- This will be a digital exam, meaning you do the exam on a computer in Aletta Jacobs Hall
- The course literature and slides are available as pdf's on the exam computer
- As this is an open book exam, you can also bring printed articles, articles, and notes
- An example exam can be found under Course Orientation

Production Planning and Quality Control
Summary notes 2022-2023
SwagMoneyInc

Table of contents

Week 1 - Manufacturing Strategy

Competitive priorities

Dominant orientation: (what is my identity?)

The dominant orientation drives your focus and culture. Mixing them is risky.
Market: know what your (potential) customers want: Heineken, Apple.
Product: be an expert in a product, find new uses for it: Shell, Tata steel
Technology: be able to exploit the newest technologies in your processes and products, push them to the market: ASML, Tesla

Dominant orientation refers to an organization's focus on a particular aspect of manufacturing performance, such as cost, quality, or delivery. An organization with a dominant orientation in cost will focus on reducing costs in order to achieve a cost advantage over its competitors. An example of this would be a company that produces consumer goods such as electronics, which focuses on reducing costs by automating production processes, outsourcing some of its manufacturing to low-cost countries, and implementing lean manufacturing techniques.

Diversification patterns: (which products do I offer In which markets?)

Multiple products in the same market: Suitsupply
Different markets with the 'same' product: Volkswagen/Skoda
Multiple links in the supply chain (vertical): Netflix Originals (produces their own movies and series)
Multiple products in different markets: spreading the risk. Microsoft (consumer, office, server, databases, hardware, cloud)

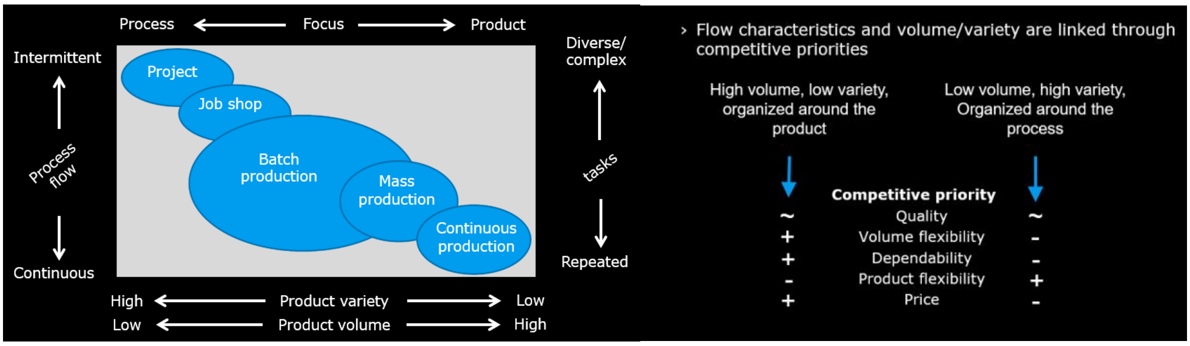
Diversification patterns refer to an organization's choice of product lines and markets. An organization that chooses to diversify its product lines and markets will be less reliant on any one product or market and will be able to respond more effectively to changes in demand. An example of this would be a company that produces a wide range of consumer goods such as electronics, appliances, and home decor, which diversifies its product lines and markets to reduce its reliance on any one product or market.

Strategy for growth: (what are my goals, and how do I get there?)

Opportunities: take new markets, increase return on investment
Threats: Not growing means competitors will (Hives versus Facebook), High growth makes it difficult to stabilize competitive capabilities (quality, efficiency, flexibility) (Tesla, Uber)

Strategy for growth refers to an organization's approach to growing its business. An organization that adopts a strategy for growth will focus on expanding its product lines, markets, and customer base in order to achieve growth. An example of this would be a company that produces consumer goods such as electronics, appliances, and home decor, which focuses on expanding its product lines, entering new markets, and increasing its customer base through targeted marketing and advertising campaigns to achieve growth and increase market share.

Product/Process matrix



Product/Process matrix: which shows that there is a limited number of stable combinations of products, and how these products are made.
that positioning too far away from the diagonal is not sustainable.

Product focus:

In a product focus, it is practical to put the machines that create the product together. For example a drilling, sawing, and bending machine to create a chair. If you distribute machines over different departments, you need lots of coordination and transportation.

A product focus means that the organization's primary focus is on developing new products or product lines, and improving the quality, features, and design of existing products. This approach is used when an organization wants to differentiate itself from its competitors by offering unique and high-quality products. In terms of manufacturing layout, this approach would require a layout that is flexible and adaptable to handle a wide range of products. An example of a company that has a product focus and this type of layout is Apple, which is known for its focus on product innovation and design in its industry, the company has a modular manufacturing layout that allows it to easily change production to accommodate new products.

Process focus:

In a process/functional focus, it is practical to put the machines that perform the process together. For example, all drilling machines. Otherwise, you could loose oversight of your machines and operators during the day.

A process focus means that the organization's primary focus is on improving the efficiency and effectiveness of its manufacturing processes, and reducing costs. This approach is used when an organization wants to achieve a cost advantage over its competitors by reducing the cost of production. In terms of manufacturing layout, this approach would require a layout that is highly specialized and optimized for specific products or product families. An example of a company that has a process focus and this type of layout is Walmart, which is known for its focus on operational efficiency and cost-cutting measures, the company has a cellular manufacturing layout that allows it to optimize the production process for specific product families.

product orientation:

Multiple departments, each responsible for a product. All necessary processes are done within the department. No coordination is needed between departments.

?How does product orientation affect the design of production processes? (Answer: Product orientation focuses on the characteristics of the product being produced, such as its features, design, and quality. This can lead to a focus on customizing production processes to suit the specific requirements of the product, rather than standardizing processes for efficiency. This may also lead to higher costs and longer lead times.)

process orientation

Machines are grouped according to the process they perform. Also called: Functional Layout, because machines are grouped according to their function.

*Certain criteria to consider that warrant deviations:
Big products, dangerous/unhealthy operations(painting), very big machines, operators as bottleneck

Flow related to Product/Process matrix:
Firms that have a product focus tend to have unidirectional flow layout, while firms that have a process focus tend to have multidirectional flow layout. The authors also found that there is a positive relationship between manufacturing strategy and layout, in which firms that align their manufacturing strategy with their layout achieve better performance.

Unidirectional flow:
Unidirectional flow refers to a linear flow of materials and products through a facility, in which materials and products move in a single direction. This type of flow is typically used when an organization has a product focus and is producing a wide range of products. An example of a unidirectional flow layout is a assembly line, in which each workstation performs a specific task and the product moves through the line in a single direction.

Multidirectional flow:
Multidirectional flow refers to a non-linear flow of materials and products through a facility, in which materials and products can move in multiple directions. This type of flow is typically used when an organization has a process focus and is producing a limited number of products. An example of a multidirectional flow layout is a cellular manufacturing layout, in which each work cell is dedicated to a specific product or product family, and the flow of materials and products within the cell is flexible and adaptable to handle different products.

volume/variety trade-off
Usually, high volume/low variety and low volume/high variety go hand in hand
Volume: how many products of a kind are being produced
Variety: how many kinds of products are being produced

Project:
Usually large scale processes for one or a few unique products (ex. Ships, infrastructure), Product might be at one place during production, Machines/tools/operators go to the product
This type of process is used for one-of-a-kind or customized products, such as building a bridge or a custom-made car. The advantages of project processes are that they are highly flexible and adaptable, and they allow organizations to create unique and customized products. The disadvantages are that they are often expensive, time-consuming, and have a high level of uncertainty.

Job shop
Few products of a type based on customer specifications, many different types possible, Usually small scale, Machine and tools are shared between products, setup time can be considerable, Processes are done by skilled operators that can be specialized
This type of process is used for low-volume, high-variety products, such as machine tools or custom furniture. The advantages of job shop processes are that they are highly flexible and adaptable, and they allow organizations to create unique and customized products. The disadvantages are that they are often expensive, time-consuming, and have a high level of uncertainty.

Batch production
Production of multiple or many of the same products (more than job shops), Still general machines and tools, Batches to prevent spending time setting up the machine, Job shop but more volume and less variety
This type of process is used for moderate-volume, moderate-variety products, such as appliances or automobiles. The advantages of batch production processes are that they are relatively efficient and cost-effective, and they allow organizations to produce a moderate number of products at a time. The disadvantages are that they are less flexible and adaptable than project or job shop processes, and they require a higher level of coordination and planning.

Mass production
Similar products being produced in large batches, Only few interruptions of the process, almost no time lost in setups, Emphasis on efficiency, less on product flexibility, Probably uses product specific dedicated machines and tools
This type of process is used for high-volume, low-variety products, such as consumer goods or automobiles. The advantages of mass production processes are that they are highly efficient and cost-effective, and they allow organizations to produce large numbers of products at a time. The disadvantages are that they are less flexible and adaptable than project or job shop processes, and they require a high level of standardization and automation.

Continuous production
The same product in large quantities (ex. Chemicals), No discrete products anymore (until packaged), Visible flow throughout the factory
This type of process is used for high-volume, high-variety products, such as chemicals or food products. The advantages of continuous production processes are that they are highly efficient, cost-effective, and they allow organizations to produce large numbers of products at a time. The disadvantages are that they are less flexible and adaptable than project or job shop processes, and they require a high level of standardization and automation. They also have high set up costs, and are only suitable for high volume products, and are not suitable for low volume products.

Resource Based View

Learning may create proprietary processes and equipment that are difficult to imitate, and that: “the capability to develop propriety processes and equipment through internal and external learning within the firm is associated with competitive manufacturing performance”
The resource-based view (RBV) suggests that a firm's resources and capabilities can be divided into two categories: tangible and intangible resources. Tangible resources refer to physical assets such as equipment, facilities, and technology, while intangible resources refer to non-physical assets such as brand reputation, intellectual property, and organizational culture.
The authors suggest that a firm's manufacturing strategy should be aligned with its unique resources and capabilities to achieve better performance. For example, a company with advanced manufacturing technology would benefit from implementing mass production processes, while a company with a strong organizational culture might prioritize job shop processes to maintain flexibility and adaptability.
Another example of how this applies to businesses is when a manufacturing firm has a strong brand reputation and a loyal customer base, it can leverage its intangible resources to charge higher prices for its products. This can be a source of sustained competitive advantage, as it is hard for competitors to imitate.
In summary, the resource-based view of manufacturing strategy suggests that a firm's resources and capabilities can be a source of competitive advantage and that a firm's manufacturing strategy should be aligned with its unique resources and capabilities to achieve better performance.

?How can the resource based view be applied to improve the performance of a manufacturing company? (Answer: The resource based view can be applied to identify and utilize the unique resources and capabilities of a company to gain a competitive advantage. This can include the efficient use of physical resources, such as production equipment, as well as the development of intangible assets, such as a strong company culture or brand reputation.)

Safizadeh, M. H., Ritzman, L. P., Sharma, D., & Wood, C. (1996). An empirical analysis of the product-process matrix. *Management Science*, 42(11), 1576-1591.

The article "An empirical analysis of the product-process matrix" by Safizadeh, Ritzman, Sharma, and Wood, published in the journal "Management Science" in 1996, presents the results of an empirical study that aimed to analyse the relationship between product characteristics and process characteristics in manufacturing companies. The authors used a product-process matrix to classify products and processes into four categories: repetitive, job shop, process, and project. They then collected data from a sample of U.S. manufacturing companies to examine the relationship between product characteristics, such as product complexity and volume, and process characteristics, such as process flexibility and repeatability.
The results of the study showed that there is a positive relationship between product complexity and process flexibility, and a negative relationship between product volume and process flexibility. The authors also found that companies with high product complexity and low volume tend to use process-oriented manufacturing strategies, while companies with low product complexity and high volume tend to use repetitive or job-shop manufacturing strategies.
In summary, the article provides an empirical analysis of the relationship between product and process characteristics in manufacturing companies, using a product-process matrix to classify products and processes. The results of the study show that there is a positive relationship between product complexity and process flexibility,

and a negative relationship between product volume and process flexibility. The paper provides insights into how manufacturing companies can use this matrix to align their product and process characteristics to improve their performance.

Wheelwright, S. C. (1984). Manufacturing strategy: defining the missing link. *Strategic management journal*, 5(1), 77-91.

The article "Manufacturing strategy: defining the missing link" by Steven C. Wheelwright, published in the journal "Strategic Management Journal" in 1984, presents the concept of manufacturing strategy and its importance in the overall strategic management of a firm. The author argues that while most firms have a marketing and financial strategy, they often lack a clear manufacturing strategy. He defines manufacturing strategy as "the means by which a company plans to achieve its manufacturing objectives, given the constraints imposed by its corporate strategy, its environment and its resources."

The article explains that a manufacturing strategy should be closely aligned with the overall corporate strategy and should take into account the constraints imposed by the environment and the resources available to the firm. The author also highlights that a good manufacturing strategy should be flexible and able to adapt to changes in the market and the competitive environment.

The author also describes the four key elements of a manufacturing strategy: production system design, process technology, supply chain management and human resources management. He argues that each of these elements should be considered in the formulation of a manufacturing strategy, and that a balance must be struck between the trade-offs that are inherent in these elements.

In summary, the article "Manufacturing strategy: defining the missing link" by Steven C. Wheelwright, published in the journal "Strategic Management Journal" in 1984, presents the concept of manufacturing strategy and its importance in the overall strategic management of a firm. The author argues that a manufacturing strategy should be closely aligned with the overall corporate strategy and should take into account the constraints imposed by the environment and the resources available to the firm. He also highlights the four key elements of a manufacturing strategy, production system design, process technology, supply chain management, and human resources management that should be considered while formulating a manufacturing strategy.

Schroeder, R. G., Bates, K. A., & Junttila, M. A. (2002). A resource-based view of manufacturing strategy and the relationship to manufacturing performance. *Strategic management journal*, 23(2), 105-117.

The article "A Resource-Based View of Manufacturing Strategy and the Relationship to Manufacturing Performance" by Schroeder, Bates, and Junttila examines the link between a company's manufacturing strategy and its performance. The authors propose a resource-based view of manufacturing strategy, which argues that a company's resources and capabilities are key determinants of its manufacturing performance. The article suggests that companies should focus on developing and managing their resources and capabilities in order to improve their manufacturing performance. Additionally, the article also examines the relationship between manufacturing strategy and performance, and finds that companies with a strong manufacturing strategy tend to have better manufacturing performance. Overall, the article argues that a resource-based view of manufacturing strategy can help companies understand the connection between their resources and capabilities and their manufacturing performance, and can help them make decisions that improve their performance in this area.

Week 2 - Lean Manufacturing

Lean Production & Flows

Lean manufacturing is a production philosophy and set of techniques that aims to minimize waste and maximize value in the manufacturing process by eliminating the 7 types of waste, improving flow and empowering workers. It's an approach that prioritizes customer value, efficient use of resources and continuous improvement, leading to a reduction of costs, increase in quality and delivery time.

Little's Law

An important balance in manufacturing is the relation between throughput time, work in process, and output -> Little's Law.

L = λW

L = Average number of item in the queuing system
W = Average waiting time in the system for an item
λ = Average number of items arriving per unit time

- $Throughput = \frac{work\ in\ process}{Lead\ time(waiting+production)}$

Work in Process and Lead Time -> total throughput
Work in Process and Total throughput -> lead time
Lead time and Total throughput -> Work in Process

?How can Little's Law be applied to improve the flow of production in a manufacturing company? (Answer: Little's Law states that the average number of items in a production system is equal to the product of the average flow rate and the average time an item spends in the system. By understanding and utilizing this relationship, a company can use techniques such as process flow analysis and line balancing to optimize the flow of production and reduce lead times.)

The performance measure pitfall

The performance measure pitfall refers to the idea that using certain metrics to evaluate the performance of a system or process can lead to unintended consequences or suboptimal outcomes. This can occur when the metrics used to evaluate performance do not align with the goals of the system or process, or when the metrics are used to incentivize behavior that is not in the best interest of the overall system.

The classic pitfall scenario is that managers are incentivized to increase the efficiency of their department by using metrics such as "setup efficiency" (i.e. the number of products produced per setup), and as a result, they may wait until they have a large enough batch of products that can use the same setup before starting production.

This behaviour can have unintended consequences, such as increasing the Work-in-Progress (WIP) inventory, which is the amount of unfinished products that are currently in the production process. This is because the manager is waiting to produce a large batch of products before starting production, rather than producing smaller batches more frequently.

Little's Law is a relationship that states that the average amount of WIP inventory in a system is equal to the product of the average flow rate (i.e. throughput) and the average lead time. In this scenario, the flow rate (i.e. the output per time period) stays the same, meaning the manager is still producing the same amount of products. However, because the manager is waiting to produce a large batch of products, the lead time (i.e. the time it takes for a product to move through the system) increases. As a result, the customers must wait longer for their products to be delivered.

There are various additional bad effects of high WIP: -Takes up a lot of costly space -Someone must be made responsible for -keeping track of work in progress -Products get damaged -Products get lost and must be made again

Toyota Production System

All manufacturing companies nowadays implement (parts of) the TPS

Multi-directional flows (cellular manufacturing)
High setup times, because you start to batch (SMED)
Anonymous work for anonymous workers (empowerment)
Machine disruptions (preventive maintenance)
Defects in products (TQM, Statistical Process Control)
Individual differences in processing times (standard operating procedures)
Unreliable suppliers (JIT in the supply chain)

Multi-directional flows: This refers to the problem of products moving through a production process in multiple directions, which can lead to confusion and inefficiencies. The solution is *cellular manufacturing*, which is a layout and production strategy that groups similar operations together in a "cell" or small area. This allows for a more streamlined and efficient flow of products through the production process.

High setup times: This refers to the problem of long setup times when changing between different products or processes, which can slow down overall production. The solution is *Single Minute Exchange of Dies (SMED)*, which is a method for reducing setup times by separating internal and external setup activities and by using tools such as standardized work, quick-changeover techniques, and visual management.

Anonymous work for anonymous workers: This refers to the problem of workers feeling disconnected from their work and not feeling motivated to improve performance. The solution is *empowerment*, which is the process of giving workers more autonomy and decision-making power in their work, as well as providing them with the necessary training and resources to improve performance.

Machine disruptions: This refers to the problem of machines breaking down frequently and disrupting production. The solution *is preventive maintenance*, which is the process of regularly inspecting and servicing machines to prevent breakdowns and prolong the life of the equipment.

Defects in products: This refers to the problem of producing defective products, which can lead to customer dissatisfaction and increased costs. The solution is *Total Quality Management (TQM) and Statistical Process Control (SPC),* which are methods for identifying and controlling the sources of defects in a production process. TQM focuses on continuous improvement and customer satisfaction, while SPC is a statistical method used to monitor and control a process to ensure quality.

Individual differences in processing times: This refers to the problem of workers processing products at different speeds, which can lead to uneven production and inefficiencies. The solution is *Standard Operating Procedures (SOPs),* which are detailed instructions on how to perform a specific task or process. SOPs help to ensure consistency and efficiency in the production process.

Unreliable suppliers: This refers to the problem of suppliers being unreliable and not delivering materials on time, which can disrupt production and lead to inventory shortages. The solution is *Just-in-Time (JIT) in the supply chain,* which is a method for managing inventory and materials by only ordering what is needed, when it is needed. This helps to reduce inventory costs and minimize the impact of unreliable suppliers.

?How can the Toyota Production System be used to improve the flow of production in a manufacturing company? (Answer: The Toyota Production System, also known as Lean Manufacturing, focuses on the elimination of waste, the use of continuous flow processes, and the empowerment of workers to identify and solve problems. These principles can be used to improve the flow of production by reducing bottlenecks, increasing efficiency, and increasing flexibility to respond to changes in demand.)

7 wastes

The goal of identifying and reducing the 7 wastes is to improve the efficiency and effectiveness of the production process, by eliminating anything that does not add value to the product or service. It's important to note that it's an ongoing process and requires continuous improvement efforts.

Overproduction: Producing more than what is needed or what can be sold, which leads to increased inventory costs and can cause delays in the production process. For example, a factory produces a large batch of products that are not yet needed by the customer. A solution for this can be implementing a pull-based system, such as Kanban, to ensure that production is based on actual customer demand.

Waiting: Delays in the production process caused by waiting for materials, equipment, or other resources to become available. For example, a factory may have to wait for a supplier to deliver raw materials before it can begin production. A solution for this can be implementing a Just-in-Time (JIT) system to minimize the amount of inventory that needs to be kept on hand and reduce waiting times.

Overprocessing: Performing unnecessary or redundant steps in the production process, which can lead to increased costs and decreased efficiency. For example, a factory may have too many inspection steps which are not needed. A solution for this can be implementing a Statistical Process Control (SPC) system to identify and remove unnecessary steps in the process.

Unnecessary motion: Workers performing unnecessary or inefficient movements, which can lead to increased fatigue and decreased productivity. For example, a worker may have to walk long distances to retrieve parts or tools. A solution for this can be implementing a cellular manufacturing system, which groups similar operations together in a small area to minimize unnecessary movement.

Excess inventory: Holding more inventory than is needed, which can lead to increased costs and decreased efficiency. For example, a factory may have a large amount of raw materials in stock that are not being used. A solution for this can be implementing a pull-based system, such as Kanban, to ensure that inventory is only replenished as needed.

Defects: Producing products that do not meet quality standards, which can lead to increased costs and decreased customer satisfaction. For example, a factory may produce a batch of products that do not meet the customer's specifications. A solution for this can be implementing a Total Quality Management (TQM) system to identify and control the sources of defects in the production process.

Unnecessary transportation: Moving products or materials more than is necessary, which can lead to increased costs and decreased efficiency. For example, a factory may have to transport a product through several stages of production before it is completed. A solution for this can be implementing a lean manufacturing system, which emphasizes minimizing transportation and maximizing flow.

Flow

Flow means fast, predictable, and reliable throughput time of products.
managers may be incentivized to increase productivity by awarding them for high productivity. However, this can lead to unintended consequences in terms of flow in the production process. In this example, each department is given one week to perform their activities. This means that the managers will be focused on completing their tasks within that one-week timeframe, in order to achieve high productivity. However, this can lead to products spending most of the time waiting, because the internal coordination within the department may not be sufficient.

Single Minute Exchange of Dies (SMED)

Single Minute Exchange of Dies (SMED) is a method used to reduce setup times in production processes. It separates setup activities into two categories: internal and external. Internal activities are those that can only be done when the machine is not running, such as cleaning the machine or removing fixtures, while external activities can be done when the machine is running, such as getting and returning tools or adding fixtures. The typical activities involved in SMED include getting and returning tools, cleaning the machine, removing and adding fixtures, calibrating the machine, and test runs or adjustments. The steps in SMED include measuring current changeover times, identifying internal and external elements, moving as many elements as possible to external, shortening internal and external elements, and standardizing and training. Advantages of SMED include less hours spent in setup, no need for dedicated staff and no need for scheduling setups. The goal of SMED is to reduce changeover times until it is not a relevant factor anymore, this can lead to similar batch size and higher productivity or similar productivity with smaller batches, improving flow in the production process.

steps

-*Measure current changeover times*: This step involves measuring the time it takes to change from one product or process to another, in order to identify areas for improvement. For example, a factory measures the time it takes to change from producing product A to producing product B and finds that it takes 1 hour.
-*Identify Internal and External elements*: This step involves identifying the activities that are required to changeover and categorizing them as internal or external. Internal activities are those that can only be done when the machine is not running, such as cleaning the machine or removing fixtures. External activities can be done when the machine is running, such as getting and returning tools or adding fixtures. For example, a factory identifies that changing the die on the press is an internal activity and getting the new die from storage is an external activity.
-*Move as many elements as possible to External*: This step involves moving internal activities that can be done while the machine is running to external activities. For example, a factory may find that cleaning the machine can be done while it is running, so it moves that activity from internal to external.
-*Shorten Internal elements*: This step involves identifying ways to reduce the time required for internal activities. For example, a factory may find that it can reduce the time required to change the die on the press by using quick-changeover techniques.
-*Shorten External elements*: This step involves identifying ways to reduce the time required for external activities. For example, a factory may find that it can reduce the time required to get the new die from storage by using visual management to ensure that the die is always in the correct location.
-*Standardize and train*: This step involves standardizing the changeover process and training workers to ensure that the process is consistently followed. For example, a factory may develop standard operating procedures for changeovers and train all workers on the proper procedures.

Advantages

-Less hours spent in setup: SMED aims to reduce the time it takes to change from one product or process to another, which leads to less time spent on setup and more time spent on production. This can increase productivity and efficiency in the production process.
-No dedicated staff: SMED involves standardizing the changeover process and training all workers on the proper procedures. This means that any worker can perform the changeover, eliminating the need for dedicated staff to handle setup tasks.
-Scheduling setups not needed anymore: By reducing the time required for changeovers, SMED eliminates the need for scheduling setups. This allows for more flexibility in production and eliminates the need for production to be scheduled around setup times.
-Similar batch size, higher productivity: By reducing setup times, SMED allows for similar batch sizes to be produced in less time, leading to higher productivity.
-Similar productivity, smaller batches: SMED allows for similar productivity with smaller batches, which can improve flow in the production process.
-Try to reduce until it is not a relevant factor anymore: The goal of SMED is to reduce changeover times until it is not a relevant factor in the production process anymore. This means that changeovers are quick and efficient, and do not have a significant impact on production times.

When are SMED's relevant

SMED is a good solution when the changeover times between products or processes are significant and are causing bottlenecks in the production process. Here are a few examples of when SMED can be used to improve flow:
-A factory produces a variety of products on a single machine and the changeover times between products are long, causing delays in production and holding up the flow of the entire process. Implementing SMED can reduce changeover times and improve flow by allowing the factory to produce more products in the same amount of time.

-A factory produces a single product, but the changeover time between production runs is long. This causes delays in production and limits the factory's ability to respond quickly to changes in demand. Implementing SMED can reduce changeover times and improve flow by allowing the factory to produce more products in the same amount of time and respond more quickly to changes in demand.
-A factory produces a product in small batch sizes, but changeover times between batches are long. This causes delays in production and limits the factory's ability to produce products efficiently. Implementing SMED can reduce changeover times and improve flow by allowing the factory to produce similar batch sizes in less time.

Batch Size and Lean Manufacturing

Process focus

If your machines are expensive, you choose a process focus. You create buffers with products before the machine, so the machine never has to wait.
-A process focus means that the focus is on making sure that the production process runs smoothly and efficiently. This can be done by creating buffers, or extra inventory, before a machine so that the machine never has to wait for materials or products to be available.
-It is a good idea to use a process focus when the machines used in the production process are expensive. This is because when machines are expensive, it is important to make sure that they are running efficiently and not wasting time waiting for materials or products. For example, an automotive factory has a paint booth that is expensive, using a process focus would make sure that the paint booth never waits for a car to paint. On the other hand, it may not be a good idea to use a process focus when the machines used in the production process are inexpensive or the cost of materials and labor is high. This is because in this case, the cost of creating buffers may be greater than the cost of the machine or the materials and labor.
-how I'd explain this to a 5 year old: ok, so a process focus is when we make sure that our machines are always working and not waiting for things. Like if we have a big and expensive oven, we make sure it always has dough to bake so it never has to wait and we can make more yummy bread!

Product focus

If your products need a short throughput time, you choose a product focus. For example, you buy lots of additional capacity so your product never has to wait.
-A product focus means that the focus is on making sure that the products are made and delivered to the customers as quickly as possible. This can be done by buying additional capacity, like more machines or hiring more workers, so that the products never have to wait to be made or delivered.
-It is a good idea to use a product focus when the products need a short throughput time, which means that they need to be made and delivered quickly. This is because when products need a short throughput time, it is important to make sure that they are made and delivered quickly to meet customer demand. For example, a restaurant that serves perishable items like salads, they will use a product focus so that they can serve fresh salads to their customers. On the other hand, it may not be a good idea to use a product focus when the products do not need a short throughput time, such as luxury goods that are not perishable, or the cost of additional capacity is high. This is because in this case, the cost of buying additional capacity may be greater than the benefit of having a short throughput time.
-how I'd explain this to a 5 year old: ok, so a product focus is when we make sure that our things are made and delivered to people as fast as possible. Like if we sell salads, we make sure we have enough people in the kitchen to make them quickly so they are always fresh.

Buffers

A buffer, in the context of production and manufacturing, refers to extra inventory or extra capacity (e.g. machines, labor) that is held in reserve to prevent delays or downtime in the production process. There are two main types of buffers:

Product buffers, also known as inventory or work in process buffers, are extra inventory or work in process that is held in reserve to prevent delays in production. For example, having extra raw materials on hand, so that if the supplier is delayed, the production process is not impacted.
Capacity buffers, also known as machine or labor buffers, are extra machines or labor that is held in reserve to prevent downtime in the production process. For example, having an extra machine as backup in case one breaks down, or having extra workers on hand to cover for absences.

Traditionally, companies have avoided using capacity buffers, which are extra machines or workers to prevent downtime, at the expense of product buffers, which are extra inventory or work in process to prevent delays in production.
The reasoning behind this is that the cost of a machine is easy to determine, but the cost of waiting time for a product is not. It can be difficult to calculate the loss of customers due to a long lead time.
In Lean Manufacturing, the goal is to avoid both types of buffers because product buffers lead to long customer lead time, and capacity buffers are expensive. Instead, lean manufacturing aims to improve flow and efficiency in the production process so that there is no need for product or capacity buffers.

?How can the use of buffers be used to improve the flow of production in a manufacturing company? (Answer: Buffers, such as work-in-progress inventories and machine buffers, can be used to smooth out variations in production flow and protect against disruptions. By having a buffer of inventory or machine capacity, a company can continue production even if there are unexpected delays or changes in demand.)

Batches

large batches

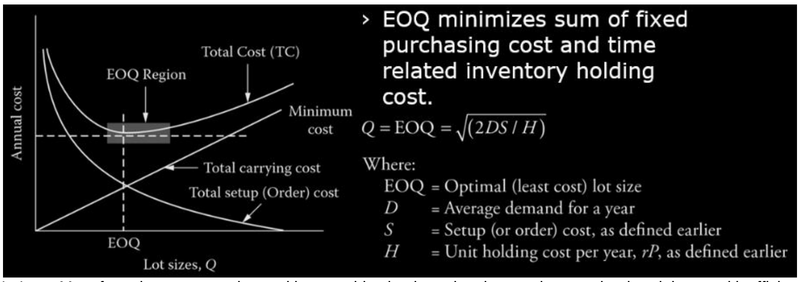
Factories often use large batch sizes to increase machine utilization and produce efficiently. The rationale behind this is that if a whole batch is produced, the machine only needs to be set up once.
For example, in the production of tables and chairs, the setup time between a table and a chair is 1 hour and the production time for one table or chair is also 1 hour.
If the factory does not use batching, each table and chair is produced individually, resulting in 4 products per day. But if the factory uses batching, the machine is set up to produce 3 tables and 3 chairs at once. This results in 6 products per day.
This is done because machines are often expensive and have large setup times, and to get high machine utilization, batch sizes must be large. However, this also means that the throughput time for the products is long, which implies a long lead time for customers and lots of work-in-process inventory.
Even if batches are not explicitly scheduled, a department may create artificial batches, only setting up the machine for a product type if multiple products are waiting to be worked on. This makes the throughput time not only long but also unpredictable.

Small batches

To increase flow, the goal is to reduce batch sizes. One way to do this is through the use of the Single Minute Exchange of Dies technique in Lean Manufacturing. This technique is designed to significantly reduce setup time from, for example, 8 hours to a few minutes, by streamlining and standardizing the process.
As a result of reducing setup time, the relative importance of other times increases, such as waiting time. When we decrease changeover time, we need less batching to produce with the same efficiency, which reduces waiting time. Additionally, we probably need to synchronize and coordinate many more processes to maintain efficiency in the production process.

The 'optimal' batch size

The optimal batch size can be calculated similar to Economic order quantity



		Focus	
		Product	Process
Flow	Uni-directional	Line balancing	Pull Production
	Multi-directional	Cellular Manufacturing	Scheduling

-In Lean Manufacturing systems, the goal is to avoid using large batches as they can lead to delays and inefficiencies. Instead, the focus is on using small batches or even one-piece flow. One way to achieve this is by using the Single Minute Exchange of Dies (SMED) technique which helps to reduce setup times, making it economically viable to work with small batches.
-However, when working with small batches, new techniques are needed to coordinate the production process. One way to do this is by establishing a product focus and using uni-directional flow, and Line Balancing. This approach is best used when there is little variety in products and they can be produced in a uni-directional flow.
-Another approach is to use Pull Production when there is considerable variety in products but they can be produced in a uni-directional flow.
-If it is not possible to use either of these approaches, it is possible to divide machines and products into small groups that have no interdependencies with each other, by creating manufacturing cells. Each cell can then be treated as an independent mini-factory within the factory.
-Finally, when all of the above methods are not possible, scheduling can be used to coordinate the production process.

Black, J. T. (2007). Design rules for implementing the Toyota Production System. *International Journal of Production Research*, 45(16), 3639-3664.

The article "Design Rules for Implementing the Toyota Production System" by Black, examines the principles and practices of the Toyota Production System (TPS) and provides design rules for implementing it in other organizations. TPS is a manufacturing system that emphasizes efficiency, quality, and flexibility, and is known for its use of lean manufacturing techniques.
The author suggests that in order to successfully implement TPS, companies should focus on five key design rules:
-Design for flexibility, which means the production line should be able to adapt to changes in demand or product design.
-Design for efficiency, by eliminating waste and reducing process steps.
-Design for learning, by implementing continuous improvement practices and involving employees in the process.
-Design for quality, by ensuring the production process is meeting the quality standards.
-Design for flow, by making surew the production process runs smoothly and without interruption.
The article provides a detailed understanding of the key design principles of TPS, which can help organizations improve efficiency, quality and overall production performance. These design rules are essential for organizations that are looking to implement TPS as a way to achieve better production performance. The design rules mentioned in the article can serve as a guide for organizations to follow while implementing TPS.

Little, J. D., & Graves, S. C. (2008). Little's law. In: *Building intuition* (pp. 81-100). Springer, Boston, MA. . (you can skip the historical background and personal note).

Little's Law is a mathematical formula that relates the average inventory of a stable system to the average rate at which items are produced or consumed (throughput) and the average time that an item spends in the system (cycle time). The formula is stated as: Inventory = Throughput x Cycle Time.
This law is used in manufacturing and production systems and supply chain management to understand the relationship between the inventory, throughput, and cycle time of a system. It helps to identify bottlenecks and optimize production. By understanding how inventory, throughput, and cycle time are related, organizations can make informed decisions about how to improve their operations and increase efficiency.
For example, if a company wants to reduce inventory, it can increase the throughput of the system by producing more items, or reduce the cycle time by streamlining production processes. Similarly, if a company wants to increase throughput, it can reduce inventory by reducing the number of items in the system, or reduce cycle time to get items through the system more quickly.
Overall, Little's Law is a useful tool for managers and operations professionals to understand the relationship between inventory, throughput and cycle time, and make informed decisions to improve production performance.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of operations management*, 21(2), 129-149.

The article "Lean Manufacturing: Context, Practice Bundles, and Performance" by Shah and Ward explores the concept of lean manufacturing and its impact on business performance. Lean manufacturing is a production philosophy that emphasizes the elimination of waste and the continuous improvement of processes to increase efficiency and reduce costs.
The authors argue that the implementation of lean manufacturing practices is not a one-size-fits-all solution, but rather, it should be tailored to the specific context of the organization. They propose that lean manufacturing practices can be grouped into "practice bundles," which are specific sets of practices that are appropriate for a particular context.
The article also examines the relationship between lean manufacturing practices and performance, and finds that there is a positive correlation between the implementation of lean manufacturing practices and improved performance in areas such as productivity, quality, and lead time.
Three examples of how lean manufacturing could be applied to a business case are:
-A company identifies and eliminates non-value adding activities in their production process to increase efficiency.
-A company implements a pull-based production system to reduce inventory and improve responsiveness to customer demand.
-A company establishes a culture of continuous improvement, where employees are encouraged to identify and eliminate waste in their daily work.
Overall, the article provides insight into the context-specific nature of lean manufacturing and the importance of tailoring lean practices to the specific needs of an organization. It also demonstrates the positive impact that lean manufacturing can have on business performance when implemented correctly.

Sobek II, D. K., & Jimmerson, C. (2004). A3 reports: tool for process improvement. In: *IIE Annual Conference. Proceedings*. Institute of Industrial and Systems Engineers (IISE).

The article "A3 Reports: Tool for Process Improvement" by Sobek II and Jimmerson introduces the concept of A3 reports as a tool for process improvement in manufacturing and business operations. A3 reports are a structured problem-solving method used in Lean manufacturing and other business processes, and are named after the standard ISO 216 paper size on which they are typically created.
The article explains that A3 reports are a way to break down and analyze a problem or opportunity in a clear, concise, and visual manner. They are used to document the current state of a process, identify the root cause of a problem, and develop a plan to improve the process. The A3 report format includes sections for problem description, current state analysis, root cause analysis, proposed countermeasures, and implementation plans.
The authors argue that A3 reports are a valuable tool for process improvement, as they help teams to focus on a specific problem, involve employees in the problem-solving process, and ensure that the improvement plan is clearly defined and communicated.
For example, a company might use an A3 report to analyze and improve a production process that is experiencing a high rate of defects. The A3 report would document the current state of the process, identify the root cause of the defects, and propose countermeasures to improve the process, such as implementing a new quality control system or retraining employees.
Overall, the article highlights the A3 report as a useful tool for process improvement, providing a clear and structured approach for problem solving and improvement planning. It emphasizes the importance of involving employees in the problem-solving process and ensuring that the plan is clearly defined and communicated.

? How can the use of an A3 report help to improve the problem-solving and process improvement skills of employees within a manufacturing company? (Answer: A3 reports are a structured problem-solving tool that help employees to clearly define, analyze and solve problems in a systematic way. These reports can be used to improve the problem-solving and process improvement skills of employees by providing a clear structure for identifying and addressing issues, and by encouraging a data-driven and continuous improvement approach to problem-solving.)

Week 3 - Design for Flows

Cellular Manufacturing

Flow needs small batches, which increases the need for coordination.

Cellular Manufacturing

Cellular Manufacturing approach is a way of organizing a factory into multiple smaller cells, each one focused on producing a specific product or sub-assembly. This approach is different from the traditional process layout, where each function has its own department. This approach is similar to multiple smaller supermarkets in a city that each have a butcher, a bakery, etc.

-Cellular Manufacturing is a production system that is designed to increase efficiency, reduce lead times, and lower costs by grouping similar machines and processes together into cells or workstations. The goal of cellular manufacturing is to create a flexible and responsive production system that can quickly adapt to changes in demand.

-In a cellular manufacturing system, machines and workers are organized into small teams, or cells, that are responsible for producing a specific product or group of products. Each cell is self-contained and includes all the machines, tools, and personnel needed to produce the products it is responsible for. This allows for more efficient use of resources, as machines and personnel are only used when they are needed.

-Cellular manufacturing also allows for more efficient use of space, as machines and workers are organized in a way that minimizes the distance that products and materials need to travel. This can lead to faster production times, as products and materials are readily available to the people who need them.

-Cellular manufacturing also improves quality control, as defects and problems can be identified and addressed quickly, and the flow of materials and products can be easily traced.

Binary ordering

Binary ordering for cellular manufacturing is a method of organizing production cells in a factory. It uses a binary matrix that has products as numbered columns and machines as rows. This matrix is used to determine which machines are needed to produce which products. The process involves several iterations, starting with a zero value in the top left corner of the matrix. A geometric sequence of 2 is then added to one side of the matrix, and the remaining rows or columns are calculated by multiplying the binary values in the matrix with the geometric sequence value. Finally, the rows or columns are shifted to put them in numerical order, resulting in a matrix with values as close to the diagonal as possible without altering the information. This method helps to make the production process more efficient by grouping similar machines and products together in cells.

Machines	
Laser Cutter	A
CNC Router	B
Drape Forming Oven	C
Belt Oven	D
Drill Machine	E
Diamond Polisher	F

Products	
Jump Screen	1
Machine Guard	2
Sneeze Guard	3
Shop Fitting	4
Garden Ornaments	5
Plaques	6

I	1	2	3	4	5	6	
A	0	0	1	1	1	1	32
B	1	1	0	0	0	0	16
C	0	1	0	0	0	0	8
D	1	1	0	0	0	0	4
E	0	1	1	0	1	0	2
F	1	0	0	0	0	0	1
	21	30	34	32	34	32	

II	5	3	4	6	2	1	
A	1	1	1	1	0	0	32
B	0	0	0	0	1	1	16
C	0	0	0	0	1	0	8
D	0	0	0	0	1	1	4
E	1	1	0	0	1	0	2
F	0	0	0	0	0	1	1
	34	34	32	32	30	21	

III	5	3	4	6	2	1	
A	1	1	1	1	0	0	60
B	0	0	0	0	1	1	3
C	0	0	0	0	1	0	2
D	0	0	0	0	1	1	3
E	1	1	0	0	1	0	50
F	0	0	0	0	0	1	1
	32	16	8	4	2	1	

IV	5	3	4	6	2	1	
A	1	1	1	1	0	0	60
E	1	1	0	0	1	0	50
D	0	0	0	0	1	1	3
B	0	0	0	0	1	1	3
C	0	0	0	0	1	0	2
F	0	0	0	0	0	1	1
	32	16	8	4	2	1	

Line Balancing

Flow line

In a flow shop, all products go through the same sequence of operations. The system is set up to "push" products through the process, meaning that demand determines the activities at the first station rather than the last station. In this system, instead of scheduling each operation individually to compensate for variations in processing times, the operations are synchronized and coordinated in the design of the production system. The goal of this type of system is to improve efficiency and reduce waste.

Line Balancing

In Line Balancing, we determine:

-First: how many 'workstations' we need

-Second: how the tasks are distributed over the workstations.

The goal is to satisfy demand, and do this as efficiently as possible.

Assumptions:

-Stable & predictable demand, or production to stock

-Limited product variation

-Stable & predictable task times for each task

!Multiple tasks in a workstation; as little idle time as possible

!Equal distribution of idle time over workstations

Step 1: Takt/Cycle Time; the amount of time it takes to produce one product

To determine the cycle time, the time available is divided by the demand. For example, if there are 8 hours available per day and the demand is for 200 products per day, the cycle time would be 480 minutes (8 hours) divided by 200 products which equals 2.4 minutes. This means that a product should be finished every 2.4 minutes for the line to be balanced and operating at the most efficient rate.

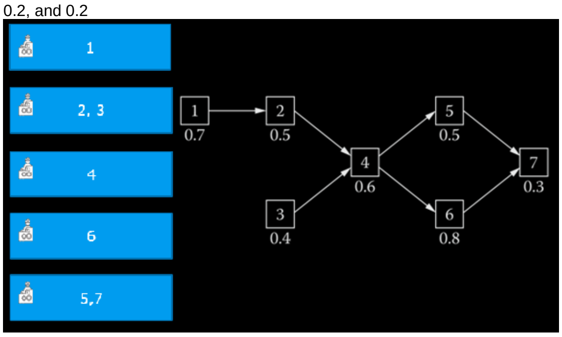
Step 2: find groups of activities that take less than or equal to the calculated cycle time

This step involves analyzing each activity that is performed on the production line and grouping them into clusters of tasks that can be completed within the allotted cycle time. This step helps to ensure that the production line is operating at its most efficient rate by making sure that there is enough time to complete all the necessary activities within the cycle time. It also helps to identify any bottlenecks or areas that may need improvement in order to achieve the desired cycle time. It's important to note that this step is also done in order to make sure that the demand is met and not producing more or less than the demand as stated in the previous step.

Longest Processing time

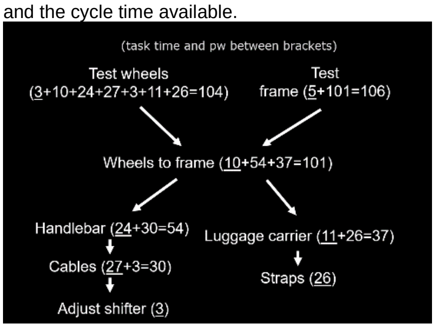
The Longest Processing Time heuristic is a method used in line balancing to determine which task or set of tasks should be assigned to a specific workstation. It is based on the principle that the task with the longest processing time should be assigned to the first workstation. This is done by looking at the time it takes to complete each task, and starting with the task that takes the longest. Then, the next task(s) are assigned based on which can be completed within the remaining time available for that workstation. This process is repeated for each workstation until all tasks have been assigned. The goal is to minimize idle time at each workstation and optimize the overall efficiency of the production line.

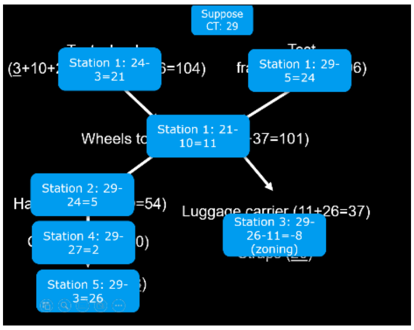
-Suppose a Cycle Time of 1 minute.
I can start with task 1 or 3.
Task 1 has the longest processing time.
So I assign task 1 to Workstation 1.
-Workstation 1 now has 0.3 minutes left.
-I can now assign task 2 or 3. Neither fits in the station, because 0.7+0.5=1.2, and 0.7+0.4=1.1. Performing both tasks would take more than 1 minute, and then I could not make 420 products in the 7 hours I have available.
-So, I open a new station, and assign task 2, because it has the longest PT.
-Which tasks can now be assigned? Only 3. Task 4 can not yet be assigned because 3 has not yet been done.
-Does task 3 still fit in station 2? 1-0.5=0.5, and 3 takes 0.4, so yes, it fits.
I have little choice now, only task 4 can be assigned. It takes 0.6, and does not fit in station 2. So I assign it to station 3.
-I can now choose from task 5 and 6. Task 6 has the longest PT, but it does not fit in station 3.
-So, task 6 goes to station 4.
-My choices are limited again. I can assign task 5, but not task 7, because it needs task 5.
-Task 5 does not fit in station 4, so it goes to station 5.
-Finally, I can assign task 7. It takes 0.3 minutes, And station 5 has still 0.5 time left. So I can assign It to station 5.
-I now have 5 stations, with idle times 0.3, 0.1, 0.4, 0.2, and 0.2



Rank Positional Weight

The Rank Positional Weight (RPW) heuristic is a method for line balancing that aims to minimize the number of workstations needed to complete a set of tasks within a given cycle time. It works by assigning tasks to workstations based on their processing time and position in the task sequence. The RPW of a task is calculated by multiplying its processing time by its rank in the task sequence. Tasks with the highest RPW values are assigned to the first workstation, and so on, until all tasks are assigned. This heuristic aims to minimize the number of workstations needed by ensuring that the tasks with the longest processing times are completed first, which allows for more tasks to be completed in subsequent workstations. This method can also take into consideration the precedence relationships between tasks and the cycle time available.





Uncertainty

Uncertainty in a paced production line can be dangerous as it can lead to delays and disruptions in the flow of the production process. In a paced production line, the product is sent to the next station even if it is not finished, which can cause problems if the tasks assigned to a workstation are not completed within the takt time. For example, if there is a 1% chance that the tasks are not finished within the takt time, with 10 workstations, there is approximately a 10% chance that one of the workstations is not finished.

To address this issue, there are several solutions that can be considered. One solution is to consider the uncertainty in the calculations, which requires more advanced line balancing heuristics. Another solution is to use small buffers between stations to help manage the flow of the production process. An unpaced line can also be used, which allows for more flexibility in the production process. Additionally, operators on non-bottleneck stations can help the bottleneck stations to ensure that the production process remains on schedule.

Greene, T. J., & Sadowski, R. P. (1984). A review of cellular manufacturing assumptions, advantages and design techniques. *Journal of Operations Management*, 4(2), 85-97.

The article "A Review of Cellular Manufacturing Assumptions, Advantages and Design Techniques" by Greene and Sadowski reviews the concept of cellular manufacturing and its advantages and design techniques. Cellular manufacturing is a production system in which similar products are produced in small groups, or cells, of machines that are located close together. This system is designed to improve efficiency, quality and flexibility by organizing the production process around the product flow.
The authors argue that cellular manufacturing can be an effective way to improve production performance, but it is important to consider the assumptions and constraints of the system before implementing it. The article highlights some of the advantages of cellular manufacturing such as:
-Reduced material handling -Reduced setup time -Increased efficiency -Increased flexibility
The article also describes different design techniques for implementing cellular manufacturing, such as:
-Group technology -Machine-part cell formation -Mixed-model assembly
The authors also discuss the importance of considering the product mix and volume, the production process, and the layout of the manufacturing facility when designing a cellular manufacturing system.
For example, a company might use the cellular manufacturing system to improve the production of a specific product line, by organizing the production process around the product flow. This can lead to reduced material handling and setup time, increased efficiency and flexibility, and improved production performance.
Overall, the article provides a comprehensive understanding of the cellular manufacturing system, its assumptions, advantages and design techniques. It also highlights the importance of considering the product mix and volume, the production process, and the layout of the manufacturing facility when designing a cellular manufacturing system.

King, J. (1980). Machine-component group formation in group technology. *Omega*, 8(2), 193-199. doi:10.1016/0305-0483(80)90023-7.

The article "Machine-Component Group Formation in Group Technology" by King, examines the concept of group technology, which is a manufacturing system that organizes machines and components into groups based on their similarity and usage. The author explains that group technology is a way to improve production efficiency and reduce costs by using common components and similar machine processes.
The article focuses on the process of machine-component group formation, which is the process of organizing machines and components into groups that are used in similar manufacturing processes. The author argues that the process of group formation is crucial to the success of group technology and that it can be accomplished through the use of mathematical and computer-aided methods.
The article also explains that the process of group formation can be broken down into three steps:
-Identifying the components and machines that are used in similar processes -Grouping these components and machines together
-Assigning a group code to each group
For example, a company might use group technology to improve the production of a specific product line by organizing the production process around the product flow. This can lead to reduced material handling and setup time, increased efficiency and flexibility, and improved production performance.
Overall, the article provides insight into the concept of group technology and the importance of machine-component group formation in the success of group technology. It also highlights the use of mathematical and computer-aided methods in the process of group formation, which can be beneficial in improving production efficiency and reducing costs.

Falkenauer, E. (2005, July). Line balancing in the real world. In: *Proceedings of the international conference on product lifecycle management* (Vol. 5, pp. 360-370).

The article "Line Balancing in the Real World" by Falkenauer, examines the concept of line balancing in manufacturing operations, which is the process of balancing the workload across different workstations in a production line to optimize efficiency and productivity. The author argues that line balancing is a crucial step in the design and planning of a manufacturing process and it can be a complex task in practice due to factors such as variations in product mix, changes in production volume, or unexpected machine breakdowns.
The article explains that line balancing can be accomplished by using mathematical models and algorithms, but in the real world, it is often necessary to make adjustments based on practical considerations such as operator skill levels, machine availability and maintenance schedules. The author suggests that line balancing should be considered as an ongoing process, rather than a one-time task, as it is necessary to make adjustments and re-balance the line as production conditions change.
The article also provides an insight into the different line balancing methods that can be used, such as:
-Heuristic methods -Mathematical optimization methods -Hybrid methods
For example, a company might use line balancing to improve the production of a specific product line by optimizing the workload across different workstations in a production line. This can lead to increased efficiency and productivity, and improved overall production performance.
Overall, the article provides a comprehensive understanding of the concept of line balancing in manufacturing operations, its importance and its complexities. It also highlights the need for an ongoing approach to line balancing, considering practical considerations and the different line balancing methods that can be used.

Week 4 – Scheduling

Scheduling

Scheduling

Scheduling is the process of allocating a firm's resources to the tasks or activities that need to be executed. In manufacturing, scheduling involves determining the time of each activity in the production process, which usually involves a number of processing steps, such as drilling, milling, bending, and assembling. At each operation, a product goes through four stages and the goal of scheduling is to balance machine utilization and due date performance for each product and machine.
Scheduling is a huge area in Operations Management, Decision Support Systems, and Operations Research and is an important task in all organizations. Examples of scheduling includes allocating staff to tasks, orders to machines, operators to machines, operators to shifts, routes to trucks, classes to time slots etc. Sometimes, reducing setup time is not possible or too expensive. The goal of scheduling is to allocate resources effectively and efficiently in order to meet the demands of the production process and meet customer needs.

First come first serve

The "first come, first served" (FCFS) priority rule is a scheduling algorithm used in computing and other environments to determine the order in which jobs or processes are executed. The rule states that the job or process that arrives first will be executed first, followed by the next job or process that arrives, and so on. One of the main advantages of the FCFS rule is its simplicity. It is easy to understand and implement, and does not require any complex calculations or algorithms. Additionally, the FCFS rule is fair in the sense that it does not discriminate against any job or process, and allows all jobs or processes to be executed in the order in which they arrive. However, the FCFS rule also has some disadvantages. One of the main disadvantages is that it can lead to poor performance, especially if there are long or resource-intensive jobs or processes that arrive early in the queue. These jobs or processes can block the execution of shorter or less resource-intensive jobs or processes that arrive later, leading to delays and poor overall performance.

SPT: Shortest processing time

The "shortest processing time" (SPT) priority rule is a scheduling algorithm used in computing and other environments to determine the order in which jobs or processes are executed. The rule states that the job or process with the shortest processing time will be executed first, followed by the next shortest processing time job or process, and so on. One of the main advantages of the SPT rule is that it can lead to improved performance and reduced completion time for all jobs or processes. By executing the shortest jobs or processes first, the SPT rule minimizes the amount of time that the system spends idle waiting for longer jobs or processes to complete. Additionally, it also helps in reducing the average waiting time for all jobs or processes.
However, the SPT rule also has some disadvantages. One of the main disadvantages is that it does not take into account other factors such as priority or resource requirements, which can lead to poor performance for certain jobs or processes. Additionally, it could also lead to starvation of certain jobs or processes if they have longer processing time but have higher priority. Advantage: many customers served
Disadvantage: long jobs keep waiting

EDD: Earliest Due date

The "earliest due date" (EDD) priority rule is a scheduling algorithm used in manufacturing and other environments to determine the order in which jobs or processes are executed. The rule states that the job or process with the earliest due date will be executed first, followed by the next job or process with the earliest due date, and so on. One of the main advantages of the EDD rule is that it can lead to less severe due date violations. By executing the jobs or processes with the earliest due dates first, the EDD rule minimizes the likelihood of missing a critical due date for a particular job or process. This is particularly useful in situations where it is important to meet specific deadlines, such as in manufacturing or other time-sensitive industries. However, the EDD rule also has some disadvantages. One of the main disadvantages is that it may lead to many small due date violations instead of a single large one. By focusing on the earliest due dates, the EDD rule may cause other jobs or processes to miss their due dates, even if they are not as critical. Additionally, it may lead to a bottleneck situation where all jobs are focused on the earliest due date and it may cause delays in others.

In practice

Scheduling theory and practice are two different things. While scheduling theory focuses on generating schedules, in practice there is much more involved. Many heuristics have been developed to solve scheduling problems to near optimality, but these techniques are not widely used in most companies. This is because the performance criteria in theory differ from those in practice, and the focus of scheduling theory is on generating schedules, while in practice there are many other factors to consider.
One of the most important tasks in organizations is shop floor control, and this is where human planners and schedulers play a crucial role. They are responsible for maintaining situation awareness and are able to make real-time adjustments to the schedule as needed. However, the role of human planners and schedulers is not typically considered in scheduling algorithms.
Most manufacturing organizations have one or more dedicated human planners and schedulers who have a huge impact on performance. They make decisions based on their understanding of the current situation, and their experience and expertise can be a valuable asset to the organization. However, their role is not typically considered in scheduling algorithms and techniques, which can lead to a disconnect between scheduling theory and practice.

Performance criteria

-Performance criteria for scheduling can vary depending on who is assessing the schedule. A scientist may focus on machine utilization, due date performance, and other factors that are related to constraints and goals. A manager may focus on factors such as the number of complaints, sick leave numbers, and the overall efficiency of the factory. A planner, on the other hand, may focus on survival, and ensuring that the schedule can be executed without any major disruptions or disasters.
-In theory, the performance criteria for scheduling are typically focused on the number of constraint violations, the costs of schedule execution, and the speed of the algorithm. However, in practice, there are many other factors to consider. These include the number of constraint violations, the costs of schedule execution, employees' preferences and wishes, errors in the schedule, robustness and adaptability of the schedule, understandability of the schedule, timeliness and reliability of initial release, flexibility regarding schedule adaptation, accessibility of schedulers, communication and harmonization quality, and the cost/efficiency of the scheduling process.
-When uncertainty is high, some of these factors become even more important. For example, the robustness and adaptability of the schedule, understandability of the schedule, timeliness and reliability of initial release, flexibility regarding schedule adaptation, accessibility of schedulers, communication and harmonization quality, and the cost/efficiency of the scheduling process are more important when uncertainty is high.

van Wezel, Wout, Kenneth McKay, and Anton Wäfler (2015). "Outflanking undecided, ever-changing puzzles: The role of the human behavior in scheduling." In: *The handbook of behavioral operations management.*

> The article "Outflanking undecided, ever-changing puzzles: The role of human behavior in scheduling" by van Wezel, McKay, and Wäfler, examines the role of human behavior in scheduling and how it affects the performance of scheduling systems. The authors argue that human behavior can be a significant factor in scheduling, as employees may not always follow the schedule as intended, making the scheduling process complex and unpredictable.
> The article explains that human behavior can be influenced by factors such as motivation, communication, and trust, and that these factors need to be taken into account when designing and implementing scheduling systems. The authors propose that by incorporating a better understanding of human behavior into scheduling systems, organizations can improve the performance of their scheduling systems and make them more adaptive to changing conditions.
> The article also provides an insight into the different scheduling methods that can be used, such as:
> -Rule-based scheduling -Heuristic-based scheduling -Optimization-based scheduling
> For example, a company might use scheduling system that takes into account the human behavior by involving employees in the scheduling process, and providing them with the necessary information and tools to achieve the schedule. This can lead to increased efficiency and productivity, and improved overall production performance.
> Overall, the article provides a comprehensive understanding of the role of human behavior in scheduling and its importance in the performance of scheduling systems. It also highlights the need for an adaptive approach to scheduling that takes into account the human behavior and the different scheduling methods that can be used.

De Snoo, C., Van Wezel, W., & Jorna, R. J. (2011). An empirical investigation of scheduling performance criteria. *Journal of Operations Management*, 29(3), 181-193. (only used for the assignment; not exam material)

The article "An Empirical Investigation of Scheduling Performance Criteria" by De Snoo, Van Wezel and Jorna, examines the different criteria that are used to evaluate the performance of scheduling systems in manufacturing and logistics operations. The authors conducted a study to investigate the most commonly used performance criteria in scheduling and their relative importance in different industries and settings.

The study found that the most commonly used performance criteria were due date performance, tardiness, and lateness. The authors also found that the relative importance of these criteria varied depending on the industry and the type of operation. In some cases, due date performance was considered the most important criterion, while in others, tardiness or lateness was considered more important.

The article argues that the performance criteria used to evaluate scheduling systems should be chosen based on the specific requirements of the operation and the industry. The authors suggest that organizations should consider the trade-offs between different performance criteria and the specific requirements of their operations when selecting performance criteria for their scheduling systems.

For example, a company that operates in the food industry might prioritize freshness and quality of the product over due date performance, and therefore prioritize tardiness as a performance criteria. While, a company that operates in the electronic industry might prioritize due date performance over tardiness or lateness.

Overall, the article provides insight into the different performance criteria that are used to evaluate scheduling systems and their relative importance in different industries and settings. It highlights the need for organizations to consider the specific requirements of their operations when selecting performance criteria for their scheduling systems.

Week 5 - Pull Production

Pull production

Pull production

-Pull production is a manufacturing method that operates on the principle of maintaining a small amount of inventory, or "buffer," at each workstation. This buffer is replenished by the preceding workstation, or "upstream" activity, as it is used by the subsequent workstation, or "downstream" activity. In this system, scheduling is focused on the final stage of production, and upstream activities are prompted to work by downstream activities rather than by a predetermined schedule. Department A, for example, only begins working when the buffer for Department B is nearly empty. It is important to note that Department B does not coordinate its schedule with Department A in this system.

-In pull production, the production process is triggered by customer demand, rather than by a predetermined schedule. This helps to ensure that the right products are produced at the right time, and in the right quantity, to meet customer needs. This approach is in contrast to "push" production systems, where production is based on forecasted demand, which may lead to an overproduction of goods that do not sell.

-One of the key benefits of pull production is its ability to respond quickly to changes in customer demand. By using a pull system, manufacturers can quickly adjust production levels to meet changing demand, which can help to reduce the risk of stockouts or overproduction. Additionally, pull production can help to improve production flow, reduce lead times, and increase efficiency.

?What are the benefits and drawbacks of using the pull production system in comparison to push production system? (Answer: The benefits of pull production include the reduction of inventory and lead times, as well as the ability to respond quickly to changes in customer demand. Drawbacks include the need for accurate forecasting and the potential for delays if supplier lead times are longer than expected.)

2-bin system

-The 2-bin system is a simple pull system used to manage inventory. It is based on the idea of maintaining a small buffer of items, in this case, jars of Nutella. The system works by keeping two bins of Nutella, one that is currently being used and one that is full and ready to use as a replacement. When the current jar is empty, it is replaced with a full one, and the empty jar is added to the shopping list.

-However, if the Nutella always runs out on Monday or Wednesday, the solution is to buy more jars to ensure that it never runs out. But in a Lean production system, the goal is to have as little stock as possible, and to avoid overstocking.

-To achieve this, pull production uses buffers, which are small amounts of inventory that are kept at each workstation. These buffers help to ensure that production flow is not interrupted by stockouts, while minimizing inventory levels.

-A key mechanism in pull production is the reorder point, which is calculated as the product of the demand rate, lead time, and safety stock. The demand rate is the rate at which the item is consumed, the lead time is the time it takes to receive a new shipment after placing an order, and the safety stock is a buffer that provides a cushion against variations in demand or lead time.

-When the reorder point is reached, the workstation upstream is authorized to start producing immediately. The lead time in a pull system includes the waiting time, setup time, processing time and transport time.

Reorder point

Reorder point = D*LT + SS,   D = Demand Rate; LT = Lead Time; SS = Safety Stock
In a pull system, LT is: Waiting + Setup time + Processing + Transport

Kanban

-Kanban is a pull production method that uses visual cards to signal the need for production or transport of goods. The cards, which are usually attached to bins or pallets, are used to authorize the movement of materials and products through the production process. The number of Kanban cards determines the stock levels and the risk of running out of stock.

-To determine the number of Kanban cards needed, the quantity in a container is first determined, and then the number of Kanban cards is calculated using a formula: $K = D(T)(1+x)/Q$, where K is the number of Kanban cards, D is the demand rate, x is a safety factor, Q is the amount in one container, and T is the production time for production Kanbans or the transport time for transport Kanbans.

-For example, if the demand rate is 135 units per day, and the container size is typically 10% of daily demand, which is 14 units in a container, and the production time is 0.4 day and transport time is 0.1 day, and the safety factor is 0. The number of Kanban cards needed for production is 4 and for transport is 1.

-Kanban cards are used in every stage of production, including waiting at the source until it is picked up, being transported from source to destination, waiting at the destination, production to fill the container, and moving the container to the input buffer. Kanban cards are also used in conveyance, including waiting in the mailbox, being transported, and card + bin transported.

-It is important to note that pull production is largely self-organizing, but exceptions can occur in cases of rush orders, very large orders, or defective items. To handle these exceptions, special cards such as express cards, temporary cards, or emergency cards can be inserted into the system, which will then adjust itself accordingly.

? How can the use of Kanban systems be used to improve the flow of production in a manufacturing company? (Answer: Kanban systems are a pull-based inventory control system that uses visual signals, such as cards or digital displays, to signal when a production process needs to be replenished. This can be used to optimize production flow by reducing the risk of stockouts and minimizing the need for safety stock.)

Pull production * notes

Pull production is a manufacturing method that emphasizes the use of a "pull" system to control the flow of materials and products through the production process. In order for pull production to work effectively, there are certain rules that must always be followed:

-Downstream activities can only order what is needed from upstream activities. This helps to ensure that the right products are produced at the right time, and in the right quantity, to meet customer needs.
-Only produce what is indicated on the card. This means that no additional batching should be done to prevent setup time. This would lead to high stock for one product and too long waiting time for another product.
-No production or transport should be done without a card. This helps to ensure that the production process is controlled and that materials and products are moved through the process in the right order.
-Defective items should not be sent downstream. This helps to ensure that only high-quality products are produced and that customers receive products that meet their expectations.
-Demand variations should be limited. This helps to ensure that the production process is stable and that inventory levels are controlled.
-Start with too many cards, but slowly reduce them. This helps to ensure that the production process is stable and that inventory levels are controlled.
Additionally, it's important to note that in many practical cases, Kanban cards are used for communication only, and that many tools in the Lean Toolbox are needed to get flow using pull production. This includes preventive maintenance on predictable times, prevent defects, (Andons, Pokayoke, etc.) and a facility layout that facilitates transport.
It's also important to note that pull production is not stockless production, as each workstation has some buffers. And although there is no centralized detailed schedule, a final assembly schedule is still needed, and this final schedule needs to have stable demand per product type.

Sugimori, Y., Kusunoki, K., Cho, F., & Uchikawa, S. (1977). Toyota production system and kanban system materialization of just-in-time and respect-for-human system. *International Journal of Production Research*, 15(6), 553-564. doi:10.1080/00207547708943149.

> The article "Toyota Production System and Kanban System: Materialization of Just-in-Time and Respect-for-Human System" by Sugimori, Kusunoki, Cho, and Uchikawa, describes the Toyota Production System (TPS) and Kanban system, and how they are used to implement the principles of just-in-time (JIT) and respect-for-human system in manufacturing operations.
> The TPS is a manufacturing system that emphasizes efficiency, quality, and flexibility and is known for its use of lean manufacturing techniques. The Kanban system is a signaling system that is used to manage the flow of materials and work-in-progress in a production process. It is used to implement the JIT principle, which aims to produce only what is needed, when it is needed, and in the quantity needed.
> The article explains that the TPS and Kanban system are closely related and that they are used together in order to achieve the goals of JIT and respect-for-human system. The JIT principle aims to reduce waste and improve efficiency by producing only what is needed, when it is needed, and in the quantity needed. The respect-for-human system aims to involve and empower employees in the production process and to create a safe and comfortable work environment.
> For example, a company might use the TPS and Kanban system to improve the production of a specific product line by implementing the JIT principle and involving employees in the production process. This can lead to reduced material handling and setup time, increased efficiency and flexibility, and improved production performance.
> Overall, the article provides a comprehensive understanding of the TPS and Kanban system, and how they are used to implement the principles of JIT and respect-for-human system in manufacturing operations. It highlights the close relationship between the TPS and Kanban system and the importance of involving employees in the production process to achieve the goals of JIT and respect-for-human system. The article also emphasizes the importance of these systems in achieving increased efficiency, quality and flexibility in production. The TPS and Kanban system are widely adopted in manufacturing industries around the world as they have been proven as effective tools to improve production performance.

Week 6 - Smart Industry
Smart Industry

Industry 4.0
Industry 4.0 is a term used to refer to the fourth industrial revolution. It encompasses a variety of technologies such as robotics, Internet of Things, machine learning, 3D printing, Big Data, and more. These technologies are collectively argued to be the next major evolution in industrial production. They are considered an evolution of existing trends in mechanical, chemical, electrical, and electronic engineering. One of the key aspects of Industry 4.0 is the use of advanced algorithms, which allow for the creation of "smart" machines and products that can control the manufacturing process themselves. This level of automation and self-regulation is thought to bring significant improvements in efficiency, quality, and overall performance in industrial production.

Automated factories
Automated factories have been a topic of interest for decades, with predictions of their widespread use in manufacturing. The concept of "lights out" production refers to the idea of a factory that can run without human intervention. This type of automation is intended to free human workers from dirty, dull, or dangerous jobs, improve product quality by reducing variability, and cut manufacturing costs by replacing increasingly expensive human labor with ever-cheaper machines. The goal is to achieve 24/7 production. The term "lights out" was coined in the 1980s by the CEO of General Motors, the largest car manufacturer in the USA. While there have been some successful implementations of fully automated factories, most factories still require some level of human involvement.

Physical internet
The Physical Internet is a new logistics paradigm which aims to improve the efficiency of the logistics sector. The Physical Internet has nothing to do with the digital internet. The current logistics system is very inefficient, with a large number of trucks on the road that are either completely empty or only half full. This leads to high costs, emissions, traffic jams, and safety issues. The Physical Internet aims to address these issues by having the cargo itself determine transportation schedules, instead of companies or schedulers.
For example, in the simplest scenario, transportation company B picks up an order from company A and the overall distance driven is less. In a more complex scenario, companies like DHL, UPS, and PostNL exchange packages at the city center, so they can each handle a part of the city. If this principle were applied to all orders of all transportation companies, it would result in a significantly more efficient logistics system. All cargo, vehicles, warehouses, and customers would be connected in real-time for information exchange, cargo, warehouses, and vehicles would continuously coordinate and schedule. An American simulation study shows that if 25% of the American supply chains would use the Physical Internet, costs could decrease by $100 billion and CO_2 emissions of road transport could be reduced by 33%.
- It is designed to increase the efficiency of transportation and logistics by connecting all the different actors in the supply chain, including cargo, warehouses, vehicles, and customers in real-time, through the use of digital technologies such as the Internet of Things (IoT) and big data.
- the Physical Internet is seen as a key enabler for Industry 4.0, as it can enable more efficient and flexible logistics processes, as well as open up new business models and revenue streams. The physical internet is considered to be a holistic approach to logistics, where all the actors in the supply chain collaborate and share information to optimize the flow of goods and services.
- They also mention that the Physical Internet concept is not only about transporting physical goods, but also about providing services such as repair, maintenance, and refurbishment. The physical internet can also support the integration of different modes of transportation, such as road, rail, sea, and air, and enable the use of smart containers and other IoT-enabled logistics equipment.

Condition based maintenance

-Maintenance is an important sector in the Netherlands, with approximately 300,000 people working in the field, representing 4% of the employed population. The size of the sector in financial terms is estimated to be €35 billion. Many companies active in the maintenance sector expect growth in the coming years. The maintenance sector faces the challenge of balancing the cost of maintenance with the cost of breakdowns caused by insufficient maintenance.
-One approach to addressing this challenge is the use of Condition Based Maintenance (CBM), which is a form of preventive maintenance that is based on condition monitoring. The goal of CBM is to perform maintenance just before a failure occurs, known as just-in-time maintenance. This approach can help to reduce the cost of maintenance and also the cost of breakdowns caused by too little maintenance.
-However, for this approach to be effective, it is necessary to have conditions that are related to the moment of failure, such as vibrations, temperature, and power consumption, and it must be technically possible and economically feasible to measure these conditions. Additionally, one of the main challenges is collecting and processing real-world data, this can be done through various sensors that are now available in the market.
-Another challenge is that it may be necessary to experience failures in order to build a model that can determine the optimal moment for maintenance. Some industries such as aerospace, automotive, and chemical have implemented condition-based maintenance with success, as long as the conditions that are related to the moment of failure are identified, and it is technically possible and economically feasible to measure them. Also, it is important to have the right tools and software to process the data and make decisions based on it.

Robotics

Robotics is an important aspect of Industry 4.0 and can be used in situations where full automation is not feasible. Robotic manipulators that mimic human behavior can be used in manufacturing and other industries. Robots can be in the form of exoskeletons, where the human and the robot cooperate, or the robot can completely take over the task. Robotics technology can be compared to autonomous vehicles and artificial companions for lonely people.
-However, there are several issues that need to be addressed in order for robots to be widely adopted. One of the main challenges is computer vision, which is the ability of the robot to perceive and understand its environment. Another challenge is haptics, which is the sense of touch, and trust and algorithm aversion.
-Despite these challenges, advancements in robotics are happening at a fast pace. Researchers and companies are working on developing robots that can perceive and understand their environment better, as -well as developing new haptic sensors and improving the algorithms that control the robots. Additionally, there are ongoing efforts to improve the human-robot interaction to make them more user-friendly, and to increase the trust of the human operators in the robots.

?How can Industry 4.0 technologies such as robotics and IoT be used to improve the flow of production in a manufacturing company? (Answer: Industry 4.0 technologies such as robotics and IoT can be used to automate repetitive tasks, increase the flexibility and responsiveness of production processes, and improve the flow of information throughout the supply chain. Robotics can be used to improve the speed and precision of production processes, while IoT can be used to enable real-time monitoring and control of production processes and to optimize the use of resources.)

Artificial Intelligence

Artificial Intelligence (AI) is a virtual artificial agent that can, to a certain extent, act autonomously. AI can be achieved through rule-based systems, which use deductive reasoning and are explicitly programmed by humans, or through machine learning, which uses inductive reasoning and can be fully autonomous if goals are specified beforehand. Neural networks and genetic algorithms are examples of machine learning techniques.
-In science, Artificial Intelligence is a separate field from Operations Research (OR), but in industry, AI often includes OR. Artificial Intelligence is used in various industries such as manufacturing, healthcare, transportation, and more to improve efficiency, reduce costs, and increase productivity. It is used in tasks such as predictive maintenance, inventory management, and logistics planning. AI is considered as a key enabler for Industry 4.0, it can enable more efficient and flexible processes, as well as open up new business models and revenue streams. Additionally, AI can improve decision-making, optimize production processes, and enable more personalized products and services. However, the implementation of AI is challenging and requires significant investments in digital technologies, as well as changes in organizational structures and business models.

Additive Manufacturing

Additive Manufacturing, also known as 3D printing, is a method of creating parts by building them layer by layer through a 3D printer. It is different from traditional methods such as manual labor, CNC machining, and liquid injection molding. One of the main advantages of additive manufacturing is its flexibility. It can be used to create parts in a variety of materials such as metal and plastics, and it can be used to create parts of different sizes.
-Additive manufacturing also has an impact on product design. It allows for the creation of more complex shapes, which results in higher product flexibility. Additionally, it is cheaper to switch to a new design when using additive manufacturing.
-Additive manufacturing also affects the supply chain. It reduces the need for spare parts, warehouses and transportation. Companies can also save costs by printing and assembling parts on premise.
-However, Additive Manufacturing is still facing some challenges such as printing speed, material cost, and strength of the parts, but these can be overcome by increasing the number of machines, developing new materials that are cheaper and stronger, and improving the printing process. Additionally, according to the articles, Additive Manufacturing is considered as a key enabler for Industry 4.0, it can enable more efficient and flexible processes, as well as open up new business models and revenue streams. It can also reduce the lead time, increase the product customization and enable the production of highly complex parts.

Internet of things

Internet of Things (IoT) is a network of connected devices that are able to collect and share data. One of the key technologies for IoT is 5G, which is the fifth generation 3GPP standard. 5G networks are very fast and low latency, which makes them suitable for applications such as video and augmented reality. However, 5G networks have a high frequency, which means they have a short range and require many cell towers to cover a wide area. 5G is not yet widely available.
-Another protocol used in IoT is NB-IoT (Narrow Band Internet of Things), which is a very slow and high latency network. It is suitable for low-bandwidth applications such as sending temperature readings every minute. NB-IoT networks have a low frequency, which means they have a long range and are able to penetrate underground and into buildings. They are also very energy efficient, with devices able to run for multiple years on a single battery. NB-IoT networks are already in use and are known for their low cost of hardware and subscriptions.
-IoT is widely used in industries like logistics and maintenance, as it enables companies to collect and analyze data from connected devices to optimize operations. For example, in logistics, IoT devices can be placed on containers to monitor their location and condition in real-time. In maintenance, IoT devices can be placed on machines to collect sensor data, which can be used to predict when maintenance is needed and to optimize maintenance schedules.
-IoT is also considered as an enabler for Industry 4.0, it can enable new business models and revenue streams, it can also enable new services and improve the decision-making. However, implementing IoT in a company requires significant investments in digital technologies, as well as changes in organizational structures and business models.

Blockchain

Blockchain technology is a way of storing data in a decentralized and distributed way, where all users together are the owners of the data. It allows for secure and transparent transactions and is particularly useful for companies that need to share data and trust one another, as it allows for a shared database that is owned and controlled by all users, rather than a single entity. This is useful in the context of IoT, as it allows for the secure storage and sharing of large amounts of data generated by connected devices. Smart contracts, which are small computer programs embedded in the blockchain, can automatically trigger actions, such as paying a bill when goods are received. In the context of Industry 4.0, blockchain technology can be used to enable new business models and revenue streams, for example, it can be used to share forecasts and manufacturing schedules, as well as customer orders for logistics, which can enable the exchange of orders. Additionally, it can be used to store track and trace information of goods and vehicles as part of the Physical Internet, and to anonymously store machine failure data to build models for condition-based maintenance.

Digital Twin

Digital twin refers to a digital copy of a physical entity such as a machine, product, or truck. This technology allows for simulations, what-if analyses, and other tests to be run on the digital copy in order to better understand the physical entity. It is used in product design to model all physical aspects of a product and test the effects of interactions. In the context of the Physical Internet, a digital twin can be used as the primary source of intelligence for cargo that only has a 5G chip. This technology is also useful for condition-based maintenance, where it can simulate the effect of future loads on a machine and help predict when maintenance is needed. Additionally, it can be used to store all intelligence of the cargo which is stored in the cloud.

Olsen, T. L., & Tomlin, B. (2019). Industry 4.0: Opportunities and Challenges for Operations Management. *Manufacturing & Service Operations Management*.

The article "Industry 4.0: Opportunities and Challenges for Operations Management" by Olsen and Tomlin, examines the concept of Industry 4.0 and its impact on operations management. Industry 4.0 is the fourth industrial revolution, characterized by the integration of advanced technologies such as the Internet of Things, big data analytics, and artificial intelligence in manufacturing and other industries.

The authors argue that Industry 4.0 presents both opportunities and challenges for operations management. On one hand, Industry 4.0 technologies can improve efficiency, flexibility, and performance in operations by providing real-time data and automation capabilities. On the other hand, they can also pose significant challenges, such as the need for new skills, cybersecurity risks, and the potential for job displacement.

The article also provides examples of how Industry 4.0 technologies can be applied in operations management, such as:

-Predictive maintenance, which uses data from sensors to predict when equipment will fail, allowing for proactive maintenance.

-Smart logistics, which uses real-time data to optimize the movement of goods and improve supply chain efficiency.

-Autonomous robots, which can perform tasks such as packaging, assembly, and transportation.

For example, a company might use Industry 4.0 technologies to improve the production of a specific product line by implementing predictive maintenance and smart logistics, which can lead to improved equipment uptime, reduced maintenance costs, and improved supply chain efficiency.

Overall, the article provides a comprehensive understanding of the concept of Industry 4.0 and its impact on operations management. It highlights the opportunities that Industry 4.0 technologies can provide for operations, such as improved efficiency, flexibility, and performance, as well as the challenges that organizations may face, such as the need for new skills, cybersecurity risks, and the potential for job displacement. The article also provides examples of how Industry 4.0 technologies can be applied in operations management, such as predictive maintenance, smart logistics and autonomous robots. It emphasizes the importance of organizations to be aware of the potential impacts of Industry 4.0 and to develop strategies to take advantage of its opportunities while addressing its challenges.

Lasi, H., Dr., Fettke, P., Privatdozent Dr., Kemper, H., Prof. Dr., Feld, T., Dipl.-Inf., & Hoffmann, M., Dipl.-Hdl. (2014). Industry 4.0. *Business & Information Systems Engineering : The International Journal of Wirtschaftsinformatik*, 6(4), 239-242.

The article "Industry 4.0" by Lasi, Fettke, Kemper, Feld, and Hoffmann, provides an overview of the concept of Industry 4.0, which is the fourth industrial revolution characterized by the integration of advanced technologies such as the Internet of Things, big data analytics, and artificial intelligence in manufacturing and other industries. The authors argue that Industry 4.0 represents a fundamental change in the way manufacturing and other industries operate, and it has the potential to bring about significant improvements in efficiency, productivity, and flexibility.

The article describes how Industry 4.0 technologies, such as cyber-physical systems and the Internet of Things, can be used to improve the performance of manufacturing and other industries. For example, cyber-physical systems can be used to monitor and control the performance of machines and equipment in real-time, while the Internet of Things can be used to collect and analyse large amounts of data from devices and machines, allowing for more effective decision-making.

The authors also discuss some of the challenges that organizations may face when implementing Industry 4.0, such as the need for new skills and the need to address cybersecurity risks. They also highlight the importance of collaboration between different industries and organizations to fully realize the potential of Industry 4.0.

Overall, the article provides an overview of the concept of Industry 4.0, its potential benefits and challenges, and how it can be applied in manufacturing and other industries. It emphasizes the importance of collaboration and the need to address cybersecurity risks in order to fully realize the potential benefits of Industry 4.0.

Week 7 - Behavioural Operations Management

Behavioural Operations Management Part 1- Introduction

Beops: Behavioral Operations

Behavioral Operations Management (Beops) is a way of thinking that focuses on finding, explaining, and solving behavioral anomalies in Operations Management (OM) models through scientific empirical research methods, primarily from psychology and sociology. It is not a separate theory from OM, but rather a way to understand and improve upon existing OM theories by incorporating insights from behavioral research. This approach can help to overcome challenges such as "algorithm aversion," where people are resistant to using automated systems and prefer to have some degree of control over them. Beops can also help to improve the design and implementation of organizational systems by taking into account the ways in which people actually behave and interact within them.

?How can behavioral operations management be used to improve the performance of scheduling algorithms? (Answer: Behavioral operations management uses insights from behavioral economics to understand and address the cognitive biases that can impact the effectiveness of scheduling algorithms. This can include addressing issues such as algorithm aversion, the Anchoring bias, and the framing bias.)

Behavioral economics

The starting point for Beops is not organizational behavior, but Behavioral Economics, which challenges the rationality assumptions of traditional economic models by highlighting the limitations of human rationality and the irrationality of human decision-making. This is due to the influence of economists on Operations Research, which dominates Operations Management. The work of Herbert Simon in the 1940s and 1950s and Prospect Theory by Kahneman and Tversky in 1979 are considered hallmarks of Behavioral Economics.

Bounded Rationality

One of the key concepts in behavioral economics is bounded rationality, which was first proposed by Herbert Simon. Bounded rationality suggests that people's decision-making is limited by the information available to them, their cognitive abilities, and the time they have to make a decision. This means that people often have to "satisfice," or choose the first option that meets their needs, rather than optimize and find the best option. For example, human working memory is limited to around 7 items, so when faced with a large number of options, people might not be able to compare them all, and instead will have to rely on simple heuristics (mental shortcuts) to make their decision.

Prospect theory

Prospect theory is a behavioral economic theory that describes how people make decisions when faced with uncertain outcomes. It challenges the traditional economic theory of expected utility, which states that individuals make decisions based on rational calculations of expected outcomes.
-Prospect theory introduces two key concepts: risk-aversion for gains and risk-seeking for losses. Risk-aversion for gains means that individuals prefer to avoid taking risks when the potential outcome is a gain, such as preferring to receive €1000 with certainty over a 50% chance of receiving €2500. Risk-seeking for losses, on the other hand, means that individuals are willing to take more risks when the potential outcome is a loss, such as preferring a 50% chance of losing €2500 over a certain loss of €1000.
-Prospect theory also suggests that people tend to feel losses more strongly than gains, a concept known as loss aversion. This loss aversion is steeper for losses than for gains, meaning that people are more likely to take risks to avoid a loss than to try to gain something.

Other Human traits

Humans tend to deviate from what is considered "normal" in decision-making. Some examples of this include being overly focused on immediate rewards, being overconfident in their abilities, being easily influenced by anchors or reference points, and being more likely to conform to the opinions of others. Additionally, there can be differences between individuals in terms of how they make decisions. For example, some people may be more inclined to take risks while others may be more risk-averse. It's also important to note that these traits can be influenced by different factors and may not be stable over time.

Some common human biases found in literature on behavioral operations include:

-Immediacy bias, also known as hyperbolic discounting, is the tendency for individuals to place greater value on rewards that are closer in time, even if those rewards are smaller than ones that are further in the future. For example, a person may choose to receive $50 now rather than $100 in a month's time.

-Overconfidence bias refers to the tendency for individuals to overestimate their own abilities and the accuracy of their predictions. For example, a person may overestimate their chances of success in a business venture and make overly optimistic predictions about its future performance.

-Anchoring bias is the tendency for individuals to rely too heavily on the first piece of information encountered when making decisions, even if that information is irrelevant or unreliable. For example, a person may make a purchase decision based on the original price of a product, even if the price is later discounted significantly.

-Conformity bias, also known as the Asch conformity effect, is the tendency for individuals to conform to the opinions of a group, even if they believe the group is wrong. For example, a person may change their opinion on a subject after hearing the opinions of others, even if they initially held a different belief.

-Search bias, is the tendency for individuals to look for information that confirms their preconceptions and hypotheses, even if the information is irrelevant or unreliable. For example, a person may only look for information that supports their belief in a certain product, even if there is information that suggests the product is not good.

-Confirmation bias: the tendency to seek out and interpret information that confirms one's existing beliefs or hypotheses, while ignoring or dismissing information that contradicts them. For example, a person who believes that climate change is not real might ignore scientific evidence to the contrary.

-Anchoring bias: the tendency to rely too heavily on the first piece of information encountered when making decisions, even if that information is irrelevant. For example, a person might be influenced by the original price of a product when deciding whether to buy it, even if it is on sale for a lower price.

-Loss aversion: the tendency to strongly prefer avoiding losses to acquiring equivalent gains. For example, a person might be unwilling to take a risk that could lead to a potential gain, because they are more focused on avoiding a potential loss.

-Representativeness bias: the tendency to judge the probability of an event based on how similar it is to a prototype, rather than on how likely it is to occur. For example, a person might be more likely to believe that a person who is described as a "typical engineer" is more likely to be a man than a woman, even though more women are becoming engineers.

-Self-serving bias: the tendency to attribute one's own successes to internal factors, while attributing failures to external factors. For example, a person might attribute their own success to their hard work and talent, while attributing other people's failures to bad luck or lack of effort.

-Availability heuristic: the tendency to overestimate the likelihood of events based on their availability in memory. For example, a person might believe that plane crashes are more common than car accidents because they hear about plane crashes more often in the news.

Problematic principles in Operations Management

Operations Management models, which are based on computers and mathematics, often lead to formalization, resulting in several problematic principles. These principles include the assumption that people are not a major factor in the operations, they are deterministic and predictable, workers are independent, stationary and emotionless and work is perfectly observable. However, models in psychology and behavioral economics, such as bounded rationality and prospect theory, have shown that people are not always rational and their decisions can be influenced by emotions, biases and cognitive limitations. This can be problematic in Operations Management, as models that do not consider these factors can lead to unrealistic assumptions when it comes to human decision-making and task design. Therefore, it is important for Operations Management models to take into account the limitations and unpredictability of human behavior in order to support and determine the tasks of human operators effectively.

Behavioral Operations Management, Part 2- Supply Chain Management

Behavioral factors in SCM

Behavioral factors in Supply Chain Management (SCM) refers to how human behavior can impact the performance of supply chain activities, such as inventory management and collaboration between companies. Research in SCM often focuses on how different practices, such as vendor managed inventory and collaborative product development, can improve supply chain performance and ultimately increase overall organizational performance. Behavioral tools, such as frequent communication and cross-functional teams, are also used to improve human collaboration in supply chains. However, research in this area is limited and often relies on surveys to understand behavioral factors, which can be affected by factors such as cultural distances and the ability to solve problems quickly. Four examples of human-based research in SCM include the study of biases in ordering, biases and framing in supplier selection, and the impact of collective psychological ownership on buyer-supplier relationships.

Dynamics of ordering

The dynamics of ordering refers to the way that orders are placed and fulfilled within a supply chain. One key issue that can arise in this process is the bullwhip effect, which refers to the phenomenon where small fluctuations in demand at the customer level can lead to larger fluctuations in demand as you move upstream in the supply chain. This can be caused by both operational factors, such as lead times and production capacity, as well as behavioral factors, such as decision makers' tendency to underweight the supply line, or difficulty accounting for time delays. The bullwhip effect can lead to inefficiencies, such as excess inventory and stockouts, and can be exacerbated by a lack of information transparency. For example, the bullwhip effect can occur when sales department start offering attractive deals to move excess inventory, which can lead to manufacturing ramping up production, causing even more excess inventory.

Pull-to-centre in ordering

Pull-to-centre is a bias in which decision-makers tend to order closer to the average demand rather than considering the full range of possible demand outcomes.
-The "pull-to-centre" phenomenon is a bias that can occur in the newsvendor problem, which is a model used to determine the optimal order quantity for a vendor when demand for a product is uncertain. The basic idea is that the vendor wants to find the balance between ordering too little and missing out on potential profits, and ordering too much and having unsold items. Optimizing this decision is relatively easy, but in practice, people often fall victim to a bias that causes them to order around the average or expected demand, rather than the optimal amount.
-In 2000, Schweitzer and Cachon conducted an experiment in which participants were given a known demand distribution (uniform from 1 to 300) and asked to make 15 purchasing decisions with different margin and salvage value. The experiment found that participants consistently ordered around the average demand, rather than the optimal amount. This phenomenon has been replicated many times with different groups of people, including students, managers, experts, and novices.
-The experiment of Schweitzer & Cachon showed that people tend to order around the average or expected demand, rather than the optimal amount. This phenomenon is called the "pull-to-centre" effect. The experiment also found that this effect is not mitigated by profit-margin and cannot be explained by any known biases or irrational tendencies. The literature suggests that the pull-to-centre phenomenon may be caused by a number of factors, including anchoring and insufficient adjustment, demand-chasing and recency bias, waste aversion, stockout aversion, and the gambler's fallacy.

Anchoring bias

Anchoring bias is a cognitive bias that occurs when a decision maker relies too heavily on an initial piece of information (the "anchor") when making subsequent judgments. In the context of supplier selection, the anchoring bias can manifest when purchasing professionals are exposed to an anchor (such as an initial price quote from a supplier) and subsequently make decisions based on that anchor, rather than considering other relevant factors. The study mentioned in the bullet points aims to investigate the anchoring bias in supplier selection by surveying purchasing professionals and testing hypotheses about how the anchor and the purchasing situation influence the strength of the anchoring bias. The study suggests that the relationship between the anchor and the anchoring bias in supplier selection is weaker for purchasing professionals in a new task situation and stronger for those in a modified rebuy situation. Additionally, the study suggests that purchasing professionals are exposed to an anchor exhibit an anchoring bias.

Framing Bias

The Framing Bias is a cognitive bias in which people respond to the same information differently based on how it is presented or framed. This can be seen in the context of supplier selection, where professionals presented with positive attributes of a supplier will provide higher evaluation scores than those presented with negative attributes. This phenomenon is moderated by the degree of uncertainty in the supplier selection process, with a stronger effect observed in situations with high uncertainty. Studies have been conducted using surveys and vignette experiments to gain insight into the framing bias and its effects on supplier selection decisions.

Psychological Ownership

Psychological ownership refers to the tendency for individuals to consider something "theirs" even if it is not legally theirs. This concept can apply to things in personal life, such as family or friends, as well as in organizations, such as teams or projects. In the context of supply chain management, psychological ownership can have both positive and negative effects on behavior and performance within the buyer-supplier relationship. A survey was conducted to test the hypotheses that psychological ownership is positively related to supply chain performance, that the psychological ownership felt by the buyer is positively related to that felt by the supplier, and that the level of interdependence between buyer and supplier moderates the relationship between the two. The study found that psychological ownership does make sense in the context of supply chain integration and that there is a relationship between psychological ownership and supply chain performance, but causality is not clear and may be iterative.

Behavioral Operations Management, Part 3- Scheduling theory versus practice

Scheduling in practice

Scheduling in practice can be difficult due to a variety of factors. One such factor is numerical complexity, as the number of sequences required in a flow shop or job shop can be very high. Another factor is timing disparity, where a decision is needed but the necessary information is not yet available. Additionally, information uncertainty such as weather can also make scheduling difficult. The interpretation of information can also be a source of difficulty, as it can be unclear what certain preferences or statements mean. Lastly, information inaccessibility can make it difficult to predict customer orders. Historically, scheduling research has primarily focused on one aspect of these challenges, but recent empirical research has shown that there is a more nuanced and complex view of the scheduling task in organizations.

Performance Criteria, Theory vs Practice

Performance criteria for scheduling can vary depending on the context of the organization or the specific scheduling task. In theory, performance criteria may include the number of constraint violations, the costs of schedule execution, and the speed of the scheduling algorithm. However, in practice, performance criteria may also include factors such as employees' preferences and wishes, errors in the schedule, robustness and adaptability of the schedule, understandability of the schedule, timeliness and reliability of the initial release, flexibility regarding schedule adaptation, accessibility of schedulers, communication and harmonization quality, and the cost/efficiency of the scheduling process. In situations where uncertainty is high, the last five criteria may be considered more important. The difference between theory and practice in scheduling is that in theory a schedule is created, released to the factory, and executed as scheduled, but in practice the schedulers work together to clarify, negotiate, and jointly solve problems. They rarely schedule from scratch, but mostly reschedule. Schedulers also use informal power such as access to information, access to networks, right to organize, expert power, personal power to make decisions and can have multiple schedules.

Algorithm Aversion

Algorithm Aversion is an important concept to understand when discussing the use of algorithms in decision-making. It refers to the phenomenon where humans tend to not trust or prefer algorithms, even when they perform better than humans. Studies have shown that this bias can manifest in various ways, such as preferring the results of a human forecaster over a statistical model, despite the model performing better.
Additionally, allowing users to interact and make changes to the algorithm can greatly reduce the aversion and even increase the performance. The level of interactivity allowed for users may also play a role in how much the algorithm aversion is reduced. Furthermore, the user's ability to understand the algorithm, the level of transparency, and the ability to understand the decision-making process can also play a role in reducing algorithm aversion.
It's important to note that human biases can greatly affect the adoption of algorithms in decision-making, and it's crucial to be aware of this when implementing algorithms in various fields. Understanding the concept of Algorithm Aversion and how it can affect the use of algorithms is crucial for anyone working in fields that involve decision-making with the help of algorithms.

Usability of scheduling algorithms

Usability of scheduling algorithms is a critical aspect to consider when implementing them in practice. The disuse of algorithms is often attributed to the models not resembling practice enough. However, studies have shown that this might not be the only reason for this phenomenon. A lack of attention to usability can also play a role in the disuse of algorithms. Factors that are considered important in usability of scheduling algorithms are things like giving users a bit of control and decision support frameworks such as the Task Acceptance Model, Task Technology Fit, and Cognitive Engineering. These frameworks can help in understanding how users interact with the algorithm and what factors can affect the usability of the algorithm. Additionally, it's been shown that allowing users to interact and make changes to the algorithm can greatly reduce the aversion and even increase the performance. It's important to note that the usability of scheduling algorithms is not only about the algorithm itself but also about the way it's being presented to the user and how easy it is for the user to interact with it. Understanding the concept of Usability of scheduling algorithms is crucial for anyone working in fields that involve decision-making with the help of algorithms.

Cognitive Ergonomics

Cognitive Ergonomics is an important field that studies how humans make decisions and how technology can support them. The decision to use decision support systems is influenced by several factors, including usefulness and ease of use. Usefulness factors include the relevance of the decision support system to the job, the quality of the output and the ability to demonstrate the results. Ease of use factors include the perceived enjoyment of using the system, the completeness of the system, the time to learn the system, and the error rate of the system. Performance and speed of the system are also factors to consider. These factors lead to initial use of the system. Continued use of the system is then influenced by factors such as trust in the system, complacency, loss of expertise, and loss of situation awareness.

Additionally, research has shown that giving users a bit of control can help overcome the bias of not using decision support systems, even if they are not perfect. Furthermore, understanding how users interact with the decision support system, what factors can affect the usability of the system, and how the system can support the users decision-making process are crucial aspects to consider when designing and implementing decision support systems.

Scheduling algorithms Problems

-Scheduling algorithms have been widely used in various fields, however, there are several problems that arise when using them in practice. These problems include a focus on puzzle solving rather than actual scheduling tasks, a lack of providing integrated information and feedback, little attention to the negative effects that the introduction of an algorithm might have on the task performance, and a static task division between human and computer. These issues can be addressed by taking into consideration the usability theories, which are based on empirical research.

-Examples of actual scheduling tasks that are not supported by the algorithm include negotiation and scenario analyses. The algorithms only provide the outcome, such as a Gantt Chart, constraint violations, and goal performance, but they do not provide conceptual reasoning for the decisions. Negative effects that the introduction of an algorithm might have on the task performance include complacency, loss of expertise, and loss of adaptability.

-An alternative approach is to focus on determining the appropriate level of automation, which can vary depending on situational circumstances such as workload of the scheduler and percentage of machine utilization, leading to a dynamic allocation of tasks between the human and computer. Increasing use of scheduling algorithms requires changes to the inner workings of the algorithms themselves, and behavior should not be considered as an add-on for scheduling algorithms.

Dietvorst, B. J., Simmons, J. P., & Massey, C. (2016). Overcoming algorithm aversion: People will use imperfect algorithms if they can (even slightly) modify them. *Management Science*, 64(3), 1155-1170.

The article "Overcoming Algorithm Aversion: People Will Use Imperfect Algorithms If They Can (Even Slightly) Modify Them" by Dietvorst, Simmons, and Massey, examines the concept of "algorithm aversion", which refers to people's reluctance to use algorithms even when they are shown to be more accurate than humans. The authors conducted a series of studies to investigate how people's willingness to use algorithms can be increased by allowing them to make small modifications to the algorithm's output.

The study found that people are more likely to use algorithms when they are given the opportunity to make small modifications to the algorithm's output. This is because allowing people to make small modifications to the algorithm's output increases their sense of control over the algorithm and increases their trust in the algorithm's output. The study also found that allowing people to make small modifications to the algorithm's output can increase the accuracy of the algorithm's output.

The article argues that organizations can increase the acceptance and use of algorithms by allowing people to make small modifications to the algorithm's output. The authors suggest that organizations can do this by providing people with simple and transparent interfaces that allow them to make small modifications to the algorithm's output, such as adjusting the algorithm's parameters or providing additional data to the algorithm.

For example, a company might use an algorithm to predict customer demand but they may not trust the predictions, by allowing the team to slightly adjust the algorithm's parameters or providing additional data, they can be more confident in the predictions, and make better decisions.

Overall, the article provides insight into the concept of algorithm aversion, and how it can be overcome by allowing people to make small modifications to the algorithm's output. It highlights the importance of increasing people's sense of control over the algorithm and their trust in its output in order to increase their willingness to use the algorithm. The study also found that allowing people to make small modifications to the algorithm's output can increase the accuracy of the algorithm's output. The authors suggest that organizations can increase the acceptance and use of algorithms by providing simple and transparent interfaces that allow people to make small modifications to the algorithm's output, such as adjusting the algorithm's parameters or providing additional data to the algorithm. The article emphasizes the importance of considering the human aspect in the implementation of algorithms and how it can affect their acceptance and success.

Gino, F., & Pisano, G. (2008). Toward a theory of behavioral operations. *Manufacturing & Service Operations Management*, 10(4), 676-691. (only section 3 and table 1 are exam material).

The article "Toward a theory of behavioral operations" by Gino and Pisano, presents a framework for understanding how behavioral factors can impact the performance of operations. The article focuses on section 3 and table 1, which discusses the key factors that influence the behavior of individuals and organizations in operations.

The authors identify three main factors that influence behavior in operations: cognitive factors, social factors, and emotional factors. Cognitive factors include things like decision-making processes, information processing, and problem-solving. Social factors include things like communication, teamwork, and power dynamics. Emotional factors include things like motivation, stress, and mood.

Table 1 presents a summary of the key factors that influence behavior in operations and how they can be used to improve performance. The table provides examples of how the different factors can be used to improve performance, such as by improving decision-making processes, promoting effective communication, and increasing motivation.

For example, a company might use the framework to improve the performance of a specific product line by improving decision-making processes and promoting effective communication among team members. This can lead to increased efficiency, reduced errors and improved production performance.

Overall, the article provides a framework for understanding how behavioral factors can impact the performance of operations and how they can be used to improve performance. It highlights the importance of considering the cognitive, social, and emotional factors that influence behavior in operations, and how they can be used to improve performance.

Example Exam

Question 1: Algorithm Aversion; Give, from the perspectives of the articles of Dietvorst et al. (2016) and Falkenauer (2015), at least one improvement in the longest processing time line balancing algorithm as demonstrated in the lecture in week 3. Make sure to make it specific; don't just say that the algorithm should consider x or y. Rather, show how it can consider x and y.

One potential improvement to the longest processing time line balancing algorithm, as suggested by the articles of Dietvorst et al. (2016) and Falkenauer (2005), would be to incorporate a user-adjustable parameter that allows for slight modifications to the algorithm. This could involve adding a "flexibility factor" that allows users to adjust the weight given to the longest processing time, in order to better balance the needs of the specific production line in question. For example, if a production line is particularly sensitive to downtime, the user could adjust the flexibility factor to place a higher emphasis on minimizing the longest processing time, even if it results in slightly longer overall processing times. Conversely, if the production line is less sensitive to downtime, the user could adjust the flexibility factor to place a greater emphasis on overall processing time, at the expense of slightly longer longest processing time.

Question 2: Smart Industry; Describe for 2 of the Industry 4.0 technologies described by Olsen & Tomlin how they influence the flow of production in manufacturing

Automated factories: Automated factories, which use advanced technologies such as robotics and artificial intelligence, can greatly influence the flow of production in manufacturing by increasing efficiency and reducing human error. Automated systems can handle repetitive tasks quickly and accurately, and can work around the clock without the need for breaks. This can result in higher production rates, lower costs, and improved product quality. Additionally, automated systems can be easily programmed and reprogrammed to adapt to changes in production demand, which can help to optimize the flow of production and minimize delays.

Internet of things: The Internet of Things (IoT) can also greatly influence the flow of production in manufacturing by providing real-time data on the performance and status of production systems. This data can be used to optimize the flow of production by identifying bottlenecks, reducing downtime, and improving overall efficiency. For example, using sensors connected to the IoT, it can detect in advance when a machine is about to fail and schedule maintenance, this is known as condition based maintenance. Additionally, IoT data can be used to monitor and control inventory levels, which can help to ensure that production is not delayed due to a lack of raw materials or finished goods.

Question 3: Scheduling;The chapter on planning (Van Wezel et al.) refers to the classification of scheduling situations of Wiers (smooth shop, social shop, stress shop, sociotechnical shop). Describe for each of those, where they would typically be placed on the product/process matrix as described by Safizadeh et al.

<u>Smooth shop</u>: A smooth shop is a scheduling situation characterized by low product variety and low process variety. This type of scheduling situation would typically be placed in the lower left corner of the product/process matrix, as described by Safizadeh et al. A smooth shop is characterized by a high degree of repetition and stability, with little variation in the products or processes used. This type of shop is typically found in high-volume, low-variety manufacturing environments, such as mass production of consumer goods.

<u>Social shop</u>: A social shop is a scheduling situation characterized by high product variety and low process variety. This type of scheduling situation would typically be placed in the lower right corner of the product/process matrix, as described by Safizadeh et al. A social shop is characterized by a high degree of product variety, with little variation in the processes used. This type of shop is typically found in environments where there is a high degree of customization or personalization, such as in the production of tailor-made products.

<u>Stress shop</u>: A stress shop is a scheduling situation characterized by low product variety and high process variety. This type of scheduling situation would typically be placed in the upper left corner of the product/process matrix, as described by Safizadeh et al. A stress shop is characterized by a high degree of process variety, with little variation in the products used. This type of shop is typically found in environments where there is a high degree of technical complexity, such as in the production of high-tech products.

<u>Sociotechnical shop</u>: A sociotechnical shop is a scheduling situation characterized by high product variety and high process variety. This type of scheduling situation would typically be placed in the upper right corner of the product/process matrix, as described by Safizadeh et al. A sociotechnical shop is characterized by a high degree of both product and process variety, with a high degree of technical complexity and a high degree of customization or personalization. This type of shop is typically found in environments where there is a high degree of technical complexity and a high degree of customization or personalization, such as in the production of customized high-tech products.

Question 7: Design; Propose a blueprint for a new production system design in which all existing and new products can be efficiently made. Include in your description the effect on the organization of planning and scheduling.

Creating a blueprint:

Step 1: Identify and Analyze Current Product Portfolio and Production Processes

- Use the product/process matrix to determine the current processes are product-focused or process-focused.
  - Classify the products according to their complexity and volume.
- Identify any issues or inefficiencies in the current system.
  - Use a flowchart that illustrates the current production process, including any bottlenecks or inefficiencies.
- Analyze the current capacity and flow of the production system using Little's Law and other performance measures.

Step 2: Align with Competitive Priorities and Dominant Orientation

- Identify the competitive priorities and dominant orientation of the organization.
  - Determine if the organization should focus on cost, quality, delivery, or flexibility.
  - Consider how this will impact the production system design. For example, if the organization is focused on cost, the production system design should be focused on reducing costs.
- Align the production system design with the organization's competitive priorities and dominant orientation by using the product/process matrix to identify which products align and which do not.

Step 3: Improve Capacity and Flow

- Evaluate the organization's current capacity and flow.
  - Identify any bottlenecks or issues with the current system.
  - Utilize the principles of lean production to eliminate any wastes such as overproduction, waiting, defects, overprocessing, overproduction, inventory, and motion.
  - Implement lean tools such as SMED, Kanban, and pull production.

Step 4: Implement Cellular Manufacturing

- Create a diagram that shows the proposed cellular manufacturing layout, including the formation of machine-component groups.
  - Use line balancing methods such as longest operation time and rank positional weight to design the production cells.
  - Use this diagram to illustrate how the proposed cellular manufacturing layout will improve flow and reduce setup times in the new production system design.

Step 5: Incorporate Smart Manufacturing Technologies

- Create a diagram that shows the proposed smart manufacturing technologies, such as Industry 4.0, IoT, and robotics, and how they will be integrated into the production system.
  - Use this diagram to illustrate how the proposed smart manufacturing technologies will improve production efficiency and reduce costs in the new production system design.

Step 6: Implement an Effective Production Control Mechanism

- Create a flowchart that illustrates the proposed production control mechanism, including scheduling algorithms, 2-bin system, and reorder point system.
  - Use this flowchart to demonstrate how the proposed production control mechanism will improve the flow and efficiency of the new production system design.
  - Consider using scheduling algorithms such as First Come First Serve, Shortest Processing Time, and Earliest Due Date to determine the production schedule.
  - Use performance criteria such as takt time, cycle time, and lead time to measure the performance of the production system.
  - Incorporate the use of Kanban system to manage the flow of materials and inventory in the production system.
  - Use pull production system to ensure that the production process is only triggered by actual customer demand.
  - implement a 2-bin system to manage inventory levels and reorder points.
  - Use the concept of Smart Industry and Industry 4.0 to integrate advanced technologies such as IoT, automation, and artificial intelligence in the production control mechanism.
  - Incorporate the use of blockchain technology to enhance the traceability and security of the production control mechanism.

Step 7: Implement a Maintenance Strategy

- Create a diagram that illustrates the proposed maintenance strategy, including condition-based maintenance, and the use of digital twin technology.
  - Use this diagram to demonstrate how the proposed maintenance strategy will improve the reliability and availability of the new production system design.
  - Incorporate condition-based maintenance to reduce downtime and improve equipment efficiency.
  - Implement digital twin technology to improve the monitoring and maintenance of equipment.
  - Use of Predictive Maintenance by using IoT sensors to detect early signs of equipment failure.
  - use the concept of Automated Factories and Physical Internet for enhanced maintenance and operation of the production system.

Step 8: Implement a Continuous Improvement Process

- Use the PDCA cycle for continuous improvement and monitoring of the production system.
  - Continuously measure and analyze performance using performance criteria such as takt time, cycle time, and lead time.
  - Use the results of the performance analysis to identify areas for improvement and implement changes to the production system design.
  - Incorporate the input and feedback of the employees and other stakeholders in the continuous improvement process.
  - Utilize the concept of Behavioral Operations and Behavioral Economics to overcome Common biases such as Anchoring bias, Framing bias, Psychological ownership bias, Algorithm aversion in the continuous improvement process.
  - Incorporate the concept of Cognitive ergonomics and Usability of scheduling algorithms to enhance the effectiveness of the continuous improvement process.

The 2023 resit was based on the Cellular manufacturing assignment case the next page includes an example of what an answer could look like. Remember to address various topics of the course, to make actual feasible design decisions. Merely stating what factors could or should be considered is not enough.

blueprint for a new production system design
Cellular manufacturing
SwagMoneyInc

Warning you are not the only person with this document, Take inspiration. Although tempting, directly copying these answers is not a good idea because it would be hella sus

SwagMoneyInc wishes you goodluck

To propose a blueprint for a new production system design for the case study company, we must consider various aspects of the organization. These include manufacturing strategy, process design, production control mechanism, options for smart manufacturing, and behavioral aspects. Our goal is to create an efficient system that can handle all existing and new products, while also improving planning and scheduling within the organization.

Manufacturing strategy:
To optimize resources, capabilities, and management, we propose adopting a focused factory approach. This approach involves dedicating separate facilities to mass production and flexible manufacturing systems (FMS). Mass production can be handled using automated assembly lines with conveyor systems, while FMS can utilize modular, reconfigurable equipment. This decision is based on the case study company's product portfolio that consists of both high-volume and customized products.
Feasibility & Benefit:
The focused factory approach is feasible as it only requires strategic allocation of resources to different facilities. The benefits include reduced operational complexity, increased efficiency, and better customer satisfaction.

Process design:
a. Mass production: Using automated assembly lines with conveyor systems for high-volume products addresses the need for speed and efficiency in mass production, as seen in the case study company's product range.
Feasibility & Benefit: Automated assembly lines are well-suited for high-volume products and can be feasibly implemented with the necessary investments in equipment and training. The benefits include reduced lead times, increased production rates, and improved customer service.
b. Flexible Manufacturing Systems (FMS): For low volume and customized products, creating manufacturing cells with a U-shaped layout and utilizing modular, reconfigurable equipment addresses the case study company's need for agility and responsiveness to handle diverse product specifications.
Feasibility & Benefit: Manufacturing cells and modular equipment are feasible with the right investments in technology and process design. The benefits of this approach include reduced setup times, flexibility for varying product demand, and potentially lower production costs.

Production control mechanism:
Implementing a centralized Enterprise Resource Planning (ERP) system that integrates MRP, capacity planning, and production scheduling can address the case study company's need for synchronized demand and supply planning and optimized resource utilization.
Feasibility & Benefit: ERP systems can be feasibly implemented through off-the-shelf or custom solutions. The benefits include improved operational efficiency, enhanced data-driven decision-making, better resource alignment, and waste reduction.

Options for smart manufacturing:
a. Advanced Robotics: Incorporating advanced robotics can automate repetitive tasks, leading to increased efficiency and cost savings.

Feasibility & Benefit: Advanced robotics are feasible with the right investments in hardware and software. The benefits of this approach include improved production efficiency, reduced downtime, and improved asset utilization.
b. Predictive maintenance: Implementing predictive maintenance technology can anticipate machine failures, thereby reducing downtime and costs associated with maintenance.
Feasibility & Benefit: Predictive maintenance is feasible with the right investments in sensors and analytics. The benefits of this approach include reduced downtime, lower maintenance costs, and improved asset utilization.

Behavioral aspects:
a. Cross-functional teams and Agile project management: Forming cross-functional teams and adopting Agile methodologies can help the case study company address its need for rapid responses to changing customer demands and market conditions.
Feasibility & Benefit: These behavioral aspects can be feasibly implemented with the right organizational structure and management practices. The benefits include improved adaptability, collaboration, and overall organizational performance.
b. Training and development programs: Implementing regular training and development programs addresses the case study company's need for a skilled workforce capable of handling new technologies and problem-solving techniques.
Feasibility & Benefit: These programs are feasible with the right investments in training materials and instructor resources. The benefits include a skilled and adaptable workforce, better operational efficiency, and improved customer satisfaction.

Effect on Planning and Scheduling:
The proposed blueprint has a significant effect on planning and scheduling. The cellular manufacturing approach, JIT system, and Kanban system all require a synchronized production schedule to ensure efficient material flow and timely delivery. The MES system and AI/ML algorithms enable real-time production tracking and adaptive scheduling to optimize resource utilization. The Lean manufacturing and CI programs require continuous monitoring and analysis of production data to identify improvement opportunities and make data-driven decisions. Overall, the proposed blueprint streamlines planning and scheduling processes to improve production efficiency, reduce lead times, and enhance customer satisfaction.