

Executive Summary

Our report is written on 67 pages and contains analysis, case studies and our recommendations regarding key technologies and Industry 4.0 applications. From Henry Ford's introduction of the assembly line to the development of electric cars, the auto industry has seen many remarkable innovations. Now, the automotive industry is on the brink of more such significant developments with the introduction of Industry 4.0 (the fourth industrial revolution). **The primary objective** of this report is to investigate what benefits Industry 4.0 brings to automakers, what are the challenges and what recommendation we can provide to assist them in this journey. **Our motivation** is three-fold: to understand industry transformations, analyze case studies and propose recommendations that will assist production managers, high level executives, and researchers in transforming manufacturing processes and keeping production efficiency up while lowering cost and decreasing waste.

In Chapter 1 we discuss key milestones of industrial revolutions and what makes Industry 4.0 unique. In the Third Industrial Revolution, we have already seen the adoption of computers and automation of industrial processes. Now the fourth Industrial Revolution represents a new stage that focuses heavily on interconnectivity, automation, machine learning, and real-time data. Industry 4.0 intended to respond to the growing needs of the manufacturing industry. Also known as Industrial IoT, Industry 4.0 combines physical operations with smart digital technology, machine learning, and big data. By connecting devices, IoT helps in creating a connected ecosystem for companies and offers new business opportunities.

In Chapter 2 we provide the context of challenges that are undergoing in the industry. The role of Industry 4.0 becomes even more critical in the backdrop of a crisis such as COVID-19. Companies utilizing digital solutions are better-positioned to weather the storm, having moved faster and further than their peers during the crisis. As companies think about restoring operations and building the muscle to deal with future crises, using digital technologies will be top of mind for many. Industry 4.0 has both expanded the possibilities of digital transformation in automotive and increased its importance to original equipment manufacturers (OEMs), suppliers, dealers, captive finance organizations, and others working in the mobility ecosystem. Technologies causing wholesale transformation of the global automotive sector are commonly called the CASE (connectivity, autonomy, shared mobility, and electrification) technologies. **We identified 11 technologies** that significantly contributed to Industry 4.0 development. These technological developments include: Cyber-physical systems; Internet-of-Things (IoTs); Machine learning and Artificial Intelligence (AI); Advanced robotics (collaborative and adaptive robots); Big data analytics; Cloud computing; Blockchain technology; 3D Printing; Smart manufacturing; Autonomy (e.g. autonomous vehicles) and drones; Immersive technologies (AR/VR/MR).

In Chapter 3 we discuss three case studies: Tesla Motors, Ford and Renault. Industry 4.0 puts the power of greatly improving manufacturing processes into the hands of operations managers with a blend of new technologies. The question for operations managers then becomes, of all of the newly available manufacturing improvement options, from virtual reality, to drones, to smart factory analytics, "where should I start?". Our case studies answer this question, here is what we found.

Tesla uses numerous Industry 4.0 technologies and principles to drive its radical and disruptive innovation. Each aspect of Industry 4.0 has been carefully chosen and tailored to fit the company's end goal of maximum efficiency and volume. Some of the technologies that Tesla uses were developed by vendors who have sold products to Tesla, while other technologies were developed in-house. The proprietary technologies that have been developed in-house are all cutting edge and have always pushed the manufacturing envelope. Tesla has been a trailblazer, particularly with software and data utilization. However, not everything that the company has produced has been effective, and Tesla continues to learn and build on past failures. It is able to do this due to the low levels of bureaucracy within the organization. When a new technology, process, or solution is shown to be beneficial, the company tries to implement it as soon as possible.

Ford invested \$45 million to build a new advanced manufacturing center where new technology is used and developed to speed manufacturing innovation. In the plant, Industry 4.0 and IoT technology enables operators to monitor data generated at different work stations. The company also has stepped up its use of digital design and virtual reality computer simulations. Ford said it has standardized software and controls as part of its digital manufacturing strategy. With its commitment to cutting edge technologies like collaborative robots, 3D printing, augmented and virtual reality, Ford has firmly established itself as an important innovator in the field of connective automotive manufacturing - both now, and into the future. In the Advanced Manufacturing Center, the Ford Motor Company has created a formidable testing ground where the latest Industry 4.0 technology can be put through its paces, before it rolls out to global factories.

Renault uses Industry 4.0 technologies, such as collaborative robots, autonomous guided vehicles and augmented worker technologies – to produce a vehicle every four seconds. The use of exoskeleton technologies has helped Renault to reduce approximately 15 kg of load per plant-operator, and the use of tablets is saving one hour per day for their plant foreman.

In Chapter 4 we provide a conclusion and summarize our findings from the case studies. We performed an adapted Pugh analysis to evaluate the degree of Industry 4.0 implementation in each of the three organizations. As expected, Tesla scored the highest while Renault scored the lowest. The analysis also showed how advanced Ford actually is in terms of Industry 4.0. Additionally, we discuss lessons learned and challenges that companies are facing attempting to implement Industry 4.0 technologies. Not all these technologies lead to expected results, therefore we investigated strengths and weaknesses of case studies.

In Chapter 5, we formulate **our recommendations, rubric and next steps**. A proposed rubric may be used by operations managers and industrial engineers, as well as senior managers who are responsible for the Industry 4.0 implementation. We found that across 11 key technologies we defined in Chapter 2, Tesla has the highest score of Industry 4.0 adoption, Ford has the 2nd place and Renault has the 3rd place. Using our rubric and approach automakers can evaluate their level of development and Industry 4.0 implementation. We also formulated our recommendations and next steps. The report concludes with summarizing the findings as well as actions to help automotive manufacturers incorporate Industry 4.0 technologies and best practice.