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Utilizing Artificial Intelligence in production planning

– Integration of AI into production planning process and the value it brings

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Utilizing Artificial Intelligence in production planning

Integration of AI into production planning process and the value it brings

The topic of this thesis is Artificial Intelligence and its integration into production planning. The goal of thesis was to find out how AI is reflected in the different stages of the production planning process and how its benefits can be maximized at each stage of the process. The goal of this thesis was to find the stages of the process that benefits the most from the use of AI and to balance the use of AI in the whole process of production planning in a way that bottlenecks are prevented.

In the thesis current AI and machine learning softwares and their potential use were researched. Particularly the focus was on AIs ability to process and analyze data in real-time and the opportunities it brings to production planning process. The study also takes the ethical questions of AI into account.

To accomplish these goals, each step of the production process was researched from the perspective of AI and various ways to utilize it were considered. When areas for improvement were identified in the stages of the production planning process, solutions were discovered using AI, machine learning and data.

Research shows that integrating AI in to the production planning process provides significant benefits in terms of cost-efficiency, flexibility and sustainability. Decision-making process and predictability become easier and more accurate with the help of AI.

Keywords:

production planning, Artificial Intelligence, machine learning, data, production control

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Kaisa Saari, Salla-Mari Kurppa

Tekoälyn hyödyntäminen tuotannonsuunnittelussa

- Tekoälyn integrointi tuotannonsuunnitteluun ja sen tuoma lisäarvo

Tämän opinnäytetyön aihe on tekoäly ja sen integroiminen tuotannonsuunnitteluun. Työn tavoitteena oli selvittää, miten tekoäly näkyy tuotannonsuunnitteluprosessin eri vaiheissa sekä miten sen hyödyn voi maksimoida prosessin jokaisessa vaiheessa. Työn tavoitteena oli löytää prosessin vaiheet, jotka hyötyvät eniten tekoälystä ja tasapainottaa tekoälyn hyödyntämistä koko prosessin ajan, niin ettei pullonkauloja pääse syntymään.

Työssä tutkittiin tämän hetkisen tekoälyn ja konepoppimisen sovelluksia ja käyttömahdollisuuksia. Erityisesti pohdittiin tekoälyn kykyä käsitellä ja analysoida dataa reaaliajassa ja sen tuomia mahdollisuuksia tuotannonsuunnittelussa. Työssä on otettu huomioon tekoälyyn liittyvät eettiset kysymykset.

Tavoitteiden saavuttamiseksi työssä tutkittiin tuotannonsuunnittelun jokaista vaihetta tekoälyn näkökulmasta sekä pohdittiin erilaisia tapoja hyödyntää sitä. Kun tuotannonsuunnitteluprosessin vaiheissa havaittiin kehityskohteita, niihin pyrittiin löytämään ratkaisu tekoälyn, koneoppimisen ja datan avulla.

Tutkimus osoittaa, että tekoälyn integroinnista tuotannonsuunnitteluprosessiin on merkittäviä hyötyä kustannustehokkuuteen, joustavuuteen ja kestävyyteen liittyen. Päätöksentekoprossesit sekä ennustettavuus helpottuu ja kehittyy tarkemmaksi tekoälyn avulla.

Asiasanat:

tuotannonsuunnittelu, tekoäly, koneoppiminen, data, tuotannonohjaus

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List of abbreviations

AGI	Artificial General Intelligence (Kalota 2024.)
AI	Artificial Intelligence (Gupta 2020.)
AM	Additive Manufacturing (Chen 2023.g)
ANI	Artificial Narrow Intelligence (Kalota 2024.)
AR	Augmented Reality (Zizic 2022.)
ASI	Artificial Super Intelligence (Kalota 2024.)
CPS	Cyber-Physical Systems (Saini 2024.)
DDDM	Data-Driven Decision Making (Rodriguez-Serrano 2025.)
IoT	Internet of Things (Redman 2023.)
LLMs	Large Language Models (Mucci 2023.)
NLP	Natural Language Processing (Mucci 2023.)
RFID	Radio Frequency Identification (SAP n.d. What is Internet of Things (IoT)?.)
SMEs	Small and medium-sized enterprises (Chen Et. Al. 2023.)
S&OP	Sales and Operations Planning (Ávila et al. 2019.)

1 Introduction

The topic of the thesis is production planning and AI and how to integrate AI to the process. The goals are to find out how to integrate AI into the production planning process and what are the pros and cons in doing so. This integration needs to be done without creating bottlenecks and without harming other parts of the process. This topic was chosen because of its relevance to quickly evolving world. AI has strengthened its position in recent years and its full potential has not even been discovered yet.

The main question that is researched is what part of the production planning process benefits the most from the use of AI. To discover the answer to the main question there are smaller topics that need to be taken into consideration. These topics are possible challenges and solutions to those, effects to quality, efficiency and costs. When all of these are taken into consideration benefits for each step of the process are found. With the findings the process can be balanced and as cost-efficient as possible. With AI, machine learning and use of data integrated to the process it keeps the process up to date and progressive. Once this is achieved resources can be redirected elsewhere, for example to develop other processes. Other benefits include competitiveness, shortening lead time and cost efficiency.

The thesis addresses the AI and the types of it, machine learning and data. Next the thesis focuses on production planning and the steps and goals of it. Lastly the future and the evolving changes ahead are reflected.

2 Artificial Intelligence

Artificial Intelligence means the capability to understand the world as well as human (Zhang Et. Al. 2021.). Definition of Artificial Intelligence is the capability to gain knowledge and apply it to different situations. Essential functions for Artificial Intelligence is also problem solving. This is done by learning from previous experiences and adapting to new situations. (Gupta 2020.) AI has the ability to carry out various functions at the same level as a human. It can process data and insights in real time, responsive technologies that enchance human abilities and increase efficiency and productivity at the same time in company. (Zhang Et. Al. 2021.)

Typically an AI system includes components like problem solving skills, AI hardware, representation of knowledge, learning and AI programming language. (Gupta 2020.). Because of this, machines can perform human like intellectual tasks, like speech recognition and image processing. The complexity and cability of AI can vary a lot depending on whether the AI is simple or more advanced. Simple AI can perform specific, narrow tasks without adapting and learning from new data over time. On the other hand, advanced AI is able to learn, reason and adjust from new data. (Zhang Et. Al. 2021.)

Automating tasks and streamlining functions in one of the most important benefit of Artificial Intelligence. Systems powered by AI can handle large amounts of information extremely quickly and this way give employees the possibility to focus on more valuable tasks. Improved efficiency leads to enhanced productivity as employees can devote their time to strategic decision-making and innovation instead of routine tasks. AI technology has revolutionized the way companies are interacting with customers. AI based chatbots can offer individualized and real time support for customers. This improves customer satisfaction and also helps companies provide flawless customer experience in different platforms. From data analyzed using AI systems, companies can recognize trends, forecast customer behavior and optimize their functions. (Zhang Et. Al. 2021.)

In the industrial sector AI is applied to automate processes, improve efficiency and operative decision making. Smart factory is a cyber physical system (CPS) that uses advanced technologies to analyze information, operate automized processes and learn. AI optimizes and informs about smart factorys automized processes and intelligent systems, continuously monitoring device conditions, predicting supply chain issues and enabling predictive manufacturing. (Mozaffar. Et Al. 2022.)

2.1 Types of AI

Artificial Intelligence is not just a single technology, it is a combination of technologies that can be utilized for different kinds of tasks. Generally, AI can be categorized into three main types: Artificial Narrow Intelligence (ANI), Articial Gener Intelligence (AGI) and Artificial Super Intelligence (ASI). Currently all AI systemas in use are classifies as narrow AI, meaning they are designed to perform specific tasks rather than posess general intelligence. (Kalota 2024.)

2.1.1 Artificial Narrow Intelligence

Artificial narrow Intelligence (ANI) is built to perform particular tasks (Kalota 2024.). It is called narrow because it is far from the human understanding or consciousness that we associate with true intelligence (Mucci 2023.). These systems are limited and cannot operate outside of their domain. Examples include voice assistans, facial and speech recognition and self-driving cars. (Kalota 2024.) ANI requires human intervention to operate and relies on pre-programmed algorithms and data (Mucci 2023.).

Artificial Intelligence can execute tasks that are repetitive and are done in similar environments. These jobs can also be based on simple classifications and machine visions. Jobs that can be done by AI are usually focused on quite specialized area. These tasks don’t involve face to face interactions and the interactions include fixed elements. (Aaltonen 2019.)

ANI systems rely on deep learning techniques to analyze large amounts of data and make predictions related to specific activities or functions. ANI is focused on a specific task and cannot adapt to new tasks or environments it hasn't been trained on. (McLean 2021.)

2.1.2 Artificial General Intelligence

Artificial general Intelligence (AGI) could successfully perform all intellectual tasks, possibly even better than humans. Like ANI systems, AGI systems would learn from experiences and recognize patterns but they would also be able to apply their knowledge to new tasks and situations. AGI has not yet been developed but research and development in the field are progressing promisingly. (Zhao Et. Al. 2023.)

An AGI would have a higher level of intelligence, capable of achieving goals in many different environments and handling complex tasks. Unlike current ANI systems which are tools that assist humans, an AGI would be an independent agent that can learn on its own. (McLean 2021.)

An AGI is an advanced AI system that can learn, understand and have problem-solving intelligence as flexibly and broadly as humans. It would be able to learn and reason across different areas, making links and drawing insights from wide range of disciplines. (Mucci 2023.)

2.1.3 Artificial Super Intelligence

Artificial super Intelligence (ASI) is defined as fully self-aware and it surpasses human intelligence. ASI could improve itself and make decisions using a level beyond human intelligence. It would be able to surpass human intelligence in cognitive fields such as creativity and general intelligence. At the moment there are no known methods to achieve this kind of intelligence. (Pohl 2025.) The creation of AGI would be a key achievement in developing an ASI. Before ASI becomes a reality, certain technologies need to be developed. There is some other processes that form the foundation of ASI and before it can become reality, these processes would need to be developed further. (Mucci 2023.)

To understand the world and learn, ASI would require vast amount of data. Natural Language Processing (NLP) in Large Language Models (LLMs) will enable ASI to comprehend and communicate with humans. Multisensory AI enables the ASI to process and interpret multiple types of data inputs to make decisions or perform tasks. Neural networks need to be more complex, efficient and advanced than they are currently. Neuromorphic computers are hardware systems that are inspired by synaptic and neural structures of the human brain. (Mucci 2023.)

2.2 The ethics of AI

The ethics of AI related to technological change effect our individual lives but also societies and economic changes (Coeckelbergh 2021.). In the ethics of AI, the focus is on how developers, authorities and manufacturers should act so that ethical risks caused by AI can be minimized. These risks include technical design, improper application or intentional misuse. (Helsingin yliopisto n.d.)

Concerning the ethics of Artificial Intelligence, there is a consensus of the following five principles: avoidance of harm, responsibility, transparency and explainability, fairness and respect for human rights, such as privacy and security. The use of AI should obey the principle of doing good and avoid causing harm. If AI causes any harm, it is important to take into consideration who is responsible and how the responsibility principle is applied. The functioning of artificial intelligence should be transparent so that its actions and why it behaves in a certain way can be understood. AI must act fairly and avoid all forms of discrimination in accordance with the principle of justice. Artificial intelligence should also respect and enhance human rights. (Helsingin yliopisto n.d.)

2.3 Intelligence decision making

Intelligence decision making refers to the process of making decisions by utilizing data, analytics and advanced technologies to achieve the best possible decision. Data-driven decision-making (DDDM) involves relying on factual information, key metrics and data insights to inform strategic business choices, ensuring they align with your goals, objectives and initiatives. (Rodriguez-Serrano 2025.)

AI can have a major impact on data-driven decision making providing various benefits, such as enhancing accuracy, speeding up decision making, improving efficiency, enhancing risk assessment and offering data-driven insights. (Rodriguez-Serrano 2025.) Decision intelligence enhances decision accuracy and speed by using AI and advanced analytics to process vast amounts of data quickly. When decision-making is based on data analysis and not gut instinct, it is more accurate. Decision intelligence enables comprehensive outlook of all available information by integrating data from different sources. This allows more in-depth analysis. Risk assessment accuracy is enhanced by decision intelligence and this enables more targeted approaches to risk mitigation. Decision intelligence helps to make proactive choices by using predictive analytics to anticipate future outcomes. This approach enables better preparation ans strategic planning to handle upcoming challenges and seize opportunities. (Kerner 2024.)

AI can use advanced algorithms and data to provide accurate insights reducing different kinds of errors. Huge amounts of data can be processed by AI incredibly fast which enables quick analysis and generating facts in real time. This results in faster and more effective decision-making. AI can handle routine, repetitive parts of the decision-making orcess, allowing humans to concentrate on more advanced and strategic work. Decision makers can identify potential risks with the help of AI since it can analyze and assess various risks factors. AI leverages large amounts of data to uncover information that might be unnoticed by humans. (Yada 2025.) Machine learning makes it possible for systems to learn from previous data and enhance decision-making skills over time without explicit programming. This enables effective predictive analytics, where AI can predict future trends and possible outcomes with the help of historical data. This helps to make proactive and data-driven decisions. (Kerner 2024.)

3 Machine Learning and Data

Combining machine learning, data and Artificial Intelligence makes the creation of intelligent systems possible. Combining these three elements, efficient and self-learning systems can be created. These intelligent systems can learn, analyse and make decisions from large amounts of data without human intervention. Those systems will enhance performance and predict future. (Oswald 2020.)

3.1 Machine Learning

Machine learning is part of Artificial Intelligence and it aims to enable computer to learn from data and get better at tasks as they gain more experience over time. (Alpaydin 2021.). AI uses and deals with data during decision-making and forecasting. AI is the intelligence of computer-based system that enables the machine to function and make decisions. Machine learning algorithms are computational models that enable computers to recognize patterns and predict or make decisions from data, all without being specifically programmed for the task. Machine learning algorithms inside AI and other systems utilizing AI, makes possible that the systems does not only go through the data but also uses it to accomplish tasks, make forecasts and learn without additional programming. (Oswald 2020.) In machine learning, algorithms are taught to recognize patterns and relationships within large datasets, allowing them to make informed decisions and predictions. These systems improve over time, becoming more precise as they are exposed to more data. (Alpaydin 2021.)

The goal of machine learning is to develop software that are constantly learning. Learning in this context means improvement of performance based on previously collected data. In programming, improvement is made by adjusting the program so that over time and with more data it produces better results based on a set criterion. (Alpaydin 2021.) AI aims to develop expert systems that exhibit intelligent behavior, can learn, provide guidance, and assist users.

Another key objective is to replicate human intelligence in machines, enabling them to understand, reason, learn, and act similarly to humans. (Gupta 2020.)

Machine learning has various defining features. Machine learning models are designed to produce very accurate results when analyzing test data. One key feature of machine learning is the strong connection between theoretical concepts and real-world applications. It focuses on techniques that are capable of processing and learning from large volumes of data. (Gupta 2020.)

3.1.1 Algorithms

Artificial intelligence analyzes data to make conclusions, decisions and forecasts. By utilizing machine learning algorithms, AI systems can analyze data, learn from it and improve their performance over time. All of this can be done without additional programming. (Yadav 2024.) The Machine learning algorithms should be trained with as much data as available. This way the algorithms produce more accurate answers and decisions. Machine learning algoritms can process data to identify hidden patterns and trends, enabling the predicition and prevention of potential problems before they occur. (IBM n.d. What is a machine learning algorithm?.) AI is the top level above all its subsets of machine learning. Machine learning is a broad field that encompasses deep learning which in turn includes neural networks as a core component. (Yadav 2024.)

A machine learning algorithm is a defined set of rules or proocedures that an AI system follows to perform specific tasks. Industries such as supply chain management, transportation and logistics, retail and manufacturing gain significant advantages from using machine learning to create new insights and content from vast datasets. (IBM n.d. What is a machine learning algorithm?.)

3.1.2 Process of Machine Learning

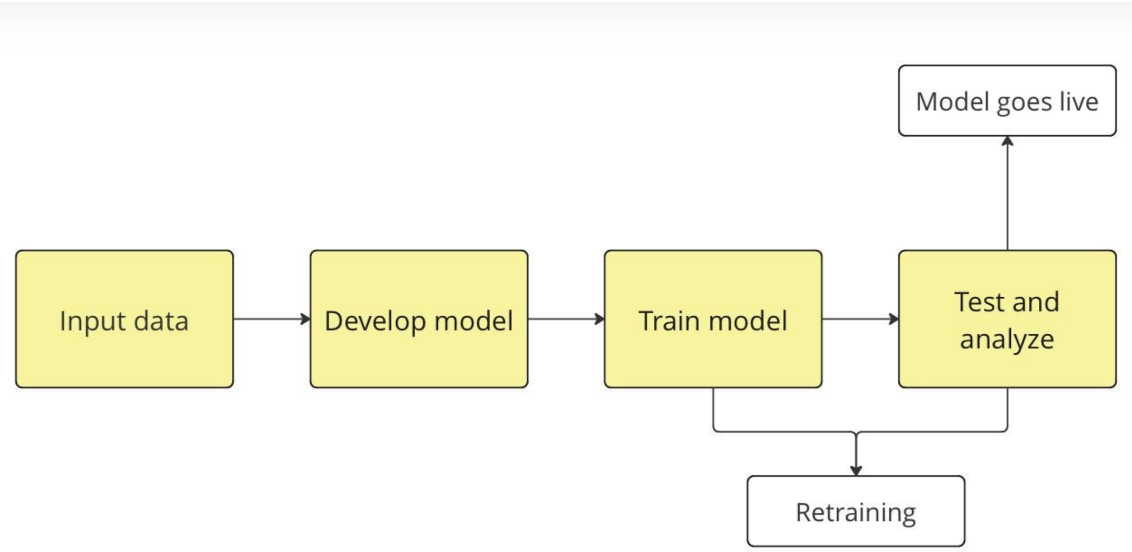

Figure 1: Process of Machine Learning

The process begins with data collection. Data can come for example from data bases, sensors or web scraping. It must be relevant, sufficient and clean to ensure accurate model development. Next, the appropriate machine learning model is selected based on the problem at hand. There is a variety of models to choose from and each is suited for different types of tasks. Once a model is chosen it's trained using imput data, where the model learns patterns by analyzing the information provided. After training, a separate data set, one that wasn't used during the training, is used to test the models performance and chek how well it handels new, unseen data. If the model performs well it is deployed in real-world setting to start making predicitions and decisions based on fresh incoming data. Its performance is regularly monitored with new data to keep its performance up to date. (Yadav 2024.)

3.1.3 Types of Machine Learning

Machine learning includes various machine learning models that utilizes different algorithmic methods. Algorithmic techniques are methods and strategies that are used in computer softwares to solve problems and to complete tasks efficiently. These models are supervised, semi-supervised, unsupervised and reinforcement. Depending on the wanted end result and the type of data, one of the models can be used. Each of these models can utilize one or more algorithmic methods. Machine learning algorithms are built to classify data, identify patterns, predict outcomes and make data-driven decisions. When working with complex and uncertain data, these algorithms can be used individually or in combination to achieve optimal accuracy. (Gupta 2020.)

3.1.4 Deep Learning

Deep learning is a type of machine learning that involves multiple layers of naural networks and processes vast amounts of complex and unsdtructured data. To accomplish deep learning, the software uses many layers of network and tries to achieve higher level outputs. Deep learning is utilizing neural networks and uses large amounts of data and at the same time engages with a multilayer neural network. (Yadav 2024.)

Deep learning is efficient especially when the data is complicated and there is a lot of it, deep learning has the ability to process this kind of data series. Deep learning can automatically identify important characteristics without human intervention. Deep learning models are usually more detailed and reliable when it comes to recognizing figures and connections. (Numminen 2023. Mitä on syväoppiminen?)

3.1.5 Neural Networks

Neural networks are inspired by the structure of biological brains. In these networks, artificial neurons, known as nodes, are organized into several layers that operate simultaneously. When a node receives a numerical input, it processes the information and triggers other connected nodes. Similar to the human brain, this process of reinforcement enhances the network's ability to recognize patterns, gain knowledge, and improve learning over time. (Numminen 2023. Mikä on neuroverkko ja kuinka se toimii?.)

Neural networks consist of cells which are neurons. Each of the neurons have multiple inputs and one output. Neurons are connected to each other through weighted connections, these connections are modified during the learning process. When an input is given to neural network, it goes through the network and each neuron processes the input and produces an output. Final output depends on the whole structure of neural network and the weights of the connections between the neurons. (Numminen 2023. Mikä on neuroverkko ja kuinka se toimii?.)

Even though neural networks are very efficient in many tasks, one of the biggest challenges is that their inner function is hard to understand and explain. In the future neural networks are expected to develop even more and the possibilities to utilize them increase. (Numminen 2023. Mikä on neuroverkko ja kuinka se toimii?.)

3.2 Data

Data is an essential part of almost everything we do, in both personal and professional lives. Most of the time data goes unnoticed and can feel almost invisible. Data overall is a very broad topic and because of that it can be divided into five smaller areas. These areas are data quality, putting data to work, organizational capacity, technology and defence. Many new technologies, including Artificial Intelligence, cloud computing and connected devices, have proven to be valuable. Even though these technologies are proven to be valuable, implementing these new technologies can be hard for companies because of powerful restraining forces getting in the way of change. (Redman 2023.)

3.2.1 Data Collection and Management

Good quality of data makes everything easier but on the other hand a lot of data collected is bad, some intentionally so and this hurts those using it. Poor quality data can prevent artificial intelligence programmes and digital transformation. Bad data quality also adds a lot of costs and friction. Privacy in the Information Age will hold the same importance as product safety did in the Industrial Age. Just as societies came to demand that companies ensure the safety of their products, they will similarly expect companies to protect customers' identities and data. Effectively managing and utilising data is the management challenge of the 21st century. (Redman 2023.)

In today's society, cyber attacks are an every day threat since the amount of different kinds of attacks has increased enormously in the 2020s decade. For example in 2021 the amounts per week increased 50 percent compared to the year 2020. At the end of 2021 there was over 900 attacks weekly per organization. These attacks don’t target just the companies and their confidential information but also their employees and customers. (Check Point 2022.)

With the development of AI the attention is focused on protecting privacy while considerating security and human dignity (Aaltonen 2019.). In cybersecurity, AI enables analyzing large amounts of data and it is capable of collecting the data from many sources within the company’s network.

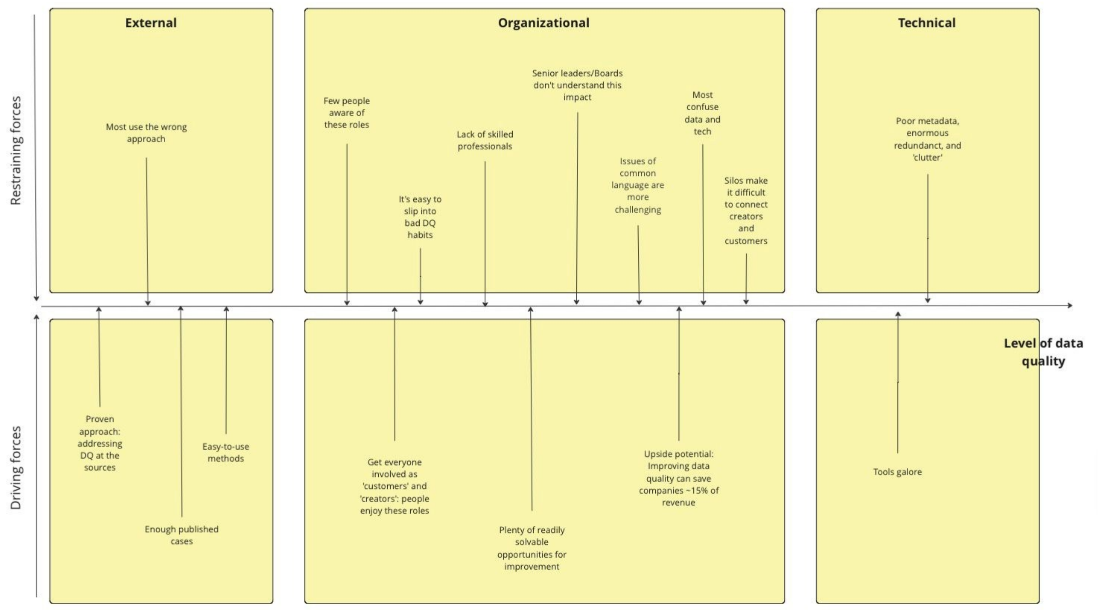

Figure 2: Quality Data

External, organizational and technical factors can either prevent or reinforce data quality. Restraining forces include for example use of wrong approaches and lack of skills to understand the importance of data quality. Driving forces include published cases, easy-to-use methods and galore tools. (Redman 2023.)

High level data quality is important in production planning because it enables accurate forecasting and decision making, improves process performance and reduce waste. (Redman 2023.)

3.2.2 Data Utilization

Data offers companies powerful ways to create competitive advantages. These are for example new wealth, new jobs and increased productivity. Unless companies utilize data in work that returns value, there is little to no business benefit. (Redman 2023.) A new challenge for the companies is to utilize the value of data and because of this the need for a analytical information system increases. With these information systems useful and sometimes hidden information is found and datasets can be searched. (Cattaneo et. al. 2018) Ways to utilize data include data science (including artificial intelligence and machine learning), creating data-driven cultures, commercialise data by selling it or building it into products and services, and treating data as assets. (Redman 2023.)

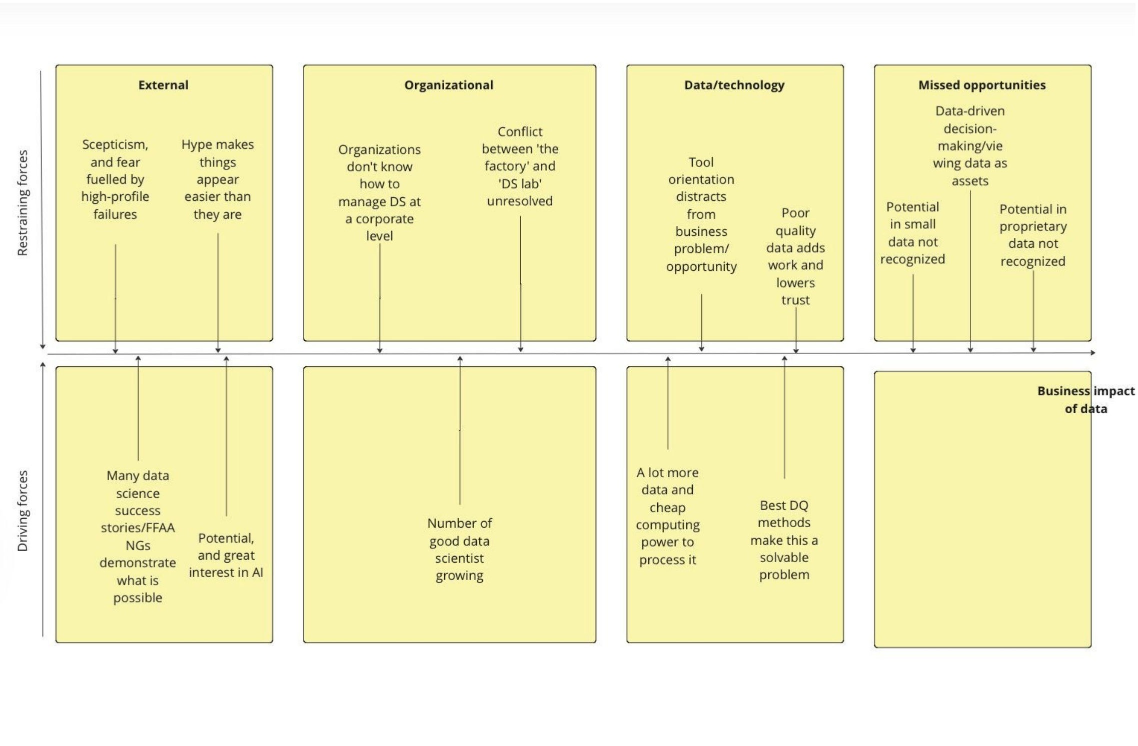

Figure 3: Putting data to work

Figure above outlines the driving and restraining forces affecting business impact through data. Each column lists specific restraining and driving forces. The key external forces impacting data science initiatives scepticism and fear from past failures, unrealistic expectations due to hype and the motivating power of success stories and new generations showcasing possibilities.

Organizational challenges often stem from managing data science at the enterprise level and resolving conflicts between traditional IT and innovative data science labs. Data and technology issues include the distraction of focusing on tools over business problems, poor data quality and the benefits of advanced technology and data quality methods. Lost opportunities arise from not adopting data-driven decision-making and failing to recognize the value of small and proprietary datasets. By understanding and addressing these forces, organizations can better leverage data for business impact. (Redman 2023.)

Driving and restraining forces that are effecting production planning include for example scepticism from previous failures, unrealistic expectations, inner challenges in organization, data quality and utilizing technology. By understanding and dealing with these forces production planning efficiency and business impact can be improved. (Redman 2023.)

3.3 Internet of Things

Internet of Things (IoT) refers to everyday objects being wirelessly connected to the Internet, such as phones, smartwatches, or cars. These devices are equipped with sensors, software, and other technologies that allow them to send and receive data. (Redman 2023.) IoT allows devices to communicate with one another, forming a large network where they can exchange information and carry out tasks automatically. (IBM 2023.) When IoT devices gather and transmit data the aim is to extract as much valuable information as possible, continuously improving the accuracy of the insights and results. This is where AI technologies come into play, enhancing IoT networks by integrating advanced analytics and machine learning capabilities. (Redman 2023.)

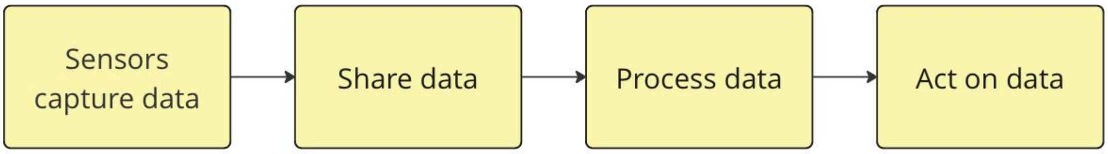

Figure 4: Main steps of IoT

The four main steps of IoT are collecting the information, sharing the information, processing the information and reacting to the information. With sensors, IoT gadgets collect information about their surroundings. Using available network connections, IoT devices send this data to public or private cloud system. At this stage, the software is programmed to take actions based on this data. The collected data from all IoT network devices is analysed. This provides valuable insights for reliable actions and business decisions. (SAP n.d. What is Internet of Things (IoT)?.)

In industry, sensor data is key part of the modern operation, especially in IoT systems. Sensors are collecting real time data about processes, machines and surroundings. This enables more efficient and accurate production management. (SAP n.d. What is Internet of Things (IoT)?.) The data gathered by IoT devices can be processed in real-time to spot trends, patterns and irregularities which can then be used to optimize operations and boost profitability. (IBM 2023.)

Sensors monitor the condition of the machines and the data collected can be used to predict maintenance needs before the equipment breaks down, reducing downtime and saving costs. Processes can be optimized using real-time data provided by sensors that measure the conditions of the production line. This helps fine-tune processes to ensure resources are used more efficiently and product quality remains consistent. Automated quality control reduces human error and improves the quality of final product. RFID- and IoT-sensors keeps track of raw materials and final products in real-time and for example temperature and humidity of these can be controlled. Following temperatures and humidity also helps prevent fires and other dangerous situations. (SAP n.d. What is Internet of Things (IoT)?.)

Efficiency and productivity can be improved by using IoT devices to automate and optimize processes. Large amounts of data collected by IoT devices and by analyzing this data, businesses can gain insight into market trends, customer behaviour and operational performance. This allows that better-informed decisions can be made. Customer behaviour data can help to create more personalized and engaging experiences which enhance customer experience. IoT can help reduce costs and improve profitability by automating repetitive tasks and reducing manual processes. (IBM 2023.)

Radio Frequency Identification (RFID) is a general term for radio frequency based technologies and it operates by storing information in an RFID tag and wirelessly reading it with an RFID reader using radio waves. (SAP n.d. What is Internet of Things (IoT)?.)

4 Production Planning

Production plan makes possible for production to have a schedule to follow. That will improve the entire process. A production plan can determine what, where, how and by who the product will be produced. Production plan is basically a necessity for the entire manufacturing process. Production planning helps to make realistic production schedules, ensure production processes run efficiently and smoothly and adjust operations when problems appear. (Jenkins 2022.)

Production planning is firmly connected to company’s other core processes. Inventory management and control helps to secure availability of raw materials and supplies when needed in manufacturing. Production control is process which ensures that the capacity of production is smartly used considering staff, knowledge and machines. (Fikuro 2023.)

The goal of production planning is to adapt the needs of market and facilities of production in a way that the capacity utilization is as even as possible. When this is achieved, promised delivery dates can be obeyed. The company must have some kind of idea of the future demand and the necessary information of available capacity so that production can be planned. When production planning is done, the plan can be put to action. (Miettinen 1993.)

4.1 Production types

Industrial production can be divided into five different production types. Division is done by looking into production volume and the variety of products being produced. These production types are project, job shop, batch production, repetitive production and continuous process. (Jenkins 2022.)

In project production, products are produced quantitatively few but each of them is a own individual and there is endless amount of varieties. The total opposite is continuous process production where products are produced on large volume but there is little to no variations. Job shop production is based on flexible resources which allows the production to produce different kinds of variations. There is specific repetitiveness that separates it from project production. In batch production products are produces in batches. Same product is produced repetitively but not all the time. Repetitive production produces products in production lines where each workstation does pre-determined tasks. Cost efficiency is achieved with precise organizing of work. The variability of production is low in a way that manufacturing a completely different product often requires a new production line. (Jenkins 2022.)

4.2 Production Planning

Production planning spells out the production targets, required resources, processes and overall schedule (Jenkins 2022.). The base of production planning is demand and based on it internal material requirements of production planning are calculated and external purchases are done. After this capacity requirements planning for production is made. The output is production order for which all the necessary materials are reserved in the information system. (Haverila 2009.)

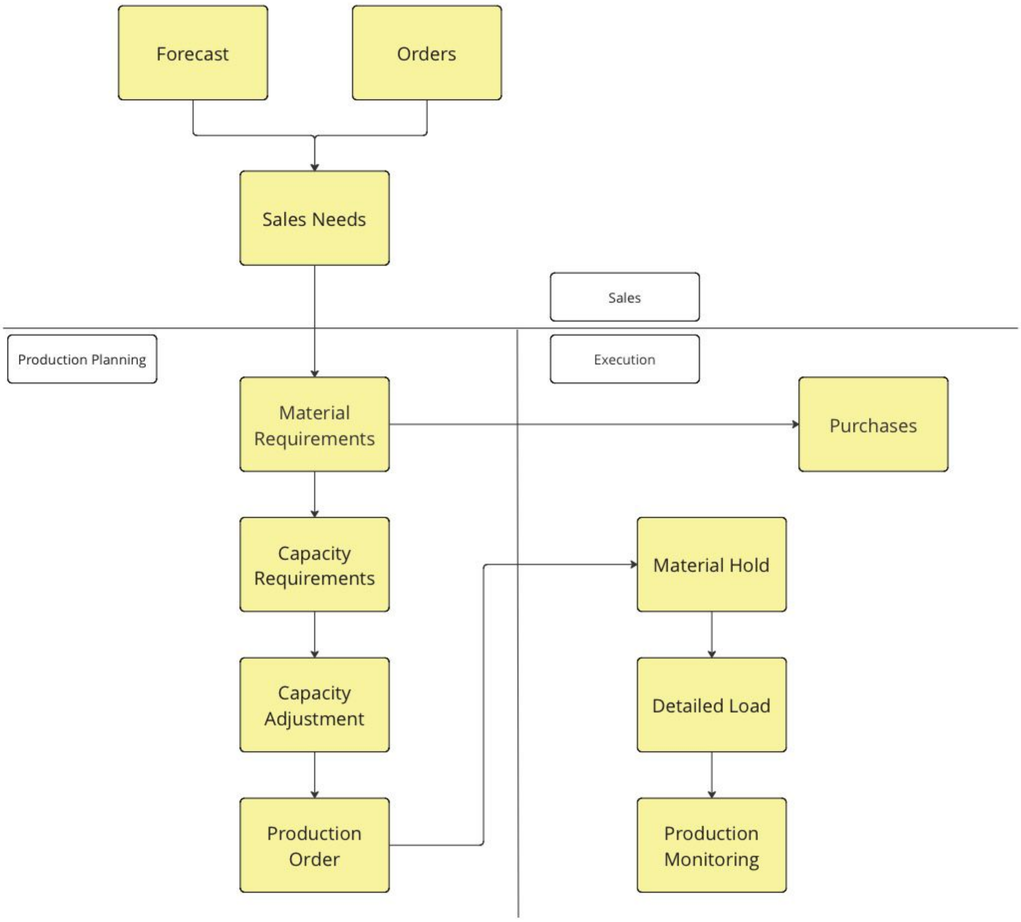

Figure 5: Production Planning and Execution

Production planning has roughly three main steps. These are sales, production planning and execution. Each step has its own characteristics that serve as the foundation for the next step. (Haverila 2009.)

Demand forecasting is done to help production planning and to purchase materials. It is based on previous data from sales and orders and also mathematic forecasting models. A sales plan is often created from the demand forecast which specifies the timing and quantity of sales for each product. Demand forecasting also takes into consideration seasonal changes and economic outlooks, such as inflation and the rising interest rates. Demand forecasting can be done for products, product groups, components or raw materials. From the forecast made at the product level, the requirements at the material level can be calculated according to the product structure. (Heizer 2017.)

The demand forecasts are a need because the changes of demand are faster than the responsiveness of production process. The globalization of the market and competition has made forecasting more challenging than before. The changes of market competition and global economic disturbance are difficult to predict. Prediction errors cause a lot problems for companies. Excess capacity or overstocked inventory led to rise of costs. Many companies aim to reduce their reliance on forecasts by developing the flexibility and responsiveness of their production. (Sap n.d. Demand forecasting for the modern supply chain.)

4.2.1 Sales and Operations Planning

Sales and Operations Planning (S&OP) is a process that attempts to balance demand and supply. It is a data collection, analysis and decision-making process which enhances data transparency and creates an understanding of the current state as well as future demand and supply. In addition, uncertainties, deviations and necessary decisions are identified. (Logistiikan maailma 2020. S&OP – Sales and Operations Planning.) In todays businessworld it’s a necessity to be able to rapidly and acuurately respond to customer requests. This requires coordination between operational functions within the company. (Ávila et al. 2019.) The aim of the Sales and Operations Planning (S&OP) process is to assist management in strategically guiding the business towards a competitive edge through tactical planning. This process provides significant benefits to the company, including improved customer service, reduced inventory levels, and shorter lead times for customers. (Jacobs et al. 2016.) The S&OP process combines all the business plans including sales, marketing, development, manufacturing, sourcing and financial, and forms one integrated set of plans. (Ávila et al. 2019.)

The S&OP process consists of five key steps: generating an unconstrained demand forecast, developing a preliminary supply plan, creating a final, collaborative operating plan, executing the plan and evaluating the process performance. The main focus of the first step in the S&OP process is to gather historical and current demand data. The first step of S&OP process focuses on what the customers want without taking into consideration limitations of the production. Initial demand forecast plan is created and it acts as a base for the S&OP process. This is usually done by sales and marketing departments. In the second step, data about stock capacity, manufacturing, logistics and supply chain logistics is collected by operational and delivery chain departments. These departments create the initial supply plan by combining the demand forecast with the best analyzed business plan regarding the customer service, revenue and profitability. Thirdly a final oprative plan, that everyone agrees on, is created. (Ávila et al. 2019.) This final plan should balance the demand and supply plan while supporting the business and strategic goals. The aim can be to increase demand with pricing or campaigns. Other option is to change supply for example with adding extra capacity for a product which demand is higher than expected. (Logistiikan maailma 2020.)

After all this the plan is implemented into everyday tasks and every department is committed to it. The workd doesn’t end when the plan is implemented but it’s a continuous process which is measured and regulated. The performance of the S&OP process is measured with KPIs (Key Performance Indicator) that vary depending on the industry. (Ávila et al. 2019.)

4.2.2 Production Planning

The most important parts of the production planning are material and capacity planning. Based on a demand plan, production plan is created from which material requirements are calculated. Existing stocks and upcoming purchases in the delivery chain has to be taken into account. This information is the base for the material requirements and call-offs, in addition capacity requirements are determined. (Jenkins 2022.)

The goal of this step is to adjust the capacity by increasing or decreasing resources. For example workforce or machine capacity can be adjusted or in some situations subcontracting can be used. (Heizer 2017.)

Material requirement planning (MRP) means calculating the required components and materials to produce the final product. Calculations are done based on product structures, inventory data and actual or forecasted demand. The calculations can be done for days, weeks, or months at a time. (Fikuro 2023.)

The goal of materials management is to ensure that production, customers, and other stakeholders in the supply chain receive the right materials at the right time, in the right location, in the correct quantities, with the right quality and at the right cost. It seeks to strike an optimal balance between material availability and costs. (Heizer 2017.)

Production planning needs to take into consideration availability and delivery time pressures without forgetting the cost-efficiency requirements. Effective production planning ensures timely product delivery, minimizes costs and allows for quick responses to issues. (Jenkins 2022.)

4.2.3 Execution

Manufacturing management means the execution of manufacturing planning on an operative level (Martinsuo 2018.). The tasks of manufacturing management are the detailed planning of manufacturing, distribution of job tasks, directing the assignments, overseeing and reporting. The repetitiveness of tasks and the layout effect the content and difficulty of manufacturing management tasks. (Haverila 2009.)

When creating the manufacturing plan, the real-time situation of production needs to be known. The work queues of different load groups, the submissions of production plans, and production disturbances effects the available capacity. (Haverila 2009.)

Manufacturing Execution System (MES) is integrated software and sensor system that produces real-time information about functions of the factory. MES can follow, document and oversee every step of the production and optimizes its output. MES keeps track on machines, materials and employees. It can point out bottlenecks and give out detailed instructions for employees based on the orders. This helps to keep processes streamlined and enables more reliable schedule. (Skyplanner n.d.)

4.3 Levels of Production Planning

Production planning has three different levels and each of these has their own roles. Preliminary action plans evolve into more detailed production plans. Precise and detailed planning is postponed until the last possible moment. This way the excessive changes in the production plans can be avoided. In figure 6 these levels of production planning and the connections between them are presented. (Martinsuo 2018.)

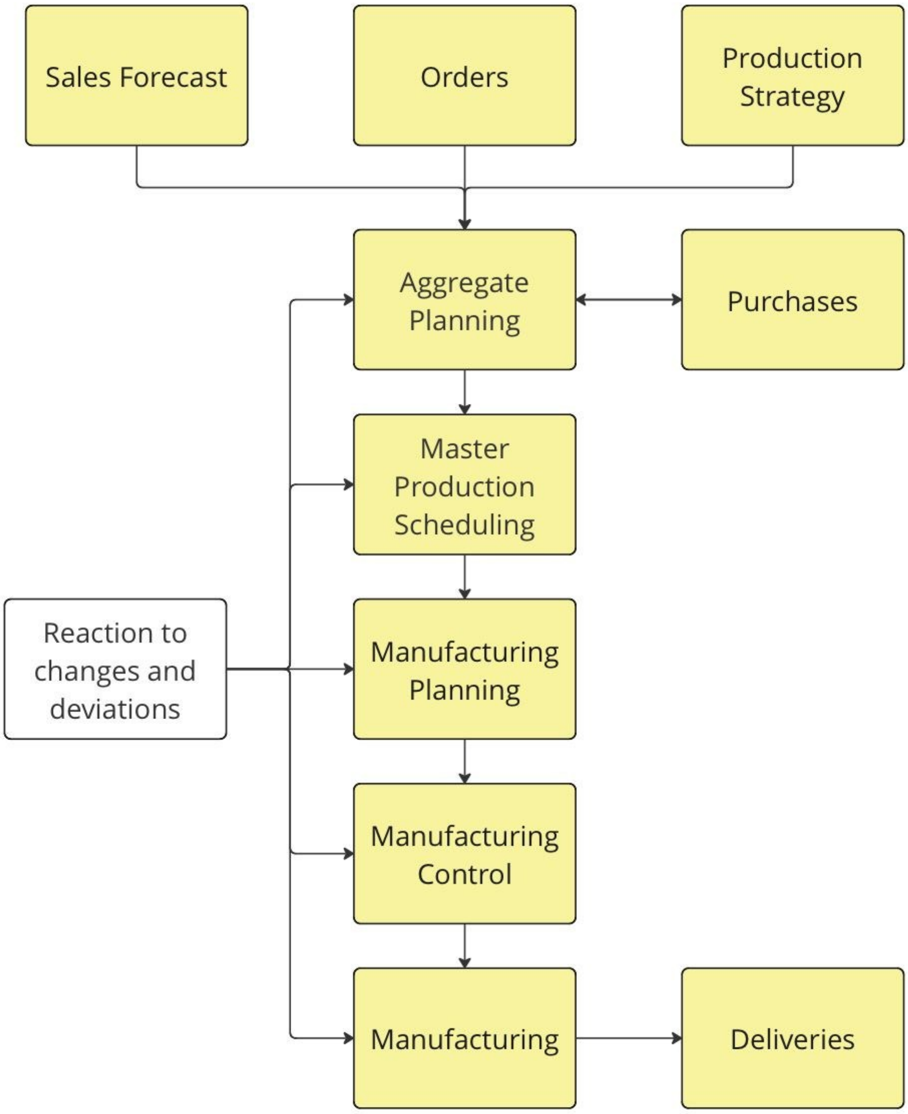

Figure 6: Process of Production Planning

Production planning is based on demand forecast that acts as basis for production capacity and load. Because of different production distruptions rescheduling and recordinating in production is needed. There distruptions can be for example matrial shortages and wquipment failures. (Haverila 2009.)

4.3.1 Aggregate Planning

Aggregate plan is the output of S&OP. Aggregate planning in production planning is fundamental component of managing and optimizing production planning processes and this guarantees quality and efficiency of production. (Heizer 2017.)

Aggregate planning determines the overall volume of production, needed resources, storages and purchases long-term goals and procedures planning. Main task is to make sure that the overall volume corresponds to the demand. Aggregate planning can cause changes of capacity and resources, replanning of inventory level and new purchase contracts. Information of aggregate planning gives the baseline for master production scheduling and detailed scheduling. Aggregate planning can be divided to product families according to companys control system, market sectors, production units or other similar principles. (Martinsuo 2018.)

The primary goal of aggregate planning is to assess operational factors within a specific time frame. These factors include production rate, workforce, overtime, machine capacity, subcontracting, backlog, and current inventory. The production rate defines how many units should be produced within a given time period, such as weekly or monthly. Workforce refers to the number of workers or the capacity needed for production. Machine capacity level indicates how many units of machine capacity are required for production. Backlog represents the portion of demand that cannot be met in the current period and is carried over to future periods. Inventory on hand refers to the planned inventory that will be maintained throughout the various periods in the planning horizon. (Martinsuo 2018.)

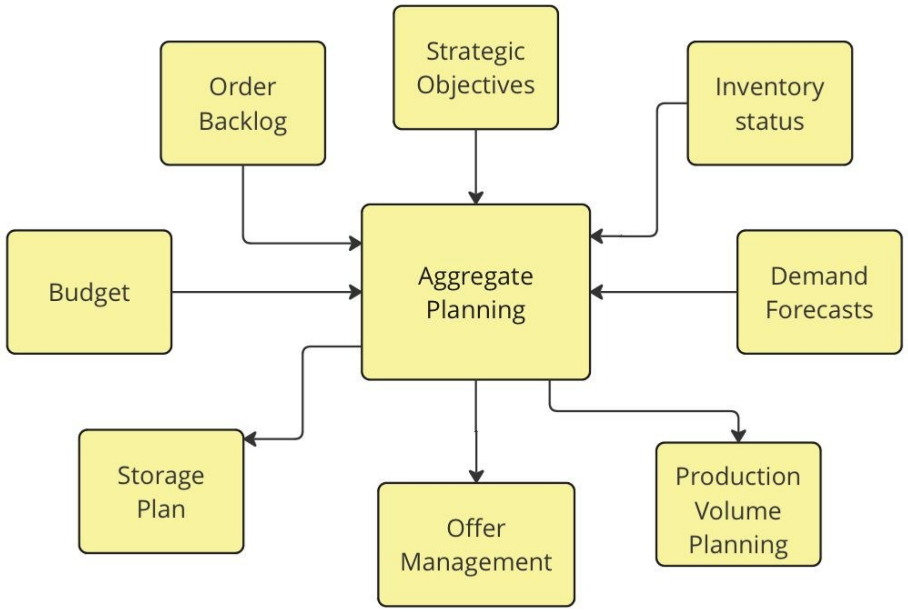

Figure 7: Aggregate Planning

Aggregate planning is based on companys order backlog, demand forecasts and inventory status. Information of aggregate planning is used for more detailed plans. Based on aggregate planning capacity changes and product and material stock levels can be planned. In addition more staff can be hired and seasonal contracts can be made with suppliers and subcontractors. (Haverila 2009.)

4.3.2 Master Production Scheduling

Master production scheduling in production planning focuses on to the general schedule and resources control in the long-term. In the master production scheduling the planning of total volume, resource requirements, inventories and procurement are taken to a more detailed level than the aggregate plan.

Detailed production batch level and its implementation in the production system is scheduled. Master production scheduling is done regularly and repetitively, usually in every few weeks. There are three main tasks in master production scheduling and those are the overall scheduling of production, resource and delivery capacity planning on this level. (Martinsuo 2018.)

Master production scheduling acts as a bridge between strategy planning and manufacturing planning. The calculation of required resources based on existing data is easy and accurate. Orders based on customized products are the most difficult to estimate and plan as accurate information may not be available in advance. Capacity and material requirements must then be estimated based on approximate assessments and rough forecasts. (Martinsuo 2018.)

4.3.3 Manufacturing Planning

The role of manufacturing planning in production planning is the detailed plan of production. The result of manufacturing planning is a specific production plan which is based on master production scheduling. In manufacturing planning production batches are formed, the timing of different stages of production batches are planned and detailed plan of the use of production resources is created. Manufacturing planning is done on a daily and weekly basis. The timeframe of manufacturing planning is aimed to be kept as short as possible so that the planning can based on the most recent and reliable information. The basis of manufacturing planning is the actual situation of production and orders. (Martinsuo 2018.)

In manufacturing planning, the scheduling of production batches aims to create a work order that fulfils the various production goals as effectively as possible. Master production scheduling and manufacturing planning requires the determination of the execution times of each step of the production. This production timing is based on the calculation of phase times for a batch. Based on the capacity requirements, the leadtime required for each step is calculated. (Haverila 2009.)

More important than the detailed planning of the work stages is the focus on value creating, even self-directed work throughout the entire production process. At the moment, the self-direction of the production process is being developed to enable manufacturing planning on a more general level. (Martinsuo 2018.)

In manufacturing planning the aim is to create a procedure by forming and timing production batches. The goal of the procedure is to execute the different goals of production as well as possible. The general goals are good delivery reliability and high productivity. Basic principles of manufacturing planning are minimizing setup time and costs, optimal use of overall capacity taking potential bottlenecks into account, the timing of the production batches, value stream-based control, information systems and visual tools in support of manufacturing planning and optimization. (Martinsuo 2018.)

5 AI Systems in Production Planning

Systems of AI, such as computer vision, agents and robotics, together make possible intelligent and autonomic production where processes are dynamic and self-optimized. AI systems in production planning bring many benefits while increasing efficiency. (Wan 2023.)

5.1 Agents

AI agents are independent systems that automate tasks, follow processes and optimize decision making in production. AI agents are helping to change traditional production processes to become intelligent and automated systems. Agents are improving efficiency and productivity while enhancing quality control. Agents can reduce downtime and costs and have capability to adapt to changing environments. (Gutowska 2024.)

AI agents can identify exceptions and inefficiencies in production in real time. With the help of agents processes can be optimized and costs can brought down by optimizing energy consumption. Agents can recognize errors and deviations from standards and can help with proactive maintenance. Agents can automatize material orders and ensure availability of raw materials. In the production process quick decisions are needed and AI agents provide assistance for employees. AI agents automate repetitive tasks and adjust production processes in real time. (Gutowska 2024.)

In the center of AI agents are LLMs. Traditional LLM-models are limited by their knowledge and understanding. These models provide answers based on the training data. Autonomic agents learn over time to adapt to the users expectations and save the previous interactions. These agents plan future actions which enables more personal and comprehensive answers without human intervention. (Gutowska 2024.)

5.2 Robotics

Robotics is part of the automation where robotic systems perform physical tasks, for example assembly, material processing and inspection. Robotics is a field of science that studies the development of robots and the use of them. On the other hand, robots are concrete machines that follow the base idea of robotics in practice. AI has a crucial role as well as in the development of robotics and the function of robots making them more intelligent, independent and efficient. (TDK n.d.)

Robotics can do repetitive but complicated tasks and do them continuously without breaks and humane mistakes (TDK n.d.). Robots can also perform tasks that are risky to people (Gupta 2020.). Robotic arm can move parts to different steps of production line and stock. With the help of robots things can be transported and organized without human interference. (TDK n.d.)

Robots contain electrical components that supply power and regulate the machinery. Manipulator, control unit and power source unit are the major components of a robot. (Gupta 2020.)

5.3 Computer vision

Computer vision is a branch of artificial intelligence that utilizes neural networks and machine learning to enable computers and systems to interpret and extract useful information from visual data. Computer vision allows computers to detect, analyze, and interpret visual information. (IBM 2021.) These systems are capable of understanding and processing visual input on the computer. (Gupta 2020.)

Computer vision is the part of AI that focuses on processing visual information with the help of cameras and sensors. It makes possible to oversee production process and recognize visible errors in real time automatically. Computer vision can oversee assembly correctness and precise installation of components on a more precise level than a human. (IBM 2021.)

6 Industry 4.0

Intelligence and information are changing the logic of production and becomes more autonomous and self-directed. More time will be available for production development and new innovations. That leads to new type of services and organizational practices will emerge. Deeper understanding of value chains and the ecosystem results in more extensive and deeper connections between various participants. There is an opportunity to explore the creation of value and meaning in a new way when AI is involved in all considerations. (Aaltonen 2019.)

Technological evolution is changing world and makes it super intelligent. This means that the intelligence of machines will surpass human intelligence because machines can learn, solve difficult tasks and achieve almost impossible goals. Jobs and tasks need to be redesigned to ensure collaboration between humans and machines is taken into consideration. Organizations needs to also take into consideration how intelligent technologies change processes and business models and what is a new intelligent organization like. (Aaltonen 2019.)

Society 5.0 is Super Smart Society and it is based on the belief in the continuous development of information technology. Collaborations between humans and machines brings enormous opportunities for innovations, growth and well-being. (Aaltonen 2019.) For example seamless collaboration improves the ability to manufacture customized products and optimize use of energy in factories. Technology would be tool for efficiency and even more of an innovation partner. This enhances the industrys ability to adapt to challenges, generate new ideas and ensure that technological development benefits whole society. (Tu 2024.)

6.1 Industry 4.0

The Fourth Industrial Revolution or Industry 4.0 refers to the integration of advanced digital technologies into manufacturing and industrial operations. It involves a range of new technologies such as AI, Industrial IoT (IIoT) networks, Big Data, robotics, intelligent agents, computer vision and automation. Industry 4.0 enables smart manufacturing and the development of intelligent factories. Its main objectives are to improve efficiency, productivity and flexibility while facilitating smarter decision-making and more personalized approaches in manufacturing and supply chains. (IBM. n.d.)

Artificial Intelligence collects data and enables analysis, prediction, comprehension and reporting. Industry 4.0 focuses on the smooth integration of different systems, tools and innovations. (IBM n.d.)

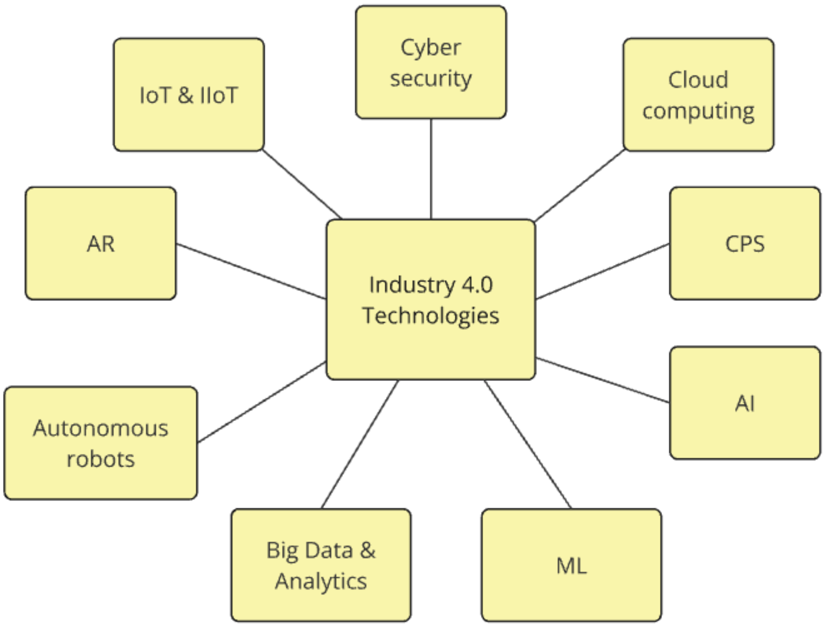

Figure 8: Key drivers of Industry 4.0

Industry 4.0 is based on the concept of smart factories and there are important key drivers. (Zizic 2022.)

IoT, services, and data enable communication between objects. Intelligence can be embedded into these objects, transforming them into smart devices. These devices can gather data from their surroundings, interact with, and control the physical world. Additionally objects can be connected through the internet to share information and data with one another. (Zizic 2022.)

Cloud computing means the delivery of networking and computing services over the internet. When services are provided through the cloud, they enable cost-efficiency and flexibility. Key benefits of adopting cloud services are reliability, scalability and centralized management of data and software. However cyber security is crucial issue. (Zizic 2022.)

Cyber-physical system (CPS) is an intelligent computer system that integrates sensor, computing, control and networking capabilities to physical objects and connects those to internet and each other. These systems can interact with humans through new modalities. In intelligent manufacturing cyber-physical systems can be utilized to controlling production and assembly lines, asset tracking, predictive analytics and supply chain management. (Zizic 2022.)

Artificial intelligence acts as the driving force behind Industry 4.0. AI facilitates cyber-physical systems in filtering a large amounts of data collected from the production system through sensors and analyzing that data. AI provides data-driven predictive analytics and the capability to support decision-making in highly complex, non-linear and multi-phase production. (Zizic 2022.)

With machine learning interconnected systems can transfer data between each other and independently improve processes based on algorithms. A continuous learning and optimization leads to unprecedented performance and the traditional automated factory transforms into a smart factory. Data collected through sensors can be processed using machine learning to identify and predict errors. By combining computer vision with algorithms, monitoring can be executed automatically without human intervention. (Zizic 2022.)

Big data is a huge amount of information that is generated at high speed. Big data is an advanced analytical technique used systematically to identify unknown patterns in data and correlate them to specific behaviour and that helps to support decision making. These analyses help to develop new products, managing risks and supply chains, speeding up decision making and optimizing product pricing based on customer behavior. (Zizic 2022.)

Augmented reality (AR) refers to the blending of real and virtual environments, where real-world objects are enhanced with computer-generated information. AR technology can be paired with human abilities to develop efficient tools that support and enhance production tasks. (Zizic 2022.)

The purpose of automation and robotics is to operate independently and efficiently in the industry to enhance productivity. Advancements in computer vision technology makes possible that robots can perform real-time visual tasks. These task can include for exmaple identifying and removing defective parts from the production line. Autonomous robots can observe problems and adjust their operations independently and flexibly to ensure smooth process flow. (Zizic 2022.)

6.2 Industry 5.0

Industry 5.0 aims to generate economic value while taking into consideration the limitations of the planet and prioritizing employee well-being within the production process. Its core principles are human centricity, environmental sustainability and resilience. The human centric way of working values the well-being of employees and their rights shifting the technology-driven approach to the side. The role of employees is changing as they are seen as investments instead of costs. Technology should serve the people and adapt to their needs, not the other way around. (Xu Et. Al. 2021.)

The industry should develop circular economy process that re-use and utilize natural resources while reducing waste and environmental impacts. Resilience refers to the ability of industry to develop stronger processes that endure disruptions and can support critical infrastructure during times of crisis. The industry of the future must be flexible and adaptable to rapidly changing political situations and natural disasters. (Xu Et. Al. 2021.)

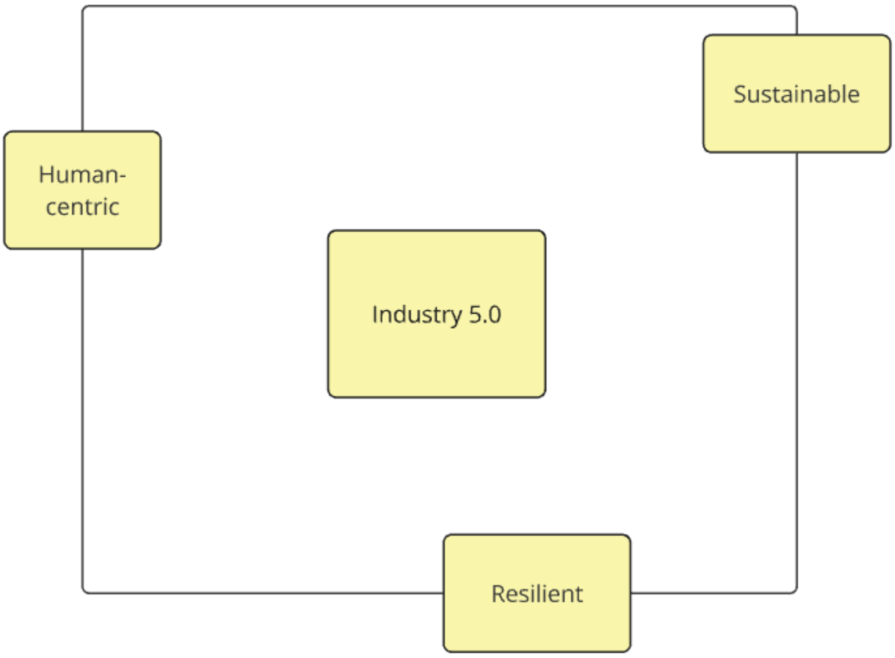

Figure 9: Industry 5.0 with key drivers

Beside these three core values of Industry 5.0, there are six key principles that it revolves around. These principles include the collaboration between humans and machines that should be seamless. The adoption of eco-friendly materials and devices, digital twins and use of renewable energy all together support the sustainability core value. The last key principles are advanced data analysis and storage and the use of Artificial Intelligence. (Patalas-Maliszewska. Et Al. 2024.)

7 The integration of AI into production planning

More advanced production planning allows efficient and flexible production management while cloud computing enables adaptation to industry 4.0. (Patlas-Maliszewska Et.Al. 2024.) Advenced production planning refers to a process where different parts of the production are combined seamlessly. These parts are for example scheduling, resource management and capacity optimizing. Advanced production planning is not only utilizing new technologies but it also requires cultural changes in the organization. This means that the companies need to be willing to adapt new ways of working and invest into staff training. (Delfoi. 2024.) AI being the key element in Industry 4.0, the fields that benefit the most from the integration of AI and production are productive maintenance, production planning and customer relationship management. The level of sustainable production can be imporved with the help of AI based methods and tools. These AI tools provide continuous analysis for example of the energy and water use in production. This analysis can demonstrate which areas of production need improvements considering energy efficiency. (Patlas-Maliszewska Et.Al. 2024.)

There are certain risks in the implementation of AI and production planning. Before the integration, it is essential to ensure that the AI goes together with already existing systems that are used in the production planning process. If these systems don’t go together it will only bring financial loss to the company. Some employees might also feel inadequate, when a machine, in this case AI, might be able to do their job. This is not necessarily the case because the integration of AI forms new jobs and reforms old jobtasks. (Patlas-Maliszewska Et.Al. 2024.) Despite the resistance, it is crucial especially for SMEs to focus on developing the production planning and scheduling softwares to improve innovative performance and stay relevant in the business. (Chen Et. Al. 2023.) These AI based tools can also be hard for the employees to understand and apply. Another risk in the implementation is cyber cecurity. It is crucial to keep an eye on the possible threats and react to them immediately. (Patlas-

Maliszewska Et.Al. 2024.) When these risks are taken into account, AI and human capabilities complement each other, bringing many advantages. (Chen Et. Al. 2023.)

Sector	Solutions	Technology
Demand forecasting	- Machine Learning processes data and identifies complex patterns making it easier to forecast - CPS facilitates data exchange and improves forecasting accuracy	- Machine Learning - CPS
Production scheduling	- Neural Networks reduce the need for rescheduling - ML Algorithms can automate the process of production planning - With the help of ML algorithms resources can be managed efficiently	- Neural Networks - Machine Learning Algorithms
Intelligent decision-making	- CPS collects and manages data to make decisions by using its digital twin - Cloud computing improves information management and enables intelligent decision making - Quality and efficiency of decision making is improved	- Digital Twin - CPS

	by integrating data and analytics	
Process optimizing	- DT and RFID enables tracing down individual items in real time to capture errors - IoT and computer vision endorses cost efficiency and can predict defects before occurring - AR enables testing different layouts and optimizing the process before the actual production	- RFID - IoT - AR
Potential customizing	- AM together with 3D printing can speed up the product manufacturing - AM increases customer satisfaction - CPS is independent and makes it possible for the production planning to be more flexible	- AM - 3D printing
Process management	- Connecting and communicating during the production planning process is easy with IoT - Cloud computing and mobile apps share and manage information	- IoT - Cloud computing - CPS

Demand forecasting

Machine learning processes efficiently and quickly large amounts of data and analyses it. With the help of AI, machine learning can learn complicated relations and models (Oswald 2020.).

Accuracy of demand forecasting can be optimized with the help of artificial intelligence methods. Using machine learning, cyber-physical systems can move data between each other and improve the process of demand forecasting independently with the help of algorithms. CPS includes components that can be utilized calculating and controlling to make the system efficient. CPS collects and dispatches data through internet and It can be used for proactive analysis. (Saini 2024.)

Artificial intelligence systems offers more precise and reliable forecasts. The progression of machine learning improves the availability and reliability of forecasts and speeds up getting those. (Sap n.d. What is Industry 4.0?.) By including AI systems into the demand forecasting process, flexibility of supply chain can be improved, distortions of demand can be avoided and accuracy of forecasting can be optimized. To fufill the demand, cloud computing relies on the available production capacity. (Chen Et. Al. 2023.)

Production scheduling

Artificial intelligence helps to create efficient production plans, manage resourses efficiently and adapt to changing circumstances in real-time. Machine learning algorithms can be utilized to optimize scheduling decisions based on different criteria.

Machine learning combined with human expertise is proposed for real-time scheduling. Machine learning requires large amounts of training data and time so integrating expertise of the field to machine learning improves the models understandability. (Chen Et. Al. 2023.)

Production planning can be automated with the use of advanced algorithms. Possibility to access and utilize real-time manufacturing data on machine performance helps planning by considering possible schedule changes. (Ferrari 2023.)

Neural networks learn and are utulized to capture the complex relationship between the input and output variables. These relatisonships are very hard to analyze, sometimes impossible. When neural networks identify the hidden relationship between input and output data, they can be applied to predict new cases they haven't encountered before. Neural networks can be used to reduce the need for rescheduling. (Tonelli 2021.)

Data mining can analyze large amounts of data and find trends, connections and patterns that can improve the efficiency and accuracy of production scheduling.

Intelligent decision making

Advanced production planning enables better predictability and planning, which is important in the efficient use of resources. This is achieved by combining real-time data and analytics and those added into the production planning processes. This then improves the quality and speed of decision making. Cloud computing improves information management for several decision makers involved. A digital twin can improve advanced control and decision-making by reducing gaps through both horizontal and vertical integration (Chen Et. Al. 2023.).

Cyber-physical systems are dependent on an intelligent network to gather, manage and analyze data to make decisions. Decision are made on the physical wordl by using its Digital Twin. CPS can transfer data to optimize operations, guide users and enhance the resilience of manufacturing systems by enabling real-world-based decision making. (Tonelli 2021.) Artificial intelligence, advanced analytics and machine learning technologies support more automated and intelligent decision making. (Ferrari 2023.)

Process optimizing

Cyber-physical systems can predict failures and reduce downtime. AI in CPS automates processes and improves production efficiency. (Saini 2024.) Digital twins that are powered by radio frequency identification, can track and trace down individual items in real-time. This makes it possible to capture disturbances and chances at they occur. (Chen Et. Al. 2023.)

Manufacturing can control machines in real time by integrating IoT sensors and data analytics. Algorithms of predictive maintenance can identify potential failures before occurring. That can reduce downtime and extend asset lifespan. (Sap n.d. What is Industry 4.0?.) Computer vision that enables machine learning and neural networks can train systems and computers to see defects and react to them (IBM 2021.)

Augmented reality (AR) makes it possible to view 3D models and proto types in real time in production. With help of AR, errors and areas of improvement can be regocnized. Components, layouts and how they work can be considered before actual production.

Potential customizing

Direct digital manufacturing uses technologies to change digital models into physical objects without any tooling. For example, 3D printing and additive manufacturing (AM) are technologies that are advantageous for a customization. (Chen Et. Al. 2023.)

Additive manufacturing makes it possible to create products based on their needs. AM can cut down time frames of production and deliveries since 3D printing can speed up product manufacture. Because AM offers customised, faster and better quality products for customers, the customer satisfaction will be increased.

CPS are flexibly changed, modulatized and reconfigured when customers needs and product changes. Modularity allows the system to be independent and makes it capable to adapt more flexibility. (Tonelli 2021.)

Process management

A digital twin acts as a simulation tool prior to production and operates as a real-time control system during the manufacturing process (Chen Et. Al. 2023.).

Connecting and communicating with IoT or AI becomes effortless with the help of cloud computing and mobile apps leading to collaborative, productive and quick-moving environment between humans and machines. While planning production, cloud computing and mobile apps can help to disseminate information and improve information management. (Chen Et. Al. 2023.)

Through the support sensors, CPS can gather, control and analyze data while actuators react to changes in production and share this information with the other compoments. (Tonelli 2021.)

8 Conclusion

In this thesis, integration of artificial intelligence in to the production planning process was researched. Every step of the production planning process was researched and analyzed thoroughly. Artificial intelligence and its possibilities were examined. Also machine learning, data and algorithms were taken into consideration. After the research, integration and the benefits it brings were reflected.

One of the key findings is the possibilities that artificial intelligence brings to the production planning. AI can affect to the quality, efficiency and costs by optimizing the process. The quality of data is a centric part of the use of AI because for example forecasting depends on data quality. For AI to learn and develop with the help of machine learning, it needs large amounts of data. The way the data is processed and utilized, is the most essential part of the function of AI. Data-driven decision making helps and speeds up the usual decision making process.

Integrating AI in to the production process enables competitiveness and staying relevant. With the integration of artificial intelligence production planning can become cost-efficient, flexible, automated and sustainable. AI creates more efficient decision making processes by dealing with vast amounts of data quickly and accurately. In contemporary industry, fast reactions and accuracy are crucial. Data is available and cloud computing makes information management easier, production planning runs smoothly and is more flexible. With the help of machine learning and CPS, trends, patterns and anomalies can be regocnized while forecasting demand.

A challenge of artificial intelligence is the difficulty of its implementation and the changes it brings to to the organization. Integrating AI to the production planning changes the process for example employees role will change. Need for expertise and cyber security are challenges considering the implementation.

Use of AI is limited by ethical questions. For example, if AI does not do its job properly, who is responsible is one important question that needs to be taken into consideration. Amount of data can limit the potential of AI if there is too little of it or it has poor quality. Full potential of AI has not yet been discovered and at the moment the use of it is more like collaboration between human and AI.

In the future human centricity, sustainability and resilience are key parts of production and those need to be taken into consideration while developing AI. Machine learning techniques and self learning needs to be researched in the future. Continuous research and development are necessary for the development of AGI and ASI. Future research is needed to unleash the full potential of artificial intelligence.

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