CHAPTER 1

Artificial Intelligence in Manufacturing

Husnu BAYSAL

Kocaeli University Hereke Asım Kocabıyık Vocational School, Türkiye

Hasan OKTEM

Kocaeli University Hereke Asım Kocabıyık Vocational School, Türkiye

To Cite This Chapter:
Baysal, H. & Oktem, H. (2023). Artificial Intelligence in Manufacturing. *Current Studies Basic Sciences, Engineering and Techonology 2023* (pp. 1-9) ISRES Publishing.

Introduction

When considering the global market, advanced industrial firms have the potential to secure consistent sustainability in both performance and productivity growth through the implementation of disruptive technologies within the production value chain (Goering et al., 2018).

Based on this argument, it can be concluded that industrial firms that have incorporated disruptive technologies in their production, particularly in the recent years, have experienced advantageous outcomes that must not be disregarded in the context of enhanced productivity and efficiency. Over the past two decades, the productivity of American industrial laborers has risen by 47%, attributed to the application of conventional techniques, specifically Lean Manufacturing, Six Sigma, a customer-centric methodology, and Total Quality Management. However, it is important to note that the incremental benefits provided by these structures are decreasing and require further attention. In this context, it can be inferred that major industrial companies are currently embracing disruptive technologies in their future operations for the sake of sustainable outcomes (Goering et al. ,2018).

Many organizations have begun integrating technologies such as machine-to-machine digital connectivity (also known as the Industrial Internet of Things or IIoT), artificial intelligence, advanced automation, robotics, and additive manufacturing into their production systems. Due to its revolutionary impact, this transformation is deemed the Fourth Industrial Revolution or Industry 4.0 (Goering et al., 2018).

Disruptive Technologies and Manufacturing

Disruptive technologies and innovative trends create opportunities for companies to gain a competitive advantage by improving business methods throughout all value chains. Furthermore, these technologies can ensure production sustainability and efficiency (Goering et al., 2018).

It is important to recognize that these opportunities vary depending on value factors, market dynamics, and different business structures. However, companies that have successfully undergone technological transformations through high levels

of technology use to maintain a competitive advantage. For instance, manufacturers experiencing high labor costs and production issues that do not involve quality can significantly decrease their error rates in production from 3% to approximately 0% whilst concurrently improving productivity at substantial levels through the implementation of advanced automation and information technology transformations alongside augmented (Goering et al., 2018).

Similarly, manufacturers who aim to maximize their highly-maintained automation processes could create solutions by analyzing available data to identify micro-losses in capacity concerning the utilization of production equipment. Automatic material handling vehicles and palletizing robots can help manufacturers with high-cost production stages to effectively eliminate material handling personnel (Goering et al., 2018).

Companies that establish appropriate objectives and perform outcome-driven actions to accomplish those objectives can take advantage of cost reductions offered by technological solutions. This enables production-focused businesses to achieve quicker transformations and obtain increased value benefits in the medium and long term by reconfiguring their networks and upgrading their IT and operating technology architecture (Goering et al., 2018).

Leading industrial companies are creating scenarios for utilization in three major areas to acquire value through digitalization across manufacturing and the supply chain: connectivity, artificial intelligence, and automation (Goering et al., 2018).

Connectivity

The realm of connectivity is expanding rapidly through the Internet of Things, with over 8 billion connected devices constituting the infrastructure. This expansion causes digital devices to link with IT-based systems instantly, thus favorably impacting the assessment and decision-making processes concerning any workflow-related matters. Ultimately, it clears the road to resolving productivity hindrances (Goering et al., 2018).

Artificial Intelligence

Advanced analytical and artificial intelligence solutions can be developed using big data related to our business to achieve superior outcomes in production, predictive maintenance, quality management, and demand forecasting. As computing power and data volume increase, machine learning algorithms become increasingly powerful. The full potential of artificial intelligence in decision-making has yet to be realized in production environments that only use a small portion of big data during production phases (Goering et al., 2018)..

In this context, it is evident that businesses in industries like automotive, aerospace, and heavy engineering are adopting artificial intelligence to automate their systems to enhance decision-making processes in response to the challenges they face managing the growing complexity of product types. To achieve this, a corporate production intelligence system can be established which collects data from numerous IoT sensors. This system facilitates the use of predictive intelligence applications for maintenance, quality, and parts supply. It can be said that this approach has increased and will enhance the overall equipment efficiency of the system as well as the percentage of right-first-time deliveries (Goering et al., 2018).

Automation

Automated manufacturing has been in existence for many years and has recently witnessed increased integration of robotics and automation into production operations. This is due to the reduced costs of technology development and the growing possibilities of expanding safe and effective work environments for robotic implementation. The implementation of

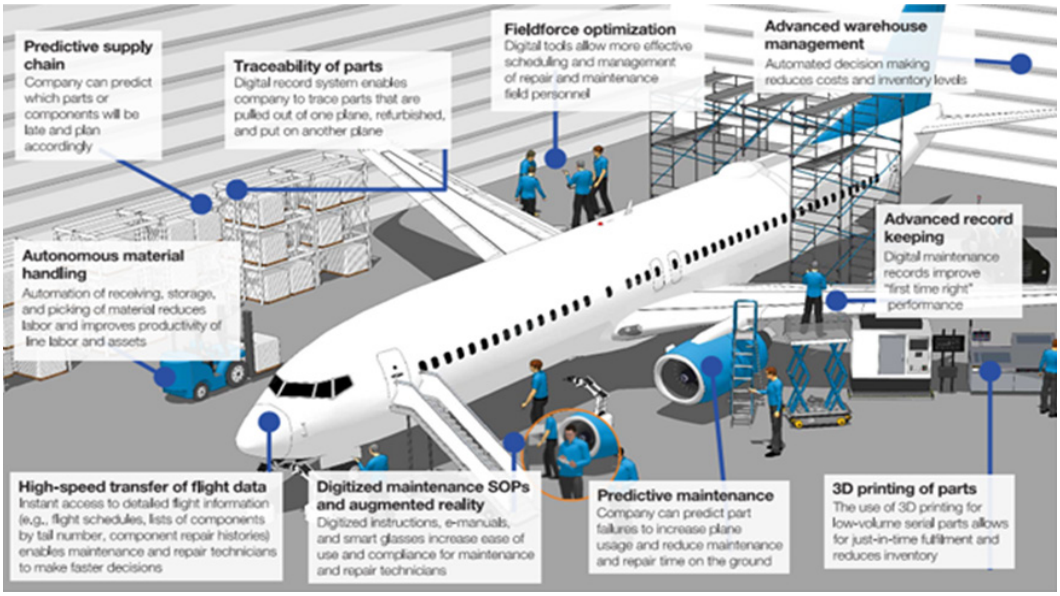
modern robotics technology in product assembly, storage, and logistics activities offers the potential to enhance productivity, quality, and safety. Potential related applications encompass self-driving vehicles employed in distribution centers, computerized systems for managing warehouses, and collaborative robots (cobots) that operate in cooperation with human workers during production processes. Projections anticipate that 60% of manufacturing duties will involve automation in the future, yet such technologies remain underused even amongst pioneers in the field (Goering et al., 2018).

Automating the entire production process, encompassing material handling, quality testing, and packaging, could reduce both direct and indirect labor costs by over 80% in several industries, including electronics (Goering et al., 2018).

These benefits facilitate companies to produce their goods in high-cost countries that are located near appealing markets. As a result, transportation costs are lowered, customer responsiveness is increased, and speed to market is improved (Goering et al., 2018).

Examples of implementing connectivity, intelligence, and automation in an aerospace manufacturing context are illustrated in Figure 1 (Goering et al., 2018).

Figure 1.
Examples of digital production at an aerospace products manufacturer (Reference: www.mckinsey .com (Charalambous et al., 2019))



Artificial Intelligence in Manufacturing As A Disruptive Technology

Companies in a producer position can enhance their business volumes, reduce energy consumption, and increase profits through the use of artificial intelligence (AI) solutions designed specifically for production (Charalambous et al., 2019).

The concept of AI, which first emerged in the mid-1950s, has increasingly become a disruptive technology in our daily lives in recent years. Digital assistants like Alexa and Siri, navigation and weather predictions, the stock market, and applications such as ChatGPT are omnipresent in our daily lives (Charalambous et al., 2019).

When examining the corporate production world, many companies, particularly cement manufacturers, are piloting schemes that exploit artificial intelligence in their restructuring processes (Charalambous et al., 2019)..

To attain enhanced production levels through pilot schemes, it is conceivable that

Artificial Intelligence could empower firms to scrutinize considerable volumes of data they frequently accumulate and assess the outcomes following their private frameworks. This could lead to decreased expenses (Charalambous et al., 2019).

Nonetheless, although AI techniques have yielded conspicuous enhancements in administrative structures and logistics, producing systems still have a ways to progress. For instance, cement plants have implemented automation and digital systems for several decades. However, they are in the experimental phase of integrating AI into production (Charalambous et al., 2019).

For decades, companies have been digitizing their production facilities with supervisory control systems and advanced process controls for production monitoring, observations, and operator decision-making processes (Charalambous et al., 2019).

Even though this digitalization provides great convenience to operators in their work, it is another issue that the need for operators cannot be reduced even though many companies in the producer status have implemented artificial intelligence solutions in analytical and decision support systems. This means that in companies that implement digitization and use artificial intelligence in production, operators rely on their intuition and decision-making skills developed based on their experience (Charalambous et al., 2019).

For instance, in modern control rooms, teams of operators are required to visually monitor the signals displayed on screens and make corresponding adjustments to ensure accurate outcomes. Concurrently, they must engage in tasks like troubleshooting, testing, and experimenting, which challenge the limits of human-scale performance for operators (Charalambous et al., 2019).

Due to the excessive dependence on operator-employee expertise in production-based firms, it can become problematic for someone else to fill the position of an experienced operator after their retirement. The disparity in operators' capabilities can have a direct impact on production performance and profitability. Therefore, the role of artificial intelligence in preserving, enhancing, and standardizing knowledge becomes increasingly crucial. For businesses experiencing challenges in recruiting and retaining proficient operators during the business cycle, the implementation of artificial intelligence algorithms capable of making intricate operational set point decisions independently can promote dependable, foreseeable, and unwavering production outputs (Charalambous et al., 2019).

From this perspective, it could be argued that artificial intelligence has surpassed or has the potential to surpass traditional decision-support technologies that rely on human operators for enhancing operations and streamlining work and production. Furthermore, by considering the dynamism of equipment and market conditions, artificial intelligence will enable companies to create their algorithms in-house at a reasonable cost and achieve sustainable outcomes. This is due to the emergence of the latest, high-performance algorithms, more speedy processing power, and memory units with larger capacity. Furthermore, artificial intelligence can fully automate intricate assignments, allowing for consistent and accurate optimal set points on autopilot. This results in a reduced reliance on human resources for maintenance and, importantly, the capacity to rapidly implement fresh solutions when production schemes and plans are updated by company management (Charalambous et al., 2019).

From a manufacturing standpoint, artificial intelligence (AI) has revolutionized the production landscape and presents numerous advantages. Enhanced efficiency, cost-effectiveness, and heightened quality resulting in minimal downtime are just a few of the many potential benefits that can be attained through the implementation of AI-based improvements. Small, medium, and large-scale manufacturers all have access to high-value, low-cost solutions making use of AI. It is essential to acknowledge that AI

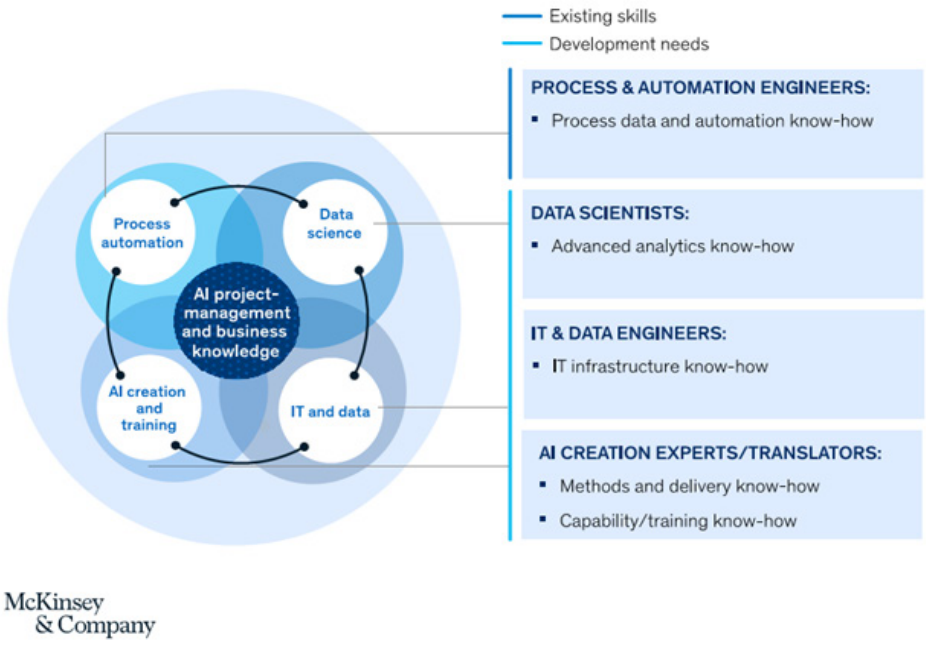
solutions provide considerable cost and efficiency benefits (Charalambous et al., 2019).

However, if a manufacturer desires to construct and uphold its AI, it must acknowledge that assembling the right team is essential. Individuals who possess expert proficiency in designing, constructing, connecting, optimizing, and sustaining an AI solution are the correct selection - those with worldwide experience who are highly skilled, possess an overview of the big picture, and have the capability to work together harmoniously towards a mutual objective (Charalambous et al., 2019).

But, with the high demand for qualified workers, and the shortage of individuals with the necessary experience to fill open positions, companies should explore the possibility of providing in-house training to current employees, specifically those who possess a background in data engineering. Alternatively, companies may need to look outside their organization to hire external experts when internal talent is insufficient (Charalambous et al., 2019).

Irrespective of the source of the skilled workforce, it is imperative for management to foster particular roles to attain favorable outcomes in AI (Refer to Figure 2) (Charalambous et al., 2019).

Figure 2.
Roles that need to be developed to create in-house artificial intelligence (Reference: www.mckinsey .com ((Charalambous et al., 2019))



Project managers (translators) and AI creation experts are critical as employees with the business skills and experience to manage technical change in the creation of in-house AI (Charalambous et al., 2019).

It is possible for employees to utilize Project Managers and Artificial Intelligence Experts as described below: (Charalambous et al., 2019).

- To offer an impartial viewpoint to staff concerning the objectives they are required to attain about artificial intelligence.
- To create knowledge, foresight, and awareness about artificial intelligence in employees
- To cultivate the competencies of personnel in process engineering, data science, business, and management.

In businesses, experts in domains such as process and production engineering should comprise the individuals who comprehend and incorporate how processes respond and how plants are configured and run. This cluster of specialists requires adequate training to efficiently collaborate with professionals from varying perspectives to construct and exhibit valuable knowledge of optimization models, particularly focused on real-time optimization of AI (Charalambous et al., 2019).

Building an experienced team of IT and data experts in-house is indispensable due to their training in core aspects of AI, comprising computer science, databases, data architecture, modeling, analytics, statistics, and mathematics. It is also prudent to incorporate data engineers competent enough to manage and devise data storage solutions and protocols, along with data scientists who can decode, analyze, and manipulate data and formulate customized models and algorithms (Charalambous et al., 2019).

It is imperative to recognize that effective internal formation and development of artificial intelligence will require advanced tools and applications. Primarily for proficient processing of big data, data visualization, data cleaning, data classification, and data model design, new and strong tools and applications that produce sustainable outcomes will be indispensable. If finding, recruiting, and retaining highly skilled data science talent poses a challenge, utilizing user-friendly data curation and AI design tools can bridge the gap. Additionally, the development of in-house engineering capabilities is of great importance (Charalambous et al., 2019).

New, efficient AI design tools can be developed in open-source languages like R or Python to automate time-consuming tasks such as data extraction, cleaning, structuring, visualization, and result simulation. These in-house apps don't need data science expertise and can be used by data-experienced engineers and other technology-oriented users to build dependable AI models. The tools yield sustainable results and don't call for specialized knowledge (Charalambous et al., 2019).

Why AI is being adopted in manufacturing?

In the context of production processes, artificial intelligence is utilized to analyze data and deliver faster, more accurate, and more sustainable outcomes than a human operator can achieve. This encompasses data supervision and decision-making (Charalambous et al., 2019).

If there is adequate data history and volume to generate predictions about production, employing artificial intelligence (AI) in the production process is feasible. This elucidates why data can yield divergent results when an operator uses identical data on the same machines, and when an analyst interprets the outcomes. Occasionally, monitoring production by observing it on screens can be fatiguing for an operator or analyst, who will interpret the outcomes based on their workload. This is where artificial intelligence can assist and help avoid or entirely eradicate human mistakes, which is also relevant in obtaining consistent results from identical data produced by the same machines. It is vital to remember that production encompasses a holistic approach. In this comprehensive procedure, a piece of data with quantifiable value in one segment of the process might be interconnected with another segment of the same process. As an operator or analyst, if you are solely examining one area, it can be difficult to comprehend the overall picture. Utilizing artificial intelligence may be crucial for an exact and constant solution (Charalambous et al., 2019).

There are five areas where AI is making a significant financial impact (Charalambous et al., 2019).

1. Predictive maintenance involves using historical maintenance data to anticipate a machine's performance under future workloads. This helps determine if and when repairs are necessary and outlines how to carry them out based on previous

outcomes. Employing this approach can significantly reduce downtime.

2. Predicting and mitigating failures through predictive quality can lead to substantial cost savings.
3. Metrics can be used to anticipate product behavior across specifications, resulting in enhanced product quality and reduced scrap.
4. Improving Efficiency and Throughput. Predicting when machines or processes will fail to meet specifications allows for corrective action to be taken in advance, resulting in a reduction of quality defects.
5. Demand and inventory forecasting can result in substantial inventory cost savings. This is achieved by gaining a comprehensive understanding of plant operations and production data to anticipate the movement and demand of essential components.

Best Practices and Potential Pitfalls

There are many questions and doubts about whether it is right to incorporate artificial intelligence solutions into production and related investments. It is important to know what approaches will lead to the successful application of artificial intelligence (Rapp, 2022).

The successful application of AI can be reduced to three approaches: problem, people, and process. Let's take a quick look at them (Rapp, 2022).

Problem: A suitable problem for AI to solve must be carefully defined.

People: The right people are needed, including people from leadership, business, production, IT, technology, digital transformation and finance, all of whom play an important role in the successful application of AI.

Process: There is a necessity to establish a method for addressing the issue related to artificial intelligence. To achieve this, it is essential to ascertain the availability of relevant data to solve said problem.

Figure 3.
Best practices and potential pitfalls
(Sourrce: www.nist.gov/blogs/manufacturing-innovation-blogs (Rapp, 2022))



When introducing any new technology, it is prudent to commence with a pilot, like deploying AI on one manufacturing line. We develop an iterative process to resolve any issues that emerge before expanding the pilot to other machines or lines. Gradual scaling of the technology can prove to be cost-effective, and it will not disrupt the financial structure of smaller manufacturers. It is imperative to prioritize return on investment when constructing a building. ROI doesn't arise from excavating the

basement. One should not anticipate immediate returns upon establishing the foundation for the implementation of AI. What are the indicators of a company being prepared to incorporate AI? (Rapp, 2022).

Consider it to be much like a three-legged stool - without all elements in situ, successful implementation is highly unlikely, rendering the company unready for AI (Rapp, 2022).

1. Top-down leadership. Top-down leadership is imperative for the successful implementation of data-driven decision-making in business. Without clear organizational priorities and initiatives supporting the use of data, the endeavor is bound to fail.
2. Invest in collecting data consistently. Without a consistent investment in data collection, disregarding data loss, and individuals saving data, success is unlikely.
3. Identify the issue and calculate the financial benefit. Can you measure the exact monetary effect of a specific problem, such as unexpected halts, waste, or production output? If not, it will be ineffective.

Let's examine some useful tips for effectively implementing AI, grounded in the expertise of Delta Bravo (Rapp, 2022).

It is recommended that mid-sized manufacturers with multiple branches establish a center of excellence for testing AI. Begin AI deployment at a single location with one production line, and then advance to 2-3 lines before expanding to other sites. Assign an implementation leader who is responsible for communicating with your supplier and overseeing this endeavor. This person should not take on a third job (Rapp, 2022).

It is important to understand your unit economics. The cloud is often discussed in regard to AI deployment as it provides an effortless method of accessing computing resources. This is accomplished by using CPUs, memory, and disks to create virtual machines with minimal maintenance. However, cloud providers do not disclose their profit structures. While they offer cost-effective data storage, costs rise significantly as soon as computing resources are utilized. It is crucial to have the ability to scale across various cloud providers or storage solutions, depending on which is most economically advantageous (Rapp, 2022).

Be cautious of being locked into a specific technology or platform. Once all of your data is in one cloud provider, migration becomes laborious and costly. Remember that committing to big technology may be easy in the beginning, but difficult to disentangle from later on. Remember, there is no one-size-fits-all solution. Avoid becoming fully dependent on any particular provider (Rapp, 2022).

Some vendors claim to offer a pre-built solution for predictive maintenance that requires only inputting your data. However, it is important to approach these claims with caution. The truly necessary solution involves comprehending your process and tailoring it to your priorities. A pre-built model is not a cure-all and can prove to be more trouble than it's worth (Rapp, 2022).

Instead of relying on a fancy machine learning model, it is crucial to consider many other factors for successful progress. This function has the potential to enhance the knowledge of all employees within the organization, not exclusively to operational personnel. An instance of this would be the automation of spreadsheet processes using machine learning, thus providing the data visualization in an analytical display that updates regularly and is accessible anytime (Rapp, 2022).

Figure 4.
Professional tips (Reference: www.nist.gov/blogs/manufacturing-innovation-blogs (Rapp, 2022))



References

Goering, K., Kelly, R.& Mellors, N. (2018). The next horizon for industrial manufacturing: Adopting disruptive digital technologies in making and delivering, https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-next-horizon-for-industrial-manufacturing (accessed date: 03.02.2023).

Charalambous, E., Feldman, R., Richter, G. & Schmitz, C.(2019). AI in production: A game changer for manufacturers with heavy assests, https://www.mckinsey.com/capabilities/quantumblack/our-insights/ai-in-production-a-game-changer-for-manufacturers-with-heavy-assets (accessed date: 03.02.2023).

Rapp, K.(2022). Artificial Intelligence in Manufacturing: Real World Success Stories and Lessons Learned, https://www.nist.gov/blogs/manufacturing-innovation-blog/artificial-intelligence-manufacturing-real-world-success-stories (accessed date: 03.02.2023).

About The Authors

Husnu BAYSAL, Lecturer at Kocaeli University Hereke Asım Kocabıyık Vocational School, Electricity and Energy, Natural Gas and Installation Program Research Areas: Electrical and Electronics Engineering, Engineering and Technology.
E-mail: hbay1307@gmail.com, **ORCID:** 0009-0006-4478-6529

Hasan OKTEM, Professor at Kocaeli University Hereke Asım Kocabıyık Vocational School, Machine and Metal Technologies, Machine Program and Head of the Department of Machine and Metal Technologies. Research Areas: Tribology, Computer Aided Design and Manufacturing, Materials, Machining Methods, Materials Testing and Control, Composites, Polymeric Materials, Heat Treatment.
E-mail: hoktem@kocaeli.edu.tr, **ORCID:** 0000-0003-2526-8364

Similarity Index
The similarity index obtained from the ithenticate software for this book chapter is 9%.