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Integrating Lean 4.0 into Customer-Centric Digital Transformation: Analyzing Work Systems Frameworks for Enhanced Operational Efficiency and Customer Value

G Sreelatha[1], Veena Angadi[2], Butchi Babu Muvva[3], Sindhu Guruprasad[4]

Associate Professors, Department of Master of Business Administration, City College, Bengaluru, India[1,2,3]

Assistant Professor, Department of Master of Business Administration, City College, Bengaluru, India[4]

ABSTRACT: In order to notice the characteristics of industry 4.0 and lean systems (ILS), or lean 4.0 systems, we use a work-systems framework in this study. We also show how the components of these work-systems come together to create a customer-centric transformation. Using this paradigm, we interpret two published cases of businesses one that adopted a lean strategy and the other that entered into industry 4.0. We note that although both companies underwent a customer-centric digital transformation, one of them used an industry 4.0 strategy that was primarily technology-driven and the other used a lean approach. The other's strategy was based mostly on process enhancements. According to our work-systems interpretation of ILS and case talks, companies may find that combining lean methodologies with industry 4.0 technology, or the so-called lean 4.0 approach, is a viable strategy for achieving customer-centric digital transformation in the future.

KEYWORDS: Lean 4.0, Industry 4.0, Customer-Centric Transformation, Work-Systems Framework, Digital Transformation Strategies

I. INTRODUCTION

Industry 4.0 is a strategy designed to help businesses use cutting-edge technologies like cloud computing, big data analytics, artificial intelligence (AI), cyber physical systems (CPS), industrial internet of things (I-IoT), and more to remain competitive in the future (Kagermann et al. 2013). In addition to addressing concerns related to "growing environmental risks and ecological scarcities," these technologies allow businesses to adapt nimbly to changing market demands and satisfy a wide range of customer needs and expectations (Beier et al. 2020; Lasi et al. 2014; UNEP 2011). The foundation of lean production systems is the idea of removing waste from the manufacturing process while making adjustments to meet customer demands and expectations (Shah and Ward 2007; Womack and Jones 1997). Industry 4.0 and lean systems share common goals, and extensive research indicates that there are similarities and overlaps between the two (Sanders et al. 2016). They envision a conceptual union of the two approaches as lean 4.0, discussing how lean production can better integrate industry 4.0 technology and how industry 4.0 technologies make lean production systems more efficient and transparent (Mayr et al. 2018).

In this work, we use Alter's (2013) work systems framework to examine the socio-technical dimensions of industry 4.0 and lean production systems (ILS), also known as lean 4.0 systems. We demonstrate how different ILS work-system components—such as participants, procedures, and technologies—cooperate to achieve the customer-centric transformation that is anticipated in ILS while debating these components individually. We also analyze two actual business cases that used the work-system architecture to implement technology and process transformation. From the two companies' case discussions, we can see that although both companies underwent a customer-centric transformation in the end, industry 4.0 one company's strategy was heavily reliant on technology, whereas the other company's lean strategy was more process-oriented. We think that by thoroughly examining how different ILS work-system components interact with one another, researchers can create innovative approaches that help businesses implement customer-focused, long-lasting digital transformations that will make them competitive in the long run.

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II. WORK SYSTEMS FRAMEWORK

Beyond the common techno-centric approaches that view such systems as composed of user-operated hardware and software, Alter (2013) presented a socio-technical perspective for business professionals to look at IT-reliant systems within businesses. He claims that a "work-system" is any system used by an organization, regardless of whether it is an Information System (IS). A worksystem is a socio-technical system in which users—humans and/or machines—perform processual or unstructured tasks while depending on information, technologies, and other resources to generate goods and services for clients, whether they are internal or external (Alter 2013). Alter presented both a static and dynamic picture of a work system within the framework of a general work-systems theory. static image of a Any stable work system can be identified by its internal and external components using the work-system, or what he refers to as the "work-systems framework." Such systems consist of the following internal components: 1) Processes/Activities, 2) Technologies, 3) Participants, and 4) Information. Customers and products/services make up two of the system's components. The environment, strategies, and infrastructure are components that are not part of these systems. The "work-systems lifecycle model," a dynamic perspective of a work system, illustrates how a work system evolves through "planned and unplanned" modifications. First, we define the work-system elements of lean 4.0 or ILS systems in this study. As we go over the work-system elements of ILS, we also show how these elements work together to accomplish the technology-driven, customer-focused process change that ILS aims to achieve. Then, using the work-system framework, we analyze published examples of businesses that implemented technology and process change, emphasizing our first findings. The two instances we talk about are: 1) Digitalization of an Industrial Giant: GE Embracing Industrial Analytics (Black and Carrick 2017); 2) Daktronics (D): Daktronics, Inc. is Affirmative about Lean Manufacturing.

III. INDUSTRY 4.0

According to Kagermann et al. (2013), Industry 4.0 is essentially a strategy for industries to remain competitive in the future through the application and integration of emerging technologies like cloud computing, big data analytics, artificial intelligence (AI), cyber physical systems (CPS), and the Industrial Internet of Things (I-IoT). According to Lasi et al. (2014) and Mayr et al. (2018), these technologies allow businesses to adapt to changing market demands and meet a variety of client needs and expectations. Concerns of sustainability related to "growing environmental risks and ecological scarcities" in the context of industrial production are also anticipated to be addressed by industry 4.0 initiatives (Beier et al. 2020; UNEP 2011). Six design elements that are fueled by diverse technologies are highlighted by Hermann et al. (2016) in order to accomplish the goals of industry 4.0. both modularity and orientation. The key technologies listed below create industry 4.0 systems based on these ideas.

Plug-and-play capabilities are ensured via interoperability, which makes sure that the interfaces of different production components are understood clearly at runtime. These manufacturing components are given identity and communication via I-IoT, which also incorporates them into an industrial network. New developments in network technologies, such as software defined networking (SDN), allow for the dynamic reconfiguration of production components and their interconnections during run-time by taking advantage of their interoperability (Kirkpatrick 2013; H. Xu et al. 2018). Cyber Physical Systems, which build on I-IoT, create a closed loop that includes data processing via computer software, data collecting from networked sensors, and autonomous actuator-based management of industrial components (Broy 2013; Wagner et al. 2017). incorporating sophisticated control, such as PLC (programmable logic), DCS (distributed control systems), and SCADA (supervisory control and data acquisition) Controller), network (such as SDN, 5G, and M2M, or machine-to-machine communication), and computing infrastructure (such as Cloud, Edge, and Fog Computing), CPS makes sure that different production process components are virtualized or represented digitally (H. Xu et al. 2018). Additionally, CPS guarantees virtual and augmented reality-based human-machine interfaces, expanding the cognitive and physical capacities of human operators in the production process (Zolotová et al. 2020). Artificial Intelligence (AI) and Big Data Analytics (BDA) enable production components to collect and evaluate data, make decisions, and self-organize in real-time. This promotes decentralization and real-time functionality in Industry 4.0 production systems. According to Kägermann et al. (2013), these features also allow production components to synchronize with the full value stream, from supplier inputs to end-customer delivery of goods and services. Sanders and others (2016). Production systems can be regarded of as a mix of software services that can be built by independent contributors and made available through the Internet of Service (Mrugalska and Wyrwicka 2017). This is made possible by the virtualization of production components allowed by CPS. Such a service-oriented architecture can enable the realization of creative and customized designs within industry 4.0 manufacturing systems (Verma et al. 2017). Finally, by taking into consideration their computational limitations and physical dynamics,

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industrial components and their virtual equivalents are integrated as modules into larger production systems (Lee 2008). The production system's flexibility is increased by the modular design, which permits dynamic modification, enlargement, or reconfiguration of component modules and their interconnections (Vogel-Heuser and Hess 2016).

Macroeconomically speaking, industry 4.0 is anticipated to accomplish three key goals: vertical integration linking entities at various hierarchical levels, ranging from machine level to enterprise planning level; horizontal integration connecting value creation modules spanning businesses within a value creation network; and end-to-end integration linking all stages of a product's life cycle (Stock and Seliger 2016). By providing people with context-specific knowledge in real-time, it is also anticipated to change the nature of work done by humans to include decision-making and adaptable problem solving (Gorecky et al. 2014). Industry 4.0 is predicted to bring forth "smart" factories of the future (GTAI 2014), made possible by intelligent machinery, goods, planners, and operators. "Smart Products understand how they are made." "Smart Planner optimizes processes in nearly real time," "Smart Machines negotiate it with them," and "Humans, assisted by technology, become smart operators supervising and controlling ongoing activities in the production process" (Kolberg and Zühlke 2015).

Production Lean

The foundation of lean production systems is the principle of being customer-centric and removing waste in the production process. Womack and Jones (1997) state that there are five essential steps in the process of lean thinking. The first step is to determine what a customer's expectations and desires for personalization mean when it comes to "value." The second step is to identify a "value stream," which details the value that is added to the client by each activity that is undertaken from product creation to delivery. The third phase is to ensure that all value-creating activities "flow" without any bottlenecks and with the least amount of inventory utilization after eliminating inefficient activities within the value stream. Reaching these procedures enable manufacturers to produce in accordance with customers' precise requirements and expectations, converting what was formerly known as "batch production" into "pull production," in which consumers are able to "pull" the products they value from the producers. Finally, lean thinking advocates for "perfecting" value stream operations by reducing their unpredictability and consistently attempting to minimize various wastes that arise during the production process, including excess inventory, overproduction, overprocessing, needless movement or transportation of people or materials, unneeded material waiting periods, and faults (Shah and Ward 2007). The realization of services can benefit equally from these lean-thinking approaches (Piercy and Rich 2009).

Within lean production systems, the previously described lean thinking principles take the form of several activities. Sanders et al. (2016) provide an explanation of these activities by classifying them into four primary categories: supplier, customer, process, control, and human. This classification is based on a more detailed one that Shah and Ward (2007) suggested. Activities that fall under the s Within lean production systems, the previously described lean thinking principles take the form of several activities. Sanders et al. (2016) provide an upplier category include just-in-time input delivery from suppliers, providing feedback from customers on finished products to suppliers, and exchanging knowledge with suppliers to advance them alongside producers. In the context of lean, consumers are the primary drivers of business for producers; hence, activities that fall under the customer category include gathering and analyzing client wants and expectations as well as include customers in the production process. preserving the flow of Activities falling under the process category include those that form the value stream without significant pauses and those that enable such flow through Kanban systems or just-in-time production, in which the start of a need from downstream customers drives the flow of material from upstream suppliers. Activities that fall under the control and human category include preventing failures through routine maintenance, guaranteeing short turnaround times for fixing problems, preventing flaws from spreading throughout the process, and involving staff in ongoing process improvement. Lean production systems are superior to mass production systems due to activities that fall under the human category. The goal of lean manufacturing systems is the meaningful integration and empowerment of employees by granting them sufficient latitude and independence throughout the manufacturing process. Compared to firms focused on mass manufacturing, lean organizations are known to retain productive people for longer periods of time by offering them a variety of flexible career mobility options (Mrugalska and Wyrwicka 2017; Womack et al. 2007).

IV. LEAN 4.0 - CONJUNCTION OF INDUSTRY 4.0 AND LEAN

Research indicates that industry 4.0 and lean production are interdependent. Specifically, studies address how industry 4.0 technologies can improve lean production systems' efficiency and transparency, as well as how lean production

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systems can better integrate industry 4.0 technologies (Bittencourt et al. 2019; Kolberg and Zühlke 2015; Mrugalska and Wyrwicka 2017; Sanders et al. 2016). Three key aspects are outlined by Mayr et al. (2018) regarding how lean manufacturing systems can be more open to industry 4.0 technologies. First, integrating industry 4.0 technologies requires "standardized, transparent, and reproducible processes," which have been refined over time in lean manufacturing systems.

This is because inefficient processes merely amplify inefficiencies. Second, under the direction of seasoned decision-makers skilled in lean procedures, To achieve the goals shared by lean and industry 4.0, such as customer-driven production and waste reduction for environmental concerns, firms can naturally incorporate industry 4.0 technologies into their current processes. Third, by limiting non-value-adding activities within the value stream and clearly identifying value for the customer, the lean manufacturing process minimizes the complexity of both the product and the process; this also results in the "efficient and economical use" of industry 4.0 tools. Sanders et al. (2016) address how industry 4.0's core technologies might enhance lean production systems' supplier, customer, process, control, and human category activities.

This speaks to the dependence of lean on industry 4.0. In 2015, Kolberg and Zühlke offer a framework that ties industry 4.0 and lean by contrasting the ways in which intelligent devices, planners, operators, and planners may support lean production systems' just-in-time and prompt failure-addressing capabilities. Mayr et al. (2018) address the intersection of lean and industry 4.0, or lean 4.0, and propose a number of technologically improved lean approaches.

V. KEY WORK SYSTEMS COMPONENTS IN ILS

The aforementioned sections covered the following topics: 1) the goals, supporting technology, and anticipated results of industry 4.0 production systems; 2) lean thinking principles and initiatives to assist businesses in realizing the benefits of lean production; and 3) the ways in which industry 4.0 and lean are interdependent and can be used by businesses to their advantage. In doing so, we provided an overview of some of the key organizational structures, technical frameworks, and business practices that support industry 4.0 and lean systems (ILS). According to Alter (2013), the elements that keep the components of the work system together are the environment, infrastructure, and strategies. These elements are not part of the work system itself. Infrastructure in the context of ILS comprises the interoperable control, infrastructure for networking and computing that serves as the foundation for creating adaptable production systems. The environment includes how open a lean organization is to implementing industry 4.0 technologies. Finally, the primary strategies guiding industry 4.0 and lean work-systems are customer-driven and sustainability-oriented aims. In this section, we examine the additional work-system components in ILS that function (a) entirely within the work system, such as participants, information, and technology, and (b) partially both inside and outside the work system, such as consumers and products/services. As we talk about these work-system elements, we also show how they relate to one another and how they help ILS achieve the customer-centric transformation that is anticipated.

VI. CUSTOMERS AND PRODUCTS / SERVICES

Industry 4.0 and lean methodologies prioritize the needs of the client. Consumers are the primary forces behind company, and ILS work systems must be adaptable enough to meet a wide range of client demands. In order for customers to extract value-added goods and services from the production process, they should be able to define "value" for them, describe the value stream and the activities that make it up, and optimize the flow of these activities with the least amount of waste possible (Sanders et al. 2016; Womack and Jones 1997). An interoperable technology infrastructure increases production process flexibility. Built upon such infrastructure, cyberphysical systems can enable dynamic modification of product specifications, allowing customers to modify their products for an extended period of time before the product freeze expires. requirements continue to be necessary until the product specifications are fixed (Lasi et al. 2014; Sanders et al. 2016). Vertical integration is made easier within ILS by process aware information systems (PAIS), which connect operations from the shop floor to corporate planning levels. PAIS are constructed over adaptable, interconnected, and digitally accessible autonomous production modules (L. D. Xu et al. 2018). According to Cannata et al. (2008), these PAIS enable the creation of service-oriented applications that can: a) notify customers of the status of production so they can follow their order in real-time; and b) integrate customer feedback, product usage history, needs, and expectations back into the production process (Mrugalska and Wyrwicka 2017). This permits not just "mass customization' of products catering to a variety of customer needs and expectations (Lasi et al. 2014), but also, products pulled by customers can be augmented with additional services like suggesting maintenance schedules, predicting faults and other value-added services (Sanders et al. 2016).

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Information about the machines they would interface with, the activities inside the value stream they would advance along, and the final customized product they would enter can all be incorporated into the components that make up the product itself (Kolberg and Zühlke 2015; Wagner et al. 2017). In order to produce goods of the highest caliber, machines are expected to interact with product components and dynamically modify work loads in response to capacity restrictions they encounter during run-time (Brettel et al. 2017). According to Mayr et al. (2018) and Sanders et al. (2016), operators can prevent the spread of faulty products and parts throughout the value stream by tracking the movement of tagged products and their parts through the production process and detecting faults early on.
Processes and activities

According to Sanders et al. (2016), pull production, continuous flow, and the reduction in setup time anticipated in lean production systems can all be made possible by industry 4.0 technologies. Pull production necessitates that customers must desire production, and each upstream producer within the value stream must produce in response to the downstream consumer's need. In lean production systems, just-in-time manufacturing is usually accomplished by the Kanban technique, in which upstream producers and downstream consumers trade Kanban cards to start the flow of materials in tiny batches from the former to the latter. It guarantees the semi-finished and final materials' flow. products, should move constantly between producers and customers to prevent significant pauses and the accumulation of excess inventory (Sanders et al. 2016; Wagner et al. 2017). According to Mayr et al. (2018), the kanban system makes sure that participants in a process step self-organize their production activities based on their downstream consumers and upstream producers. Kanban can be changed into e-Kanban with the use of technologies like RFID, in which empty bins are automatically identified and a trigger is transmitted to producers upstream (Kolberg and Zühlke 2015). Artificial intelligence (AI) and big data analytics (BDA) can leverage processual data and give production components the ability to self-organize, allowing operations within Transparency in the value-stream allows value to move through the business more efficiently. Process flow can be enhanced, for example, by evaluating information shared amongst networked production components and moving materials from capacity-constrained machines to other, less-constrained machines (Brettel et al. 2017; Sanders et al. 2016). Businesses can adjust to dynamic changes in product specifications or the quantity of products requested as they develop autonomous and self-organizing production components, which cuts down on setup times for operations (Sanders et al. 2016).

VII. PARTICIPANTS, INFORMATION AND TECHNOLOGIES

ILS are able to respond to a variety of consumer needs and expectations with to technologies like CPS and I-IoT, which offer flexible, modular, and decentralized production systems (H. Xu et al. 2018). Information flow must occur in nearly real-time since customer requirements must be coordinated with upstream process stages or activities inside the valuestream (Sanders et al. 2016). Real-time information flow is ensured by networking and communication technologies not just between machines but also between humans and machines. Humans are considered to be the most adaptable entities in ILS, with the ability to solve problems and make decisions (Gorecky et al. 2014; Mrugalska and Wyrwicka 2017). As CPS and other technologies help close the gap between Decision-making and social interaction abilities, which are hard to develop in the cyber world, are now in the hands of humans in both the real and virtual worlds (Waschull et al. 2020). Technologies for data collection, information processing, and computing collaborate to provide workers with personalized knowledge about the general context and their local surrounds (Fantini et al. 2020; Krugh and Mears 2018). When machine learning models are trained on historical processual data, they can offer predictive insights that help human operators anticipate crucial occurrences, promptly notify others on the scene, and act swiftly in the event of a production process breakdown (Fantini et al. Kolberg and Zühlke (2015); al. 2020). Dialogue systems, multimedia displays, adaptive interfaces, and virtual/augmented reality devices are examples of human-machine interaction technologies that further extend human physical and cognitive capabilities during production, turning workers into intelligent operators (Zolotová et al. 2020).

A summary of the ILS work-system components is shown in Figure 1. Infrastructure, strategies, and the organizational environment are external to the work system yet serve to connect the other elements. Consumers and goods/services are both internal and external components of the work system. Within the work-system, individuals, information, processes, and technology are all in operation.

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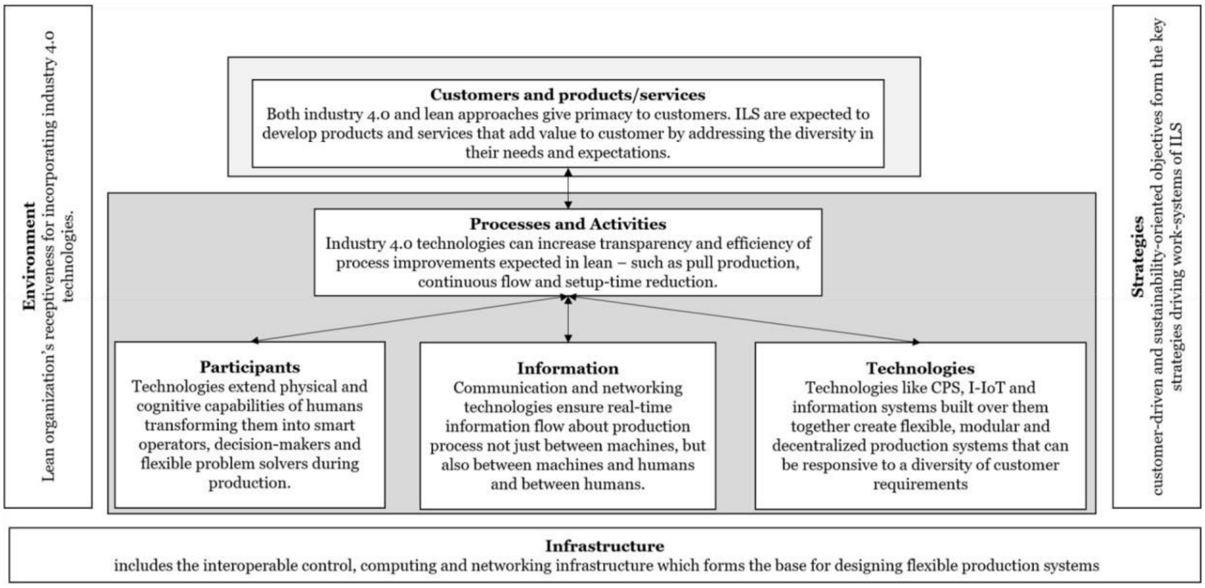

Figure1.1 Lean 4.0

VIII. CASE OF GENERAL ELECTRIC (GE) ADOPTING INDUSTRY 4.0

Black and Carrick (2017) provide a detailed case study that explains GE's adoption of industry 4.0 technology and their implementation strategy. Here, we provide a succinct synopsis of this example using the work-systems framework (Alter 2013). Historically, General Electric (GE) was an industrial hardware firm that made money from selling its goods to consumers and via customer service agreements (CSAs), which produced a consistent flow of income by maintaining devices over their lifetime. GE had a long-standing advantage in the scientific fields that supported its goods. However, as rivals caught up, GE was now confronted with the task of differentiating its products in order to obtain a competitive edge. For this, GE examined two regions. Predictive maintenance and process optimization are areas where companies can use their goods to assist customers. It was anticipated that predictive maintenance of their devices would shield clients from unanticipated maintenance losses. Given that GE's clients have to manage high-fixed-cost business operations, any procedure They experienced amazing gains from optimization. Given that a number of GE's products were integrated into customer value streams, the company considered self-optimizing the functionality of its products to increase the effectiveness of its customers' business operations. In order to improve its customers' business operations, GE created a cloud-based software platform called "Predix" that could collect data from sensors in its products and analyze it to produce useful insights. According to GE, creating software platforms that are tailored to their own products will benefit customers more than creating generic platforms that are unaffected by the owners of individual items. Still, as client value-streams had products or components from other manufacturers as well. Later, GE and Accenture worked together to create a different software platform called "Taleris," which users could use regardless of the source of the parts in their value-stream. By offering this extra service, GE has been effective in using internal resources to provide clients with even more value.

IX. CONCLUSION

The emerging literature on lean4.0 discusses the connections between Industry 4.0 and lean production techniques. We believe that the WorkSystems platform offers a comprehensive platform to examine this progress. This framework has the advantage of going into the building blocks of work within an organization, which makes it possible to categorize and map out the various paths that lean4.0 changes can take. We were able to explain the different work-system components that make up industry 4.0 and lean systems using the work-systems framework. We also demonstrated how these components interact to provide flexible production systems that can meet a range of client wants and expectations. In this topic, there is a good deal of theoretical literature, and we decided to comprehend its applicability by highlighting two particular instances that underwent these changes. The worksystems framework we employed

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enabled us to analyze the technological and process changes implemented by GE and Daktronics, as reported in the case studies. We can see that lean approaches are generally process-oriented, whereas industry 4.0 approaches are more technology-driven based on our analysis of these two scenarios using the worksystems framework. According to our work-systems interpretation of ILS and case talks, combining lean methods involving the industry Lean 4.0, often known as 4.0 technologies, appears to be a promising strategy for businesses looking to achieve long-term, customer-focused digital transformation. However, achieving it would require a deeper comprehension of the organizational worksystems, which the Work-systems framework clarifies.

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