

Beyond industry 4.0: Novel systems for optimising technology in the manufacturing sector.

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Advanced Industry 4.0

ACPA7000

21/07/2023

Summary;

A discussion on the potential avenues for augmenting industry 4.0 technologies, that are sometimes held back by incomplete implementation. Including examples of lean manufacturing and six sigma exploitation and new technology interconnectivity that goes beyond Industry 4.0 in terms of advancement and effectiveness.

Introduction

Technology is changing the way we do almost everything. In the UK, there are dozens of well-known examples of emerging, technological, business models that have changed the status quo dramatically. Examples include: the online banking system that has all-but replaced the traditional high street bank; And online estate agents who can compete aggressively on the cost of selling homes by having virtually no premises, customer flexibility and tiny overheads (1). Neither of these would be possible without the internet and computerisation of worker's tasks.

The raft of Industry 4.0 (I4.0) technologies that are available today are sometimes incorporated rapidly and in isolation, often leading to poor return on investment or incomplete functionality (2,3). Researchers and industry leaders are now looking at ways to incorporate emerging and recently developed business models with I4.0 to act synergistically and drive further growth and improvement. Looking at business models like lean manufacturing and Industry 5.0 that have a forward-looking approach and the principles of which can be expected to be augmented by technology. Furthermore, there is value in exploring the synergies between I4.0 technologies to complement each other and increase their effectiveness. (2,3)

Discussion

In the manufacturing industry, Lean Manufacturing (Lean) and Six Sigma are well-established management processes, that have been developed to compliment manufacturing processes and increase efficiency through innovation and reduction of waste, without compromising quality (4,5).

The principles and processes of Lean manufacturing were developed by Toyota automobile company in the 1950s and 60s, although the term Lean wasn't used until the 1980s (4). It has become famous in the industry, partially because of the success it has brought Toyota, but also, because Toyota have packaged it and sold it as a management process to competitors and collaborators alike (6).

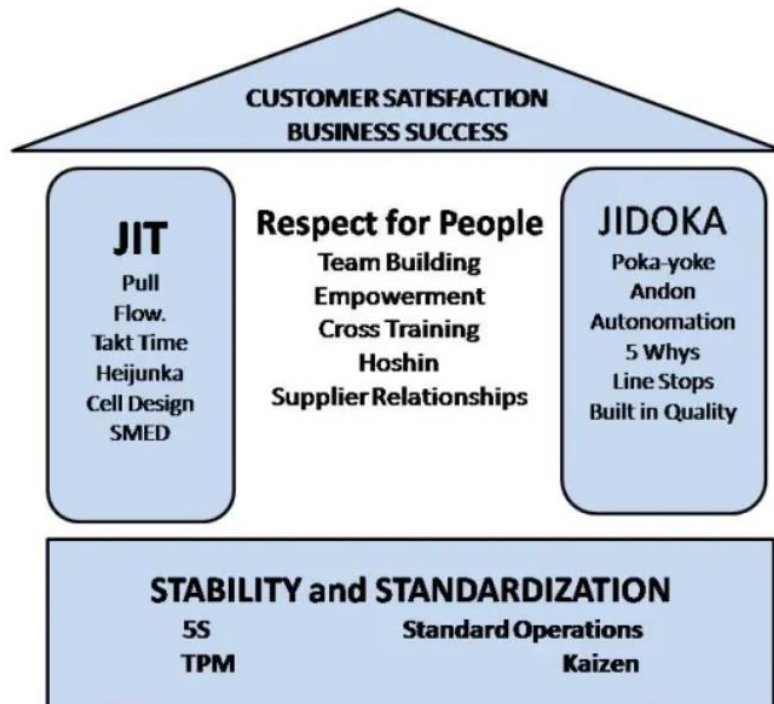


Figure 1. The pillars of Lean manufacturing are JIT and JIDOKA. (REF)

One of the two pillars of Lean is Just in time manufacturing (JIT). There are clear parallels with advanced logistics. RFID tags and scanners could be used to track items both inside the factory and within the supply chain. Combined with databases that track the availability of couriers, warehouse space and machine availability to provide complete visibility over the supply chain. The whereabouts and delivery dates of raw materials would allow precise production planning and dispatch dates. Data could also feed into, and improve, Single Minute Exchange of Die (SMED) and takt time by getting real data about the process and potential bottlenecks. As discussed by (7) the gains are large and the spillovers into Lean are evident.

Six sigma was developed by Bill Smith, while working at Motorola in 1986. As of 2005, Motorola had attributed \$17 billion of savings to the implementation of Six Sigma. (8) It is a method for controlling quality; using statistics and focussing on a defect rate below 3.4 parts per million. It is used to standardise processes and minimise variability by measuring, analysis and identifying areas for improvement.

Industry 4.0 can contribute to improving and augmenting the Six Sigma approach by virtue of the amount of data that can be captured by smart sensors in an Industrial Internet of Things (IIoT). The IIoT system could draw on the Define, Measure, Analyse, Improve and Control (DMAIC) system of six sigma (9), by carrying out the MAIC components: (Big) data capture and artificial intelligence can measure and analyse, generate statistics, and spot trends concealed in vast quantities of data. Decisions could be learned or preprogrammed into the system, so that decision making for improvements could also be semi-automated. For examples, a defect in the early stages of the production process would be indicative of a downstream failure, a smart system could compare measurement to previous data and either stop the process or correct for the deviation. (Almost like In-line rework). The control

phase would then be the learned component, whereby a change in process is either accepted or rejected, based on intelligently assessed data. (10)

Digital twin simulations are further technologies that can combine with Lean or six sigma to make strategic decisions without the cost of physically trialling changes. Using empirical data from the IIOT to accurately model the process, then run simulated scenarios, such as assigning resources differently or testing assumptions about potential efficiency gains. This could provide optimisations in a digital environment that improve the 'Flow' prescribed by lean and/ or reduce defects by perfecting a process with fewer iterative, empirical, experiments. (10)

Industry 5.0 (I5.0) is the name given to the emerging vision of Industry 4.0. It is an attempt to return a more humanistic approach to working, moving away from a technological imperative and prioritising automated systems that collaborate with humans. The key part is integrating human brainpower and creativity with intelligent computerised systems. Furthermore, it aims to go well beyond the I4.0 toolkit, with new technological combinations and innovation (11).

Some technologies that come under the banner of Industry 5.0 include:

Smart additive manufacturing, Predictive maintenance, Cloud manufacturing, Cyber-physical Cognitive systems, Hyper-customisation aka Mass individualisation and Reconfigurable manufacturing systems.

Smart additive manufacturing.

This involves using Artificial intelligence (AI), cyber-physical systems and new technology to improve 3d printing using real time data on the process. Correcting errors, as they happen, for example. This results in higher resource utilisation efficiency (12). Also makes it possible to carry out lightweighting of components, with deliberate gaps, while maintain their mechanical characteristics.

Predictive maintenance.

This saves time by limiting the amount of unplanned downtime. For example, signals are received and processes on a component, any changes are diagnosed, the expected failure point is predicted, the best decision is chosen, and maintenance can be scheduled at the most convenient time. AI can also perform computations on acceptable components failure rate based on statistical data and cost of servicing and in terms of time taken for servicing with feedback to planners, regarding downtime (13).

Cloud manufacturing

Facilitates the collaboration of remote, diffused, stakeholders and the ability to share knowledge and data. In the future, it could allow the strategic location of processing plants anywhere in the world. They can be placed in economies with lower running costs or closer to raw materials. IIOT sensors could be uploading live data to the cloud, to provide feedback to remote workers who can schedule manufacturing and even operate processes remotely. The reduction in transport waste is likely to be large (14).

Cyber-physical Cognitive systems.

Sometimes, referred to as Collaborative robots (contracted to COBOTS). Robots typically handle risky, demanding, or mundane work. And, traditionally, will only perform one task. Cobots can be deployed to augment a human's ability to do some of these tasks and reduce physical stress on that person.

They can incorporate decision making software. For example, a robotic arm, that linked to sensors and AI can learn the movements and decision making of a human operator and start to pre-empt their actions. For example, picking up the next required tool or component and 'handing' it to them or taking over some of the tasks, as it sees fit. Unlike traditional robots, they also have sophisticated proximity sensors to ensure they do not come into contact with people. (11)

Hyper-customisation aka Mass individualisation

A novel product design process that is driven by the customer. Often comprises a hardware platform and software and/ or components that can be integrated into the platform to give the end user a bespoke product. As opposed to traditional products, that tend to have discrete, immutable characteristics. (15)

Reconfigurable manufacturing systems.

Rapid adjustment of production capacity by modifying hardware and software in the system. Modification, addition and removal of certain process capabilities would allow rapid adaptation to changes in market demands or the ability to run multiple products, with vastly reduced equipment requirements and a smaller footprint. (14)

Conclusion

Industry 4.0 in isolation appears to be fairly limited and hard to implement with significant gains. Tortorella & Fettermann, 2018 (3) indicated that lean can be used to improve successful implementation of I4.0. Using the right combinations of I4.0 technologies, Industry 5.0 approach and human centric management principles is becoming accepted as the better way to operate. Compared to job losses and completely automated factories, upskilling people and empowering them to work with cyber-physical systems is better for society and humanity. The possibilities of new, customisable products and efficient, proactive ways of working should make for a bright future. Clearly, properly implemented management of change and the providing the right tools for the right job are challenges that face the manufacturing industry and need to be addressed in the scoping stages of any I4.0 implementation project.

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