

LEAN METHODOLOGIES AND IT FRAMEWORK FOR INDUSTRY 4.0

TECHNICAL REPORT

01 April 2022

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Module: Advanced Industry 4.0 (ACPA7000)

ABSTRACT

Nowadays, customers like to customise and personalise their products. Industry 4.0 technologies are readily available in the market to support businesses in increasing flexibility and adapting to the customers. The main challenge in this adoption is the lack of skills and methodologies to support the industry 4.0 deployment. This document demonstrates that the lean methodologies used for years have evolved to support businesses in using industry 4.0 technologies. The IT architecture and connectivity are a relative new area in manufacturing. Therefore, some fundamentals on deploying IT framework for these technologies is described in a second section.

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INTRODUCTION

The industry is currently in its Fourth revolution. This revolution is mainly driven by the shift in customer-demand and all the new technologies available on the market. Although the technologies development is evolving at an extremely quick pace, the adoption in the real industry world is slower. Indeed, it is quite difficult for industries especially small industries to integrate and implement such systems in their manufacturing facilities as these require investments in machines, technologies but also an evolution in the skills' workforce. New competencies and knowledge are required for the implementation and maintenance of Industry 4.0 architecture. Finally, the cultural change and adoption by the workers of these technologies is another aspect to consider. In this document, the first section will describe lean methodologies used to improve processes in the Industry 3.0 and how they have shifted to be still appropriate for the new industry revolution and support the manufacturing businesses. Secondly, fundamentals of IT architecture to support the deployment of technologies and automation in industry will be detailed.

1. FROM LEAN PRODUCTION TO LEAN AUTOMATION METHODOLOGIES

a. LEAN PRODUCTION METHODOLOGIES AND THEIR FIT IN THE INDUSTRY 3.0

“Lean manufacturing has enabled businesses to increase production, reduce costs, improve quality, and increase profits by following five key principles: identify value, map the value stream, create flow, establish pull and seek perfection.” (Manufacturing.net, 2016)

The Lean Manufacturing principles have been inspired by the Toyota factory (Toyota Production System – TPS – 1930) in Japan. As these principles were relevant and brought values to industries, these methodologies have been implemented worldwide. However, for some companies, the implementation of these methodologies has been quite challenging especially in small businesses as per the complexity of the principles. Moreover, these principles didn't evolve for years therefore their relevance to the current customer-demands and industry evolution has decreased over the years (Tortorella, G et al., 2020).

Today the customer demand has shifted to customised products therefore there is a need of modular supply chain, flexibility, interoperability, and scalability. The Fourth Industry revolution supports these changes. The lean approaches and Industry 4.0 are complementary as the first one relies on continuous improvement and the second one on advanced technologies (PAVLOVIĆ, D. et al., 2020). Some research has been conducted in this direction and some methods are already used in industries. That will be explained in the next section of this document.

b. ADAPTATION OF THE LEAN METHODOLOGIES FOR THE INDUSTRY 4.0 (LEAN AUTOMATION) AND THEIR POSITIVE IMPACTS

Lean Automation framework is the integration of Industry 4.0 into Lean Production principles (Tortorella, G et al., 2020).

The Lean Production principles in the supply chain department would ensure the delivery of the right quantity at the right time and the right place. With Lean Automation and Industry 4.0 technologies, these verifications can be automatised using Manufacturing Execution Systems (MES). This technology eases the lean principles application and by automatising this operation the human factor is removed and therefore the reduction of errors.

Another example would be the Kanban methodology developed by Taiichi Ohno at Toyota (linked to the “Pull system” principle of the Lean Production). This method is *“a visual system used to manage and keep track of work as it moves through a process”*. (WhatIs.com, n.d.). Originally, operators have to move manually the cards on the board to update the status of the production process. With the Industry 4.0, technologies are available to automatise this physical board by using a Kanban software based. If one operation is delayed, the following card tasks will be automatically updated. Moreover, by moving from the physical board in the shopfloor to a software interface, the Kanban can be accessed by several persons at the same time from anywhere with an internet connection (Dennis

Kolberg et al., 2017). These kind of tools allow a real-time information access of the operations to the management team.

Finally, the anomaly detections by humans can be supplemented by sensors and other IoT tools which will support operators and by this, it will increase the quality and effectiveness of the production (linked to the “Perfection” or “Zero Defect” principle of the Lean Production).

c. DRAWBACKS TO CONSIDER

The implementation of these new tools and technologies could be disturbing for workers. Some operators are using the same techniques for years therefore there is a real care to take in explaining the reasons for this change and providing easy to use and adapted technologies to them as well as appropriate training to avoid rebellion.

As explained in the previous section, these technologies offer visibility to the management team. Workers in the shopfloor could be reluctant to use them if they feel tracked and monitored by managers constantly.

The first section highlights the lean methodologies supporting industries in running effective operations. The next section will focus on the technologies and some best practices to support their implementation.

2. INDUSTRY 4.0 AND TECHNOLOGIES DEPENDANCE

“Progress towards smart factory is driven by Cyber Physical Systems (CPSs)” (Tortorella, G et al., 2020)

a. CYBER PHYSICAL SYSTEM (CPS)

The 6 principles of Industry 4.0 are: Interoperability, Virtualization, Decentralization, Real-Time capability, Service Orientation and Modularity (Davis et al., 2020). All these principles have in common the technologies as enablers. There are proposed frameworks such as the Reference Architecture Model for Industry 4.0 (RAMI 4.0) developed by Plattform Industrie 4.0 or Industrial Internet Reference Architecture (IIRA) developed by Industrial Internet Consortium, but they are still at a research stage and really few companies have used these frameworks yet for implementation. (Lin et al., 2017)

The focus of this section will be on the understanding of the foundations for a good implementation. The integration of computation, networking and physical processes is called Cyber Physical System (CPS). Another way to define CPS could be as per Svetan Ratchev: *“Systems of collaborating computational entities which are in intensive connection with the surrounding physical world and its ongoing processes, providing and using, at the same time, data-retrieval and data-processing services available on the Internet”* (Svetan Ratchev, 2020).

There is a CPS for production named Cyber Physical Production Systems (CPPS): “*autonomous and co-operative elements and subsystems that are connected based on the context within and across all levels of production, from processes through machines up to production and logistics networks*” (Svetan Ratchev, 2020).

3 main characteristics can describe CPPS:

- Intelligence (machines and tools can “make decision” based on exchanged data)
- Connectedness (ability to connect everything together and collaborate with humans)
- Responsiveness (Svetan Ratchev, 2020)

The 5C architecture summarises the key elements for an appropriate implementation:

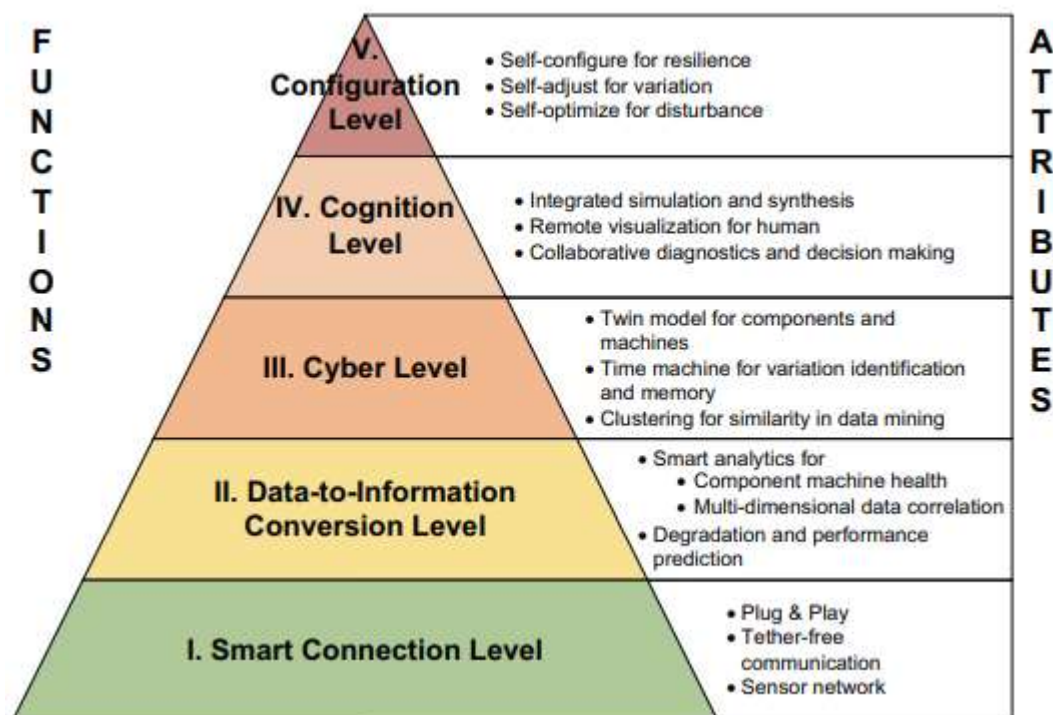


Figure 1- 5C architecture of CPPS (Vogel-Heuser, Lee and Leitão, 2015)

These 5 levels give a step-by-step approach of what should be considered when implementing Industry 4.0 technologies. The first level at the bottom of the pyramid is the first step: connecting devices/sensors. The second step is smart analysis, data from the connected devices is used to predict issue(s). The third step is the creation of a twin model of the physical connected devices. Then, the Cognition level can display visuals for users to see the potential issue predicted based on the peer-to-peer comparison of the physical machine and its twin model. The last step, the Configuration Level, is the self-configuration and adjustment by the machine based on the data. (Vogel-Heuser, Lee and Leitão, 2015)

Connected, smart factories, using Industry 4.0 technologies are as seen before the solution to stay competitive and be able to meet customers demand which evolves over the years. Recently, with the Coronavirus pandemic, industry 4.0 technologies have enabled virtual solutions to support the operations (e.g., doing online viewing of the products using VR/AR, 3D displays, etc.). These technologies also allow businesses to extend their coverage: by enabling virtual customer connections, businesses don't have geographic limitations and can target the whole world.

Sustainability and Zero Carbon emission is important to be considered today in industries. Using industry 4.0 technologies such as sensors, consumption can be controlled and adjusted to be minimalised.

b. DRAWBACKS TO CONSIDER

There are also some drawbacks to consider when deploying these technologies. Indeed, by using the connected world businesses are exposed to cy-criminality threats.

Also, as the current workforce doesn't have automatically the skills needed to work in businesses using industry 4.0 there is a considerable difficulty to deploy these technologies. There is a shift in competencies needed and these big gaps cannot be filled only by hiring new employees. There is a need to train and upskill the current workforce which is not a simple task as that means that for some operators, the job that they are currently doing will disappear and they must do something else that they might not like. It is an important cultural change. For example, an operator doing drilling on a wing can be moved to a position where he looks at a screen to watch a robot doing the drilling operations in his stead and the operator only intervenes if an issue occurs. This is obviously a challenging change if the person likes manual work and doesn't like to be seated at a desk.

CONCLUSION AND RECOMMENDATION

The shift in demand by customers is quite a big leap compared to the previous revolution. Therefore, the adoption of new methodologies and techniques to maintain industries in becoming more flexible is necessary. As seen above, there are several lean methodologies such as e-Kanban which have been adapted and enabled by the Industry 4.0 to support industries to stay at the cutting edge to face competitors.

My recommendation to support this evolution is to train the current workforce in acquiring new skills regarding connectivity, automation, digitalisation but also take care of the change management to maintain a good harmony and a good team spirit in the company. This can be supplemented by hiring new worker(s) having the expertise to support the change.

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