test bed Sweden*. In addition, two separate actions plan have been launched in 2016 and 2017. Many initiatives on national and regional level are developed and performed by different organizations in Sweden to enhance the digitalization, such as the Strategic Innovation Programs *Produktion2030* and *Process Industrial IT and Automation*. The larger manufacturing companies in general are advancing in their digital development of products, processes and business models, but attention must be put also on the digital transformation of small and medium enterprises.

One of the national initiatives for accelerating and supporting the digitalization of SMEs in Sweden is the *Kickstart* project funded by Swedish Agency for Economic and Regional Growth and managed by the Association of Swedish Engineering Industries in close co-operation with the trade union IF Metall and a number of partners within the Swedish Innovation System [10]. The project is based on a workshop concept where about 10 companies in each Kickstart-Round meet three times, starting with an inspiration part and then work together in groups sharing best practices and ending up with each company deciding on 1-3 small digitalization actions as a small step to initiate (or continue) their digital transformation. Per August 2017, nine Kickstart's in nine regions were performed in the pilot project. The concept is now being scaled up on a national basis, in the up-scale project called Kickstart 1000+, where 100 Kickstart rounds will be performed to engage more than 1000 companies from manufacturing industry and other industry sectors. The goal is to speed up the digital transformation of SMEs in Sweden. The areas for digitalization are broad, as shown in figure 5, including products & service, business and business models besides internal processes and production.

From the initial SME-digitalization pilots with about 80 companies attending we can draw some general conclusions. The separate start-activities identified by the SMEs are of different kind and could involve everything from creating a customer-portal or product configurator, to improve internal processes by new software. The Kickstart-workshops reveal that digital platforms, softwares etc. and the overall task of how to communicate

internally and externally, are problems that the SMEs face. For example, Excel is still used by many SMEs, both for separate processes and as a program to which data from other systems are manually transferred. The vision of a fully automated information flow in the factory and between manufacturing and its stakeholders is quite far away from the SME reality, at least to what is indicated in the pilot project of about 80 companies [10]. This supports the perspective in the IT-readiness study by Jentz et al [11], where it appears that no disruptive event transforms industry into smart manufacturing or the forth industrial revolution. They rather observe a gradual shift towards more IT-supported business.

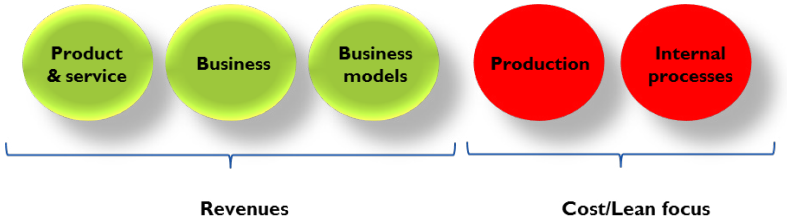

Fig. 5. Content focus in the Kickstart project.

Another example of a Swedish smart factory effort is found at Scania, a large truck, bus and engine manufacturer. Scania's lean based production system philosophy states that the company should always work with continuous improvements of the production system to make it more effective and efficient. As part of their effort to continuously improve, different initiatives are taken within the digitalization area. One initiative is the establishment of a smart truck- and bus production lab. The aim of the lab is to adapt, evaluate and demonstrate production and logistics technologies at one geographical location. The company believes that there is a need to gather several technologies in one location to be able to show and evaluate the full potential of digitalization. At the same time, it provides the possibility to test combination and integration possibilities of several technologies.

Currently, an event driven IT architecture are developed and evaluated. Collaborative robots, automotive guide vehicles, hand tools and various sensors are connected to be able to control equipment and gather data in real time. Also production preparation tools for off-line programming, visualization, simulation and control are connected. This creates a closed loop between the digital pre-runner of the shop floor, the physical shop floor and the digital twin of the shop floor. So far, the company has focused on the three lower levels of the Scania's smart factory pyramid; i.e. standardization, connected technology and data gathering, see Fig 6. Scania is now aiming for the higher levels in the pyramid to also be able analyze, predict and prescribe.

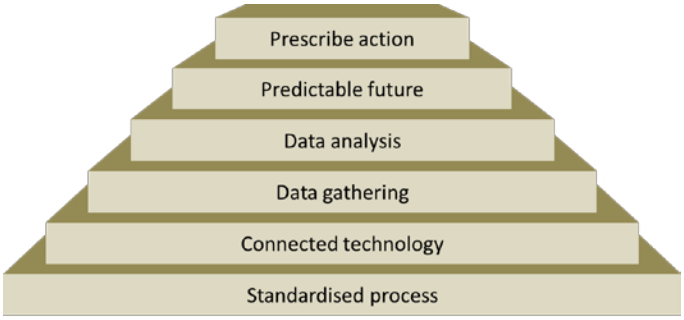

Fig. 6. The smart factory pyramid by Scania

4. Comments on implementation enablers and hindrances of a Smart Factory

Based upon the sporadic examples on smart factory efforts in South Korea and Sweden mentioned, four key general areas of implementation enablers and challenges can be envisioned concerning (1) Smart Factory integration

with corporate production systems, (2) key application areas within core value adding processes, (3) transformational inabilities of legacy systems and (4) Smart Factories for a sustainable production:

The technologies for data collection, connectivity, integration and advanced analytics exist but key challenges remain concerning robustness and business integration of these technologies. The manufacturing companies of South Korea and Sweden are in most cases highly skilled in terms of operational excellence programs, lean programs, production system models for continuous improvement and operational development schemes. One key area of development and research is how the technology dimension of the smart factory initiatives can align with these production operations management structures. The smart factory initiatives need to be business motivated but still not be inhibited by existing ways of working. The South Korean examples is one indication on how operational measures for productivity, logistics and quality can be improved by smart factory technologies and data integration, leading to decreased overall cost for productions and higher net profits.

Six key applications areas have been identified in previous studies and the projects mentioned, as parts of the order-to-delivery (OTD) process or the product and production development process, within manufacturing:

1. Predictive maintenance: Smart technologies can lead to real time operational status and maximized equipment utilization by IoT, machine learning technologies, data integration and advanced analytics,
2. Seamless virtual verification for product development: Major commercial software vendors support development of virtual factories via integrated solutions for product, process and system design, simulation, and visualization.
3. Smart IT in assembly and materials handling: Technology solutions for human-robot collaboration as well as AR and VR based operator support will radically change the operator work situation.
4. Quality control and risk management: Internal and external data as well as technologies (e.g. AI and machine learning) can be used to improve overall quality, traceability and regulatory compliance.
5. Automated real time management: Cyber-physical systems have been identified as monitoring physical processes and creating a virtual copy of the physical world to support decentralized decision-making [12].
6. Supply chain transparency: Traceability, adaptability and predictability within the supply chain are highly supported by smart technologies enabling decentralized decision making.

In addition to manufacturing areas, it was evident in the SME effort described, that many companies still see many improvement efforts needed also within supportive business processes (e.g. HR, finance, sales, purchasing).

The profitability of an investment is highly dependent on the existing real and human capital legacy systems. As both South Korea and Sweden are highly industrialized countries with extensive manufacturing industries, the gradual shift towards a highly IT-supported manufacturing is highly dependent on the transformation of a “brown field” industrial landscape where changes and investments must be done as “windows of opportunity” arise [13]. In many cases it can be easier to show bigger steps of improvement for less effort, where no existing legacy system exists. These cases can be found at e.g. SMEs, in interfaces between actors in the supply chain or in previously less focused business processes, where the level of IT integration is less developed. One strategy to handle this challenge of targeting and transforming processes with extensive legacy systems is to build demonstration arenas off-line, such as witnessed by the Scania smart truck and bus production lab. However, the major challenges of timing and prioritization for transforming the real manufacturing system and key processes still remain.

Building environmentally sustainable manufacturing is the key challenge for our future. The smart factory initiatives can be one instrument in this effort, where energy and material efficiency can be targeted more effectively. Indicated from studies on including environmental sustainability aspects in smart factories, today’s practice of environmental performance measurement generally suffers three shortcomings: (1) System level: measures are well represented on site or company level, less on work station and team level. (2) Topic: measures are well represented on energy usage, less on material efficiency. (3) Frequency: measures are well represented in annual environmental reports, less in daily improvement efforts. By monitoring physical processes and creating a virtual copy of the physical world by smart factory solutions, it is believed that decentralized decision-making and large scale engagement also for environmental issues can be targeted.

5. Conclusion

This paper use examples from South Korean and Swedish SMEs and large companies, in an effort to bring the high level smart manufacturing concept to the concrete. These sporadic examples contribute to the definition of smart factory and its corresponding development scheme by discussing four key enabling and hindering dimensions for building the "smart-factory-capability" of a company; the need of integrating the technology-driven smart factory initiatives with the operative production systems, different perspectives on initial quick-win application areas within the value adding processes, challenges of introducing new processes and technologies in an industrial structure inhibited by its legacy systems, and the contribution of 'smart factory' in becoming also sustainable.

Based on the brief examples and overview of national efforts within the two countries, one reflection could be that the South Korean national Smart Factory initiative appears to be more target-driven and focused on developing SMEs' smart manufacturing capabilities, while Sweden's national initiative appears to be more diversified and decentralized in supporting smart capabilities to industry in general. It is obvious that the degree of maturity differs between companies, starting from companies that are in their very initial phase of understanding what digitalization means to them and how they could take some first actions, to companies where digitalization is part of their business model and product. Digitalization is considered important both to achieve increased efficiency and cost reduction (automation and digitalization of production and internal processes) and as a mean to create revenues through new products and product features, new businesses and business models (where new disruptive business models are considered the most advanced level).

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