Lean Thinking: An Essential Mindset

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Abstract*—*Lean thinking is a fundamental mindset to promote societal transformations and prepare society to properly adopt and use Industry 4.0 technologies. These technologies continue to rapidly develop and have started to evolve to Society 5.0 and Industry 5.0. Although these technologies may provide economic, social, and sustainability benefits, their use must fit society's needs. Society's digital path must be aligned with workers' physical and safety conditions. These technologies should promote creativity, responsibility, resilience, and critical thinking for individuals to be prepared when digital systems do not work or when disruptive events happen—such as pandemic, catastrophic, and violent conflict situations. Lessons and challenges for practice and organizations are identified and summarized.

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I. INTRODUCTION

TOYOTA founder, Sakichi Toyoda, was an inventor motivated, at the beginning of his career, by the need to help his mother in her loom activities. With the Jidoka mechanism, he accomplished this objective. Jidoka became one of the pillars of the Toyota production system (TPS), being the other just-in-time concept.

John Krafcik of the Massachusetts Institute of Technology International Motor Vehicle Program called the TPS as a lean production system (LPS) [1]. Essentially, Toyota was *doing more with less* and used the *minds of workers* instead of just using their hands. Toyota had a more human approach to the assembly line concept by considering the operator in the line as more than just a machine extension.

Toyota put the operator working teams to think about the process and improve it. Toyota evolved from a technocentric production system to a more anthropocentric production system. A slogan of TPS *is making people, before making products* [2].

TPS evolved further with the book *The Machine that changed the world* into an LPS [3]. A few years later, the five principles of lean thinking were published as a fundamental mindset for companies to follow if they wished to achieve TPS [4].

TPS principles, concepts, and tools appeared in many previous places [5], [6], [7], [8]. Each of these previous publications reinforced the operator's role in the production system, where technology is needed to help them in their functions.

Example quotes from these early sources included:

> "In short, robots, like any other kind of technology must remain the tool of men and not the other way around!" [9, p. 236]

> ". . . a work environment that is safe physically, emotionally, and professionally for every employee" [10].

> "Adopt and adapt technology that supports your people and processes" [11]

Each quote provides evidence of TPS care for people—the main driving principle. TPS has focused on

respect for people and continuous improvement since its origins.

Technology is omnipresent—from the moment we get up until the moment we go to bed, in our houses, in our car, in our job, and in our leisure time. This fact expands the care for people outside the factory.

Technological importance has been exponentially increasing across almost all human and industrial activities. The Fourth Industrial Revolution or Industry 4.0, as an example of an emergent technology, needs to be aligned with the human capability of adaptation. Society 5.0 and Industry 5.0 [12]—concepts recently promoted—are calling for a new paradigm for a sustainable, human centric, and resilient industry. In this article, we discuss how lean thinking can help achieve Society 5.0 and Industry 5.0.

The rest of this article is organized as follows. Section II presents additional background. Then, Section III presents some examples of how lean thinking supports Industry 4.0 technologies to address the pillars of Industry 5.0. Section IV overviews some industry projects with the application of these lean thinking principles. Section V discusses some challenges faced by organizations due to such paradigms. Finally, Section VI concludes this article.

II. Background

Lean thinking has been defined by the following five principles:

1) value;
2) value stream;
3) flow;
4) pull production; and
5) pursuit of perfection [3].

These principles are intended to guide organizations along a journey that transforms them into a lean enterprise [13] by adding value by constantly eliminating waste. Waste as categorized by Ohno [6] includes the following:

1) transport;
2) inventory;
3) motion;
4) waiting;
5) defects;
6) overprocessing; and
7) overproduction.

This last waste type is considered the worst because it is the origination of all other waste—implying additional cost incurred by clients and more importantly the planet. Overproduction means producing more than clients need. It does not mean the organizations are necessarily satisfying them properly.

This situation means all energy, water, and natural resources employed to make the products are wasteful. Pursuing this reduction, global development, responsible for consumption and production, is more likely to be achieved [14].

Another type of waste is untapped human potential [15]. This waste is related to capitalizing on operator suggestions, creativity, and inventive ideas—a key TPS concept. Creative people are needed even more now that the technology surrounding us is greater than ever—lean promotes creativity [16].

Technology may also inhibit creativity and restrict actions. For this reason, technology introduction needs to be well planned and justified.

Individual's creativity and potential can be effectively unlocked when technologies are well integrated. Lean thinking integrated with Industry 4.0 can help [17]:

1) develop smart products through lean product development;
2) develop and improve processes with smart machines;
3) transform conventional manufacturing systems into smart factories;
4) promote thinkers, decision makers, and problem solvers to fulfill their potential;
5) establish good relations with suppliers and with customers (internal and external); and
6) provide ecoefficient solutions to pursue sustainable development goals by exploring the *lean-green* synergy.

Technology is necessarily a part of engineering curricula and competencies that will help students to use them wisely are critical. Of the top 10 competencies identified by the World Manufacturing Forum in 2019 [18], 6 of them are related to transversal competencies.

These competencies are a part of the Society 5.0 concept. This concept states:

> "People will be expected to exercise rich imagination to identify a variety of needs and challenges scattered across society and the scenarios to solve them, as well as creativity to realize such solutions by using digital technologies and data. Society 5.0 will be an Imagination Society, where digital transformation combines with the creativity of diverse people to bring about *problem solving* and *value creation* that lead us to sustainable development. It is a concept that can contribute to the achievement of the Sustainable Development Goals adopted by the United Nations" [19].

Industry 5.0 recognizes [12]:

1) power of industry to achieve societal goals beyond jobs and growth;
2) need to become a resilient provider of prosperity, by making production respect the boundaries of our planet; and
3) need to place the well being of the industry operator at the center of the production process.

Industry 5.0 complements the existing Industry 4.0 paradigm by having research and innovation drive the transition to a sustainable, human centric, and resilient industry, being these three pillars of this new paradigm [14].

Both Society 5.0 and Industry 5.0 concepts refer to a fundamental shift of society and economy toward a new paradigm.

III. Using Lean Principles for Industry 4.0 to Evolve to Industry 5.0

In this section, we discuss how Industry 4.0 technologies using lean thinking principles result in human centric, sustainable, and resilience benefits—the Industry 5.0 pillars. Cyberphysical systems, Internet of Things, Services, or People, robotics (e.g., collaborative robots or *cobots*), augmented reality/virtual reality (e.g., human augmentation; use of radio frequency identification or RFID; use of three-dimensional (3-D) simulation with 3-D space; digital twins), big data, and artificial intelligence (e.g., machine learning) are key technologies of Industry 4.0 that support lean concept [17].

When these technologies are used in the industrial context, we will have the Industrial Internet of Things allowing a smart factory to produce smarter products, using, for example, additive manufacturing or 3-D space printing that are quickly moved in an automated guided vehicle or mobile industrial robots.

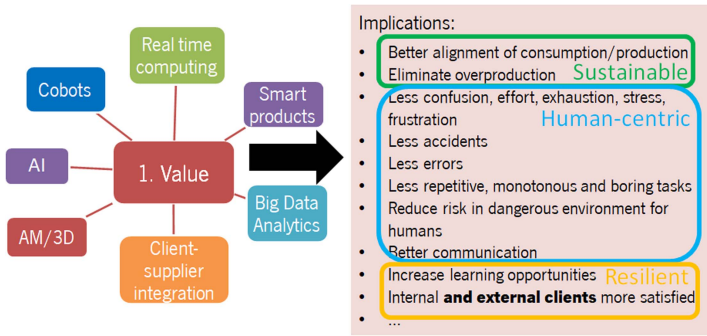

Figure 1. Industry 4.0 technologies supporting the lean value principle.

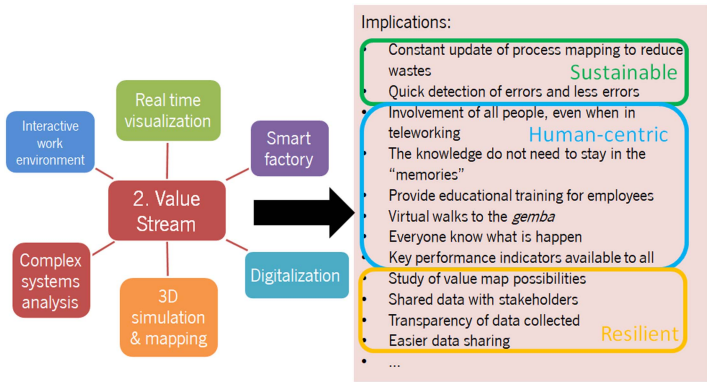

Figure 2. Industry 4.0 technologies supporting the lean value stream principle.

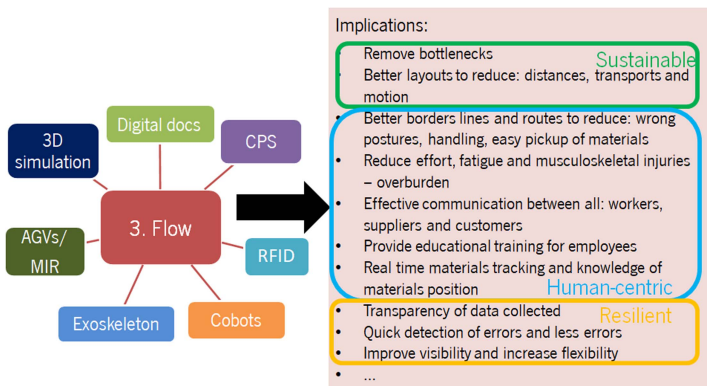

Figure 3. Industry 4.0 technologies supported by the lean flow principle.

A. First Lean Principle: Value The first principle is value. Value means identifying—or creating—value from a client's perspective. This process would remove any activities (waste) for which they are unwilling to pay.

Figure 1 depicts some technologies enabling value and outcomes, including human centric, sustainable, and resilience outcomes.

B. Second Lean Principle: Value Streams The second principle—value streams—requires organizations to focus on removing wastes from the value chain. Figure 2 summarizes technologies supporting the second principle and sustainable, human centric, and resilience consequences.

C. Third Lean Principle: Flow The third lean principle is flow. It is necessary to eliminate wastes after they have been identified in order to maintain flow. Figure 3 depicts some of the technologies that enable the third principle, as well as some of its consequences.

D. Fourth Lean Principle: Pull Production The fourth concept, pull production, entails allowing customers to pull their demand for products or services when they need it, and the amounts, they require—

also known as just-in-time. Figure 4 depicts this principle, enabling Industry 4.0 technology and some Industry 5.0 consequences.

E. Fifth Lean Principle: Pursuit of Perfection Figure 5 summarizes the fifth principle—pursuit of perfection—which means to continuously search for wastes in order to eliminate them. These wastes could be related to human effort, untapped human potential, and environmental wastes.

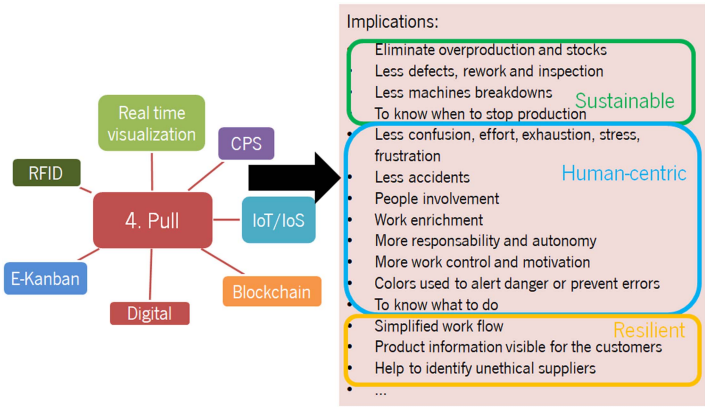

Figure 4. Industry 4.0 technologies supporting pull production principle.

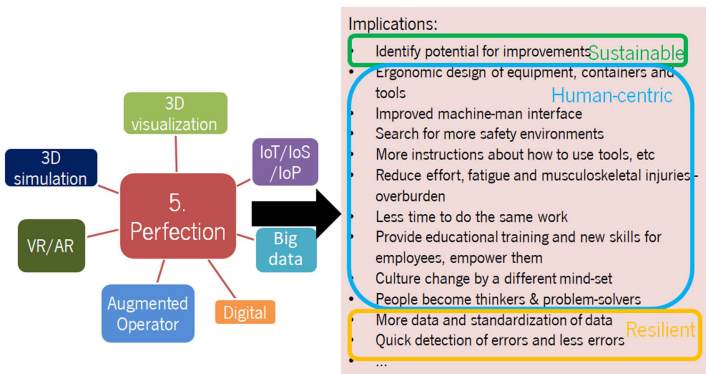

Figure 5. Industry 4.0 technologies supporting the pursuit of perfection lean principle.

IV. Projects With Industry Applying Lean Thinking Principles

The technologies described in this study are only used as examples; many more are likely to assist operators in decreasing their job effort and managing other organizational wastes. We worked on projects with the industry to accomplish such improvements. Some of these examples appear in Table 1. In this table, we also presented the aim and Industry 5.0 impact achieved by the project. All of them were developed in a lean context, and with each project developed, lead time and cost reduction were also accomplished.

V. Challenges to Overcome

Although the Toyota and lean mindset have proven their merit, many organizations continue to refuse to accept this mindset or make their own interpretation, focusing on the economic side only. The inappropriate use of lean is still a problem—for example, organizations tend to believe that they found a good strategy to dismiss people, unaware of what motivated Toyota to promote a production system different from the well-known Ford production system.

There are clearly some challenges that companies need to overcome in order to implement lean, namely,

TABLE 1. Projects With Industry.

Reference	Aim	Impact
Pereira et al. [20]	Automation of the standard worksheets and control and fabrications instruction	Facilitates the coworker's training; increases consistency; less paper; less errors
Abreu et al. [21]	Digitalized manual work instructions and standard work	Less paper; more flow; less errors; quick detection of errors
Freitas et al. [22]	RFID technologies and information for better internal logistics	Reduced human intervention; real-time information; less errors and movements
Frontoni et al. [23]	Satisfaction of new requirements of higher sales volume and digital channels	Higher goods security level and a real-time data sharing policy
Oliveira et al. [24]	Automation of the process in the warehouse	Increase the speed of communication and information processing
Afonso et al. [25]	Reduce human interaction in a postpandemic scenario by an automatized transport	Less ergonomic risks; less energy consumption and associated CO_2 emissions; better flow of materials
Afonso et al. [26]	Automatized transport	Reduced human effort, reduced motion
Witeck et al. [27]	Digitalized measures in the product development process	Increase communication; reduce errors
Witeck et al. [28]	Mobile technologies in the product development process	Better management of priorities and resources; improved follow-up and communication

being afraid of having to invest in resources, top and middle management support, lack of employee experience, and learning in this environment and the process, among others enablers and/or inhibitors [29].

It is important to mention that, as Monden [9] referred, before investing in new machinery, equipment, or technology, manual operations should be improved and many times, this is what is needed to have a better process and, consequently, a better production system. Otherwise, the result without improving processes manually first will be increasing the generation of waste and automating this waste.

In addition, top and middle management need to be involved and leading implementing a lean culture. They need to view this as a never-ending journey. In this context, it will be necessary to provide work conditions that employees feel free to suggest improvements, to learn, to create, to be prepared for unknown and unpredictable events, and to embrace changes as being part of the "normal" situation. Also, employees need to deal with the new technologies that will help them in performing their job, not the way around. Achieving this, every disruption in the process will be quickly fixed because people will be capable to do that.

VI. Final Remarks

Lean thinking principles implementation supports Industry 4.0 technologies transformation to Industry 5.0 pillars. Although such relations were empirically presented in this article, much of what we have written is from our practical experience in projects developed in the industry. To uncover further evidence of such consequences, more in-depth research using more formal research methodologies is required. A systematic literature review and several cases could be used to support such research. Also, we encourage practitioners in the industry to also provide their insights.

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