The Application of AI in Automotive Manufacturing

1. Introduction

The battle for leadership in the automotive industry causes a constant development in advanced technologies. In addition, new regulations like emission-free production and the COVID-19 pandemic have changed automotive manufacturing and caused a significant profit reduction (Demlehner et al., 2021: 1). Therefore, automotive companies must remain competitive and continuously optimise productivity for their success. Hence, it is necessary to apply new technologies to minimise the production cost to survive in the very demanding competition (Belton & Olson, 2019: 5).

One of the emerging trends in computer science is artificial intelligence (AI), which has the potential to reduce costs and increase manufacturing productivity by using human-level intelligence (Candrall, 2019: 10). With AI applications, production problems can be identified and deliver solutions to eliminate those whereby humans would never be able to do so. As a result, productivity, flexibility, quality, safety, and cost can be enhanced (Arinez et al., 2020: 1).

Forbes Insight survey, 44% of respondents from automotive manufacturers consider AI will be significant in the following years and 49% the key to success (Buchmeister et al., 2019: 85). However, because of the vast gap in knowledge in applying AI technologies in manufacturing, most car producers have a hard time utilising it (Demlehner et al., 2021: 2).

This essay will follow the research question: To what extent do AI technologies in production influence the automotive manufacturing process? In addition, a case study to this question on one of the largest automobile companies in the world, Volkswagen, will be conducted.

The essay begins with the background of AI and the connection with the automotive manufacturing, following by the case study on Volkswagen and a conclusion.

2. Artificial Intelligence

Dr. Herbert Simon (1960, as cited in Candrall, 2019: 10) predicted in 1960 that "machine will be capable, within 20 years, of doing any work that a man can do". Sixty years later, the dream of humanity replacing a human, mainly human intelligence, has come closer. However, it is still in development and complex to reflect this algorithmically. Nowadays, AI focuses on what humans can do and not how they do it (Candrall, 2019: 10). The following Figure 1 demonstrates an overview of the interrelationships between AI, Machine Learning (ML) and Deep Learning (DL).

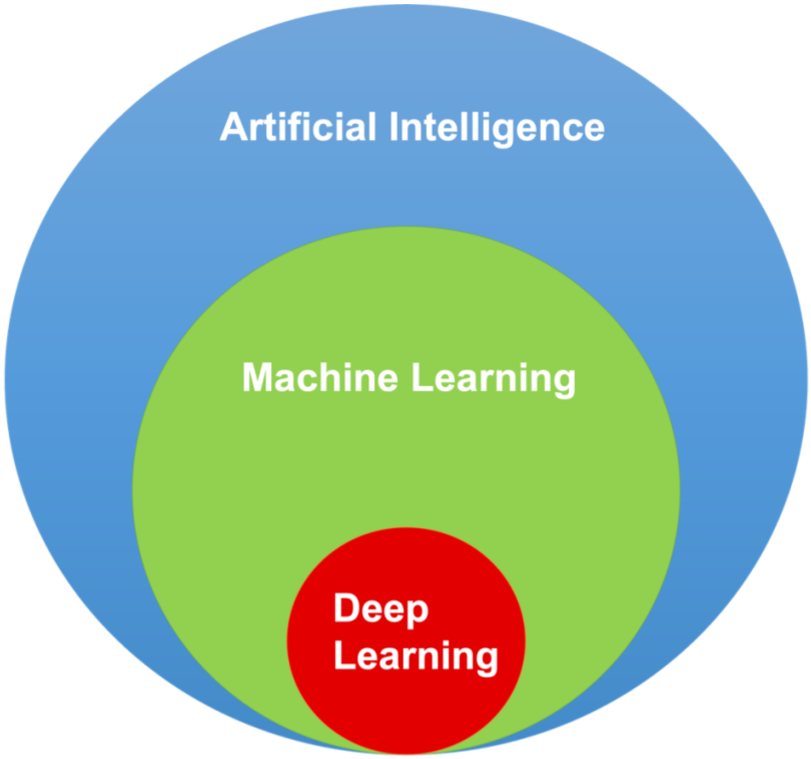

Figure 1: Relationships between AI, ML and DL (own representation based on Tong et al., 2019: 10826).

ML is the subset of AI, and DL is the subset of ML. Therefore, to understand how AI works, an understanding of ML and DL is necessary.

ML is distinguished in three parts:

1. Supervised learning: The machine learns from labelled data (input and output data) to train the machine to predict future data.
2. Unsupervised learning: This method uses unlabeled data (only input data) to train the machine to predict future data.

3. Reinforcement learning: This technique uses an agent and the environment to learn actively from the agent's action by trial and error (without initial data)—a practical way to predict the best result.

ML is a method to achieve AI by algorithms trained with data. In this process, ML includes a training and testing phase. Whereby at the training phase, ML models learn from data and in the testing phase, it predicts future data based on the learning data (Tong et al., 2019: 10826-10828).

DL is associated with the three attributes of ML, and it is used to implement ML. In addition, it has an artificial neural network with numerous layers. The neural network includes an input layer (neuron as input), one or more hidden layers and an output layer. The hidden layers are between the output and input layers (Tong et al., 2019: 10827-10828). An example: The technique is to detect an object in an image. First, the image will divide into many raw pixels. Then, the neural network will find through a non-linear transformation function matching patterns as output. Next, it uses the output for the next layer as input until a final output is given and the object is recognized. The performance depends on the amount of data. As a result, the more data is given, the better the performance (Chatsiou & Mikhaylov, 2020).

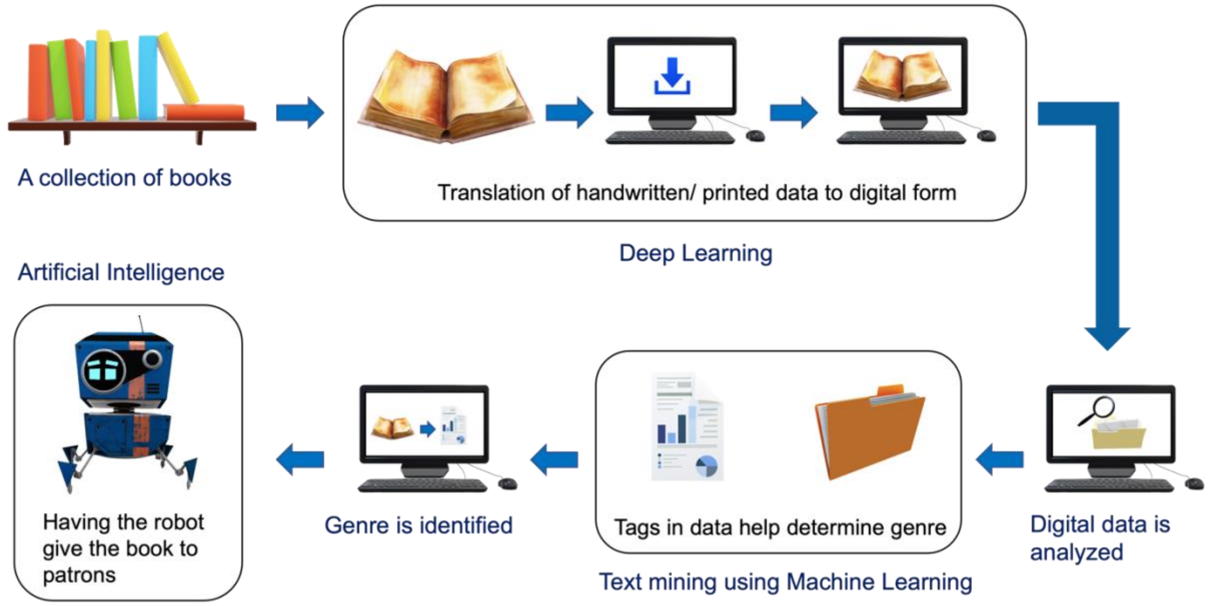

Figure 2: AI with Machine Learning and Deep Learning (own representation based on Simplilearn, 2018: 13:05)

With ML and DL, an AI system can perform human intelligence tasks (Tong et al., 2019: 10825-10828). Figure 2 shows how AI works with ML and DL together. First, a collection of books as initial input goes through the DL, where the digital data will be analyzed. Next, ML helps identify the desired book genre, and finally, the robot interacts with the patron (AI) and gives them the right book (Simplilearn, 2018: 13:05).

3. AI in the Automotive Manufacturing

3.1. Automotive Manufacturing

To understand where an AI system can be deployed, an overview of the vehicle manufacturing process is necessary.

Figure 3: Vehicle manufacturing process (Demlehner et al., 2021: 3)

In principle, the process of car manufacturing is divided into five generally procedures. (Figure 3):

1. Press shop: In this step, raw materials such as aluminium are pressed together to form individual automotive body parts, like the door, for instance. Furthermore, this step is up to 90% automated.
2. Body shop: This procedure is responsible for the car body construction and is even over 90% automated with the assistance of robots.
3. Paint shop: The step where the car gets the desired colour of the customer. Nowadays, this procedure is vastly automated as well.
4. Assembly: One of the biggest and most complex procedures in car manufacturing. Many parts of the car will be assembled step by step by robots and humans. Also, many suppliers deliver assembly parts to the right step. Hence, the automation is less than 20% of the above procedures.
5. Finish: In this step, the car is already built. However, it needs to get tested, and if there are any complaints, they must be corrected by humans. The car is ready for delivery to the customer when it has passed all tests. The automation of this procedure is less than 20% (Demlehner et al., 2021: 2).

3.2. Use Cases of AI

The essay focuses on AI technologies with the skills of sensing, learning, judging, and planning which can be applied in automotive manufacturing to optimize production. Demlehner et al. (2021) conducted a Delphi study (expert survey method) of 13 AI use cases in car manufacturing, which provided an excellent overview of the relationship between business value (added value to enhance the productivity) and realizability (how easy is the application of the AI use case). Firstly, the following Figure 4 shows the overview of the above-described relationship.

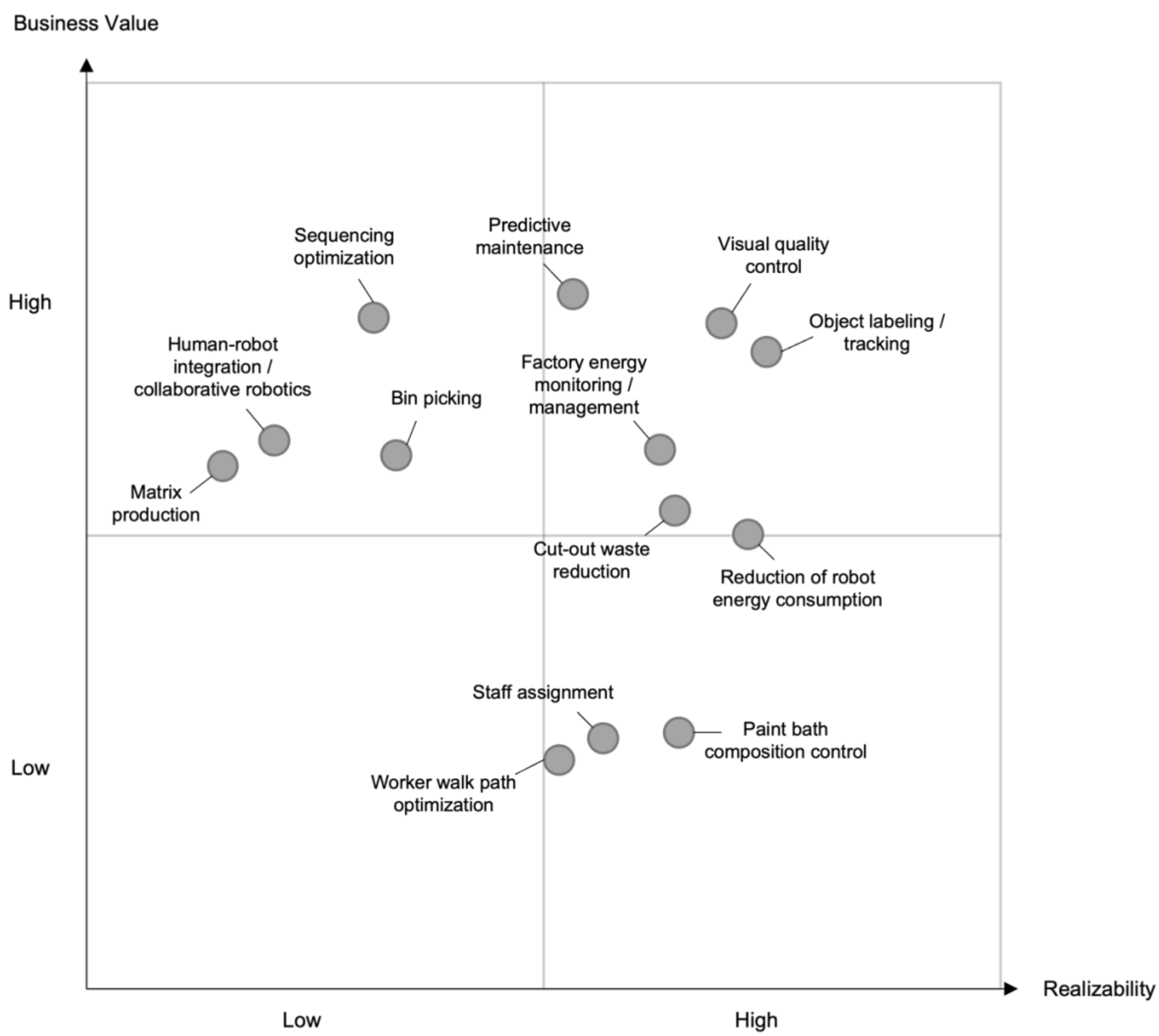

Figure 4: AI use cases in the car manufacturing in the relationship between business value and realizability (own representation based on Demlehner et al., 2021: 11)

Many AI use cases have different solutions for comparable problems (Demlehner et al., 2021: 3). Because of the essay's size limitation, not all cases will be described. Hence, here are the best four AI use cases with the highest business value and realizability:

1. Predictive maintenance: AI application for prediction of future maintenance of machine by analyzing changing data in the course of time.
2. Visual quality control: Improving quality control by using an AI visual recording incoming data.
3. Object labelling/ tracking: AI technology to recognize objects such as boxes.
4. Factory energy monitoring/management: AI application for calculating the wastage of the whole factory energy to manage the consumption in an efficient way.

All four use cases can be applied on all five production procedures (Demlehner et al., 2021: 3-4).

4. Case study on AI Application in the Volkswagen Organisation

4.1. AI tool Computer Vision for the Car Production

Volkswagen is one of the leading automakers globally and constantly striving to be the best. To be the best needs to permanently optimize the production in all sections of the car manufacturing. Volkswagen applied the AI technology Computer Vision (Volkswagen, 2020). It is related to the AI use case visual quality control and is perfectly suitable for the car manufacturing accordingly to the realizability and business value (Figure 4).

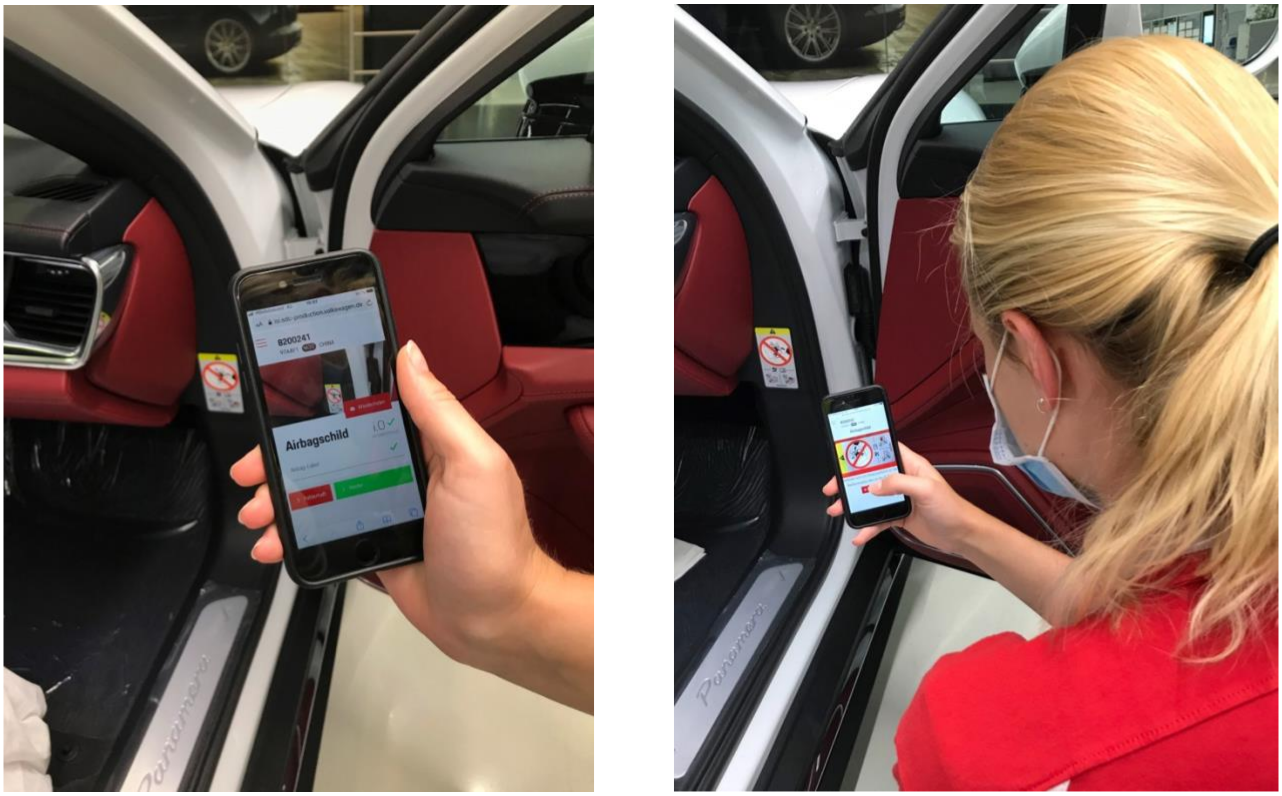

Figure 5: AI application Computer Vision (Volkswagen, 2020)

The Volkswagen Group, with its automotive brands Audi, Porsche and many others, have been working with Computer Vision for many years, but Volkswagen is constantly developing it. The process gathers information from visual data from around the factory, and through AI, the data is analysed. The AI capability is linked to the human ability to recognise, process, and analyse images (Shahan, 2020).

Several labels are attached to every produced car, for example, information about the airbags (Figure 5). In addition, many of these labels are written in different languages due to international customers. Furthermore, Computer Vision secures the proper application of these labels. For using computer vision to examine those labels, employment check with an app the labels of the car by scanning it with a phone camera (Figure 5). The app provides real-time feedback if the label has the right content and is written in the appropriate language. The application area of this method is in the assembly and finish procedure of car production (Shahan, 2020).

Another application area is the press shop, where large sheet metal parts are pressed. Computer Vision can even recognise minor damage. In addition, it can be used group-wide since the type of damage looks like all other car production companies (Menzel, 2020).

4.2. Benefits and Drawbacks

The process of Computer Vision saves several minutes per vehicle. Thus, it is assumed that factory workers had to spend much time checking by themselves whether the labels were adequately applied. As a result, the faster the production, the better the productivity. According to Volkswagen, the application of Computer Vision will lead from 2016 until 2025 to a 30% productivity improvement in its production processes. Furthermore, a cost reduction in the double-digit million range is expected (Shahan, 2020).

However, there are limits to deploying Computer Vision. In the end, the self-learning machines do not manage higher levels of complexity. On the other hand, humans remain unbeatable if things get too complicated. Therefore, the challenge for Volkswagen is to find out where the AI can be applied so that do not overtax them. In addition, the number of cameras used in production needs to increase at Volkswagen shortly. However, this also creates data protection problems (Menzel, 2020).

4.3. Influence of AI Application on the Automotive Manufacturing Process

The application of Computer Vision influences the car production process. Chapter 4.2 describes that AI technology improves productivity enormously; however, how it can be imagining the enhancement of the production process. Figure 6 shows an example of how the production increase can proceed.

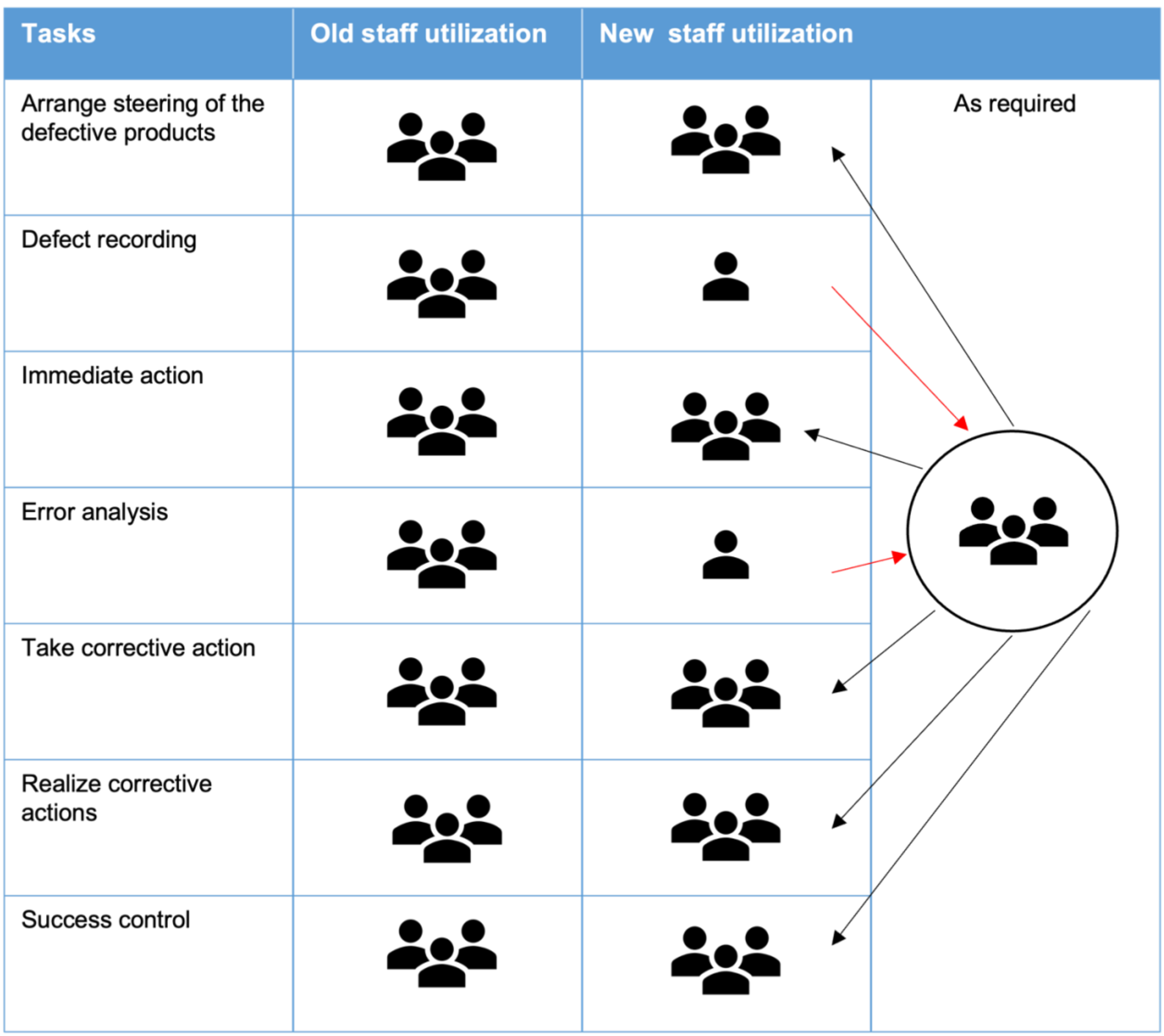

Figure 6: Comparison of the workload in the fault elimination process (own representation based on Linß, 2018: 503)

The assumption is that free work capacity among personnel for defect recording and error analysis can be created by implementing Computer Vision. The free work capacity can be distributed according to demand. The resulting consequences are a reduction in quality-related costs such as defect costs, defect prevention costs, and inspection costs. Likewise, product quality can be ensured, and the rework rate is reduced through freed-up competencies and more efficient working methods (Linß, 2018: 502-504).

4.4. Challenges and Recommendations

As chapter 4.2 mentioned, data protection will be a problem while increasing the cameras used in production. The company cannot use employees' data without further ado. Moreover, the cameras must not become an instrument of control; the anonymity of the employees must be preserved. A solution to this problem is to pixelate captured images with recognizable faces and unique identifiers such as tattoos from the outset (Shahan, 2020).

Another Challenge of the AI application is the availability of jobs. Chapter 4.3 shows that with the introduction of Computer Vision, the related work activities are no longer needed. However, Volkswagen and other companies should take it as a challenge for the future.

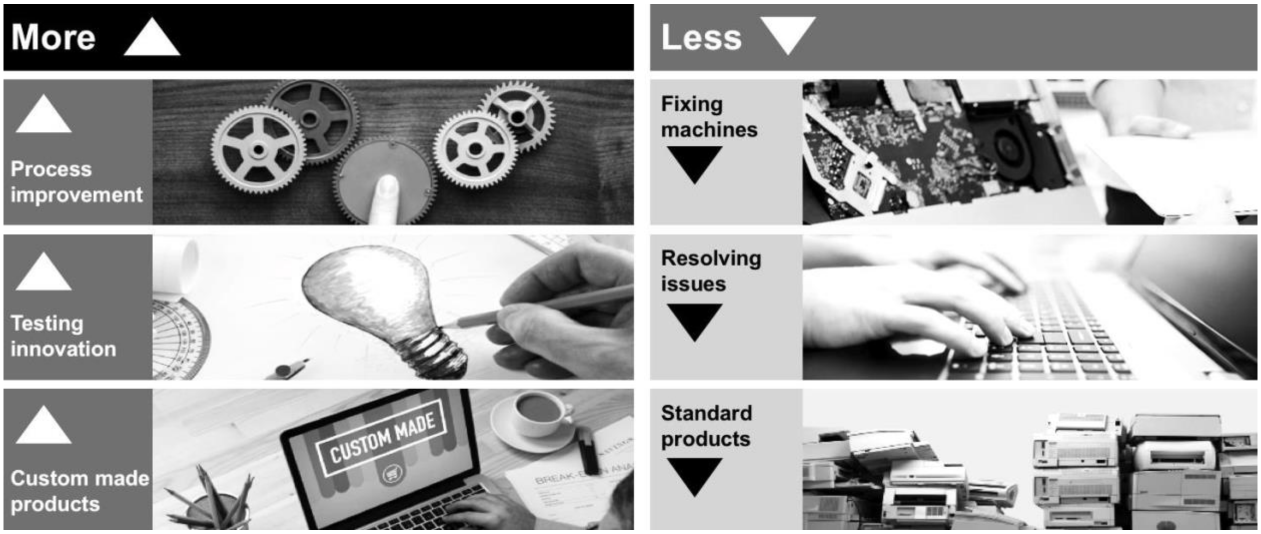

Figure 7: Changes in production jobs due to AI (Buchmeister et al., 2019: 91).

Figure 7 displays the change in production jobs due to the application of AI. Workers need to adapt to the advancement of technology and dedicate themselves to complex and innovative tasks. To avoid the lack of know-how, companies must promote a worker to train for a new position in the design, maintenance, and programming (Buchmeister et al., 2019: 90-91).

Conclusion

This essay examined the extent to which the use of AI technologies in manufacturing affects the manufacturing process in the automotive industry. There are many AI use cases for car manufacturing. However, companies still have a hard time applying it in production due to the lack of knowledge. The case study with the paradigm organisation Volkswagen provided a significant demonstration that an AI application in car production can influence processes considerably. As a result, the AI technology Computer Vision saves each produced car severe minutes, which leads to an increase in production efficiency. Furthermore, it creates free work capacity, which can be distributed according to demand. In conclusion, the application of the AI effect leads to an improvement in production and consequently to a significant reduction in costs.

It is true that the automotive industry confronts many challenges by applying AI technologies. Whether the restructuring of human tasks or the challenge of protecting personal data, to be successful and competitive in this difficult time, a strive for permanent production improvement is essential. Thus, AI offers great potential to achieve this.

References

Arinez, J. F., Chang, Q., Gao, R. X., Xu, C. & Zhang, J. (2020) Artificial Intelligence in Advanced Manufacturing: Current Status and Future Outlook. *Journal of Manufacturing Science and Engineering* 142(1): 1-16. DOI: https://doi.org/10.1115/1.4047855

Belton, K. & Olson, R. (2019) The Promise of Smart Manufacturing. Smart Factories: Issues of Information Governance: 5-9. Available from: https://policyinstitute.iu.edu/doc/mpi/smart-factories.pdf#page=12. [Accessed 7 April 2022].

Buchmeister, B., Palcic, I. & Ojstersek, R. (2019) Artificial Intelligence in Manufacturing Companies and Broader: An Overview. *Daaam International Scienticif Book* 7(1): 81-98 DOI: 10.2507/daaam.scibook.2019.07

Crandall, D. (2019) Artificial intelligence and manufacturing. Smart Factories: Issues of Information Governance: 10-16. Available from: https://policyinstitute.iu.edu/doc/mpi/smart-factories.pdf#page=12 [Accessed 7 April 2022].

Chatsiou, K. & Mikhaylov, S. J. (2020) Deep Learning for Political Science. *The SAGE Handbook of Research Methods in Political Science and International Relations* 1: 1-51. DOI: https://doi.org/10.48550/arXiv.2005.06540

Demlehner, Q., Schoemer, D. & Laumer, S. (2021) How can artificial intelligence enhance car manufacturing? A Delphi study-based identification and assessment of general use cases. *International Journal of Information Management* 58(1): 1-14. DOI: https://doi.org/10.1016/j.ijinfomgt.2021.102317

Linß, G. (2018) *Qualitätsmanagement für Ingenieure.* 4th Edition ed. Munich.

Menzel, S. (2020) Warum VW die Tattoos seiner Mitarbeiter verpixelt. Available from: https://www.handelsblatt.com/unternehmen/industrie/computer-vision-in-der-fertigung-warum-vw-die-tattoos-seiner-mitarbeiter-verpixelt/25964026.html [Accessed 24 May 2022].

Shahan, Z. (2020 Volkswagen nutzt Computer Vision zur Steigerung der Produktionseffizienz. Available From: https://gettotext.com/deutsch/volkswagen-nutzt-computer-vision-zur-steigerung-der-produktionseffizienz/ [Accessed 24 May 2022].

Simplilearn (2018) *Machine Learning vs Deep Learning vs Artificial Intelligence* **|** *ML vs DL vs AI* **|** *Simplilearn* [Online Video]. Available from: https://www.youtube.com/watch?v=9dFhZFUkzuQ&t=1071s [Accessed 22 May 2022].

Tong, W., Hussain, A., Bo, W. X. & Maharjan, S. (2019) Artificial Intelligence for Vehicle-to-Everything: A Survey. *IEEE Access Secial Section on Emerging Technologies on Vehicle to Everything (V2X)* 7: 10823-10843. DOI: 10.1109/ACCESS.2019.2891073

Volkswagen (2020) Computer Vision to make production within the Volkswagen Group even more efficient. Available from: https://www.volkswagen-newsroom.com/en/press-releases/computer-vision-to-make-production-within-the-volkswagen-group-even-more-efficient-6170 [Accessed 23 May 2022].