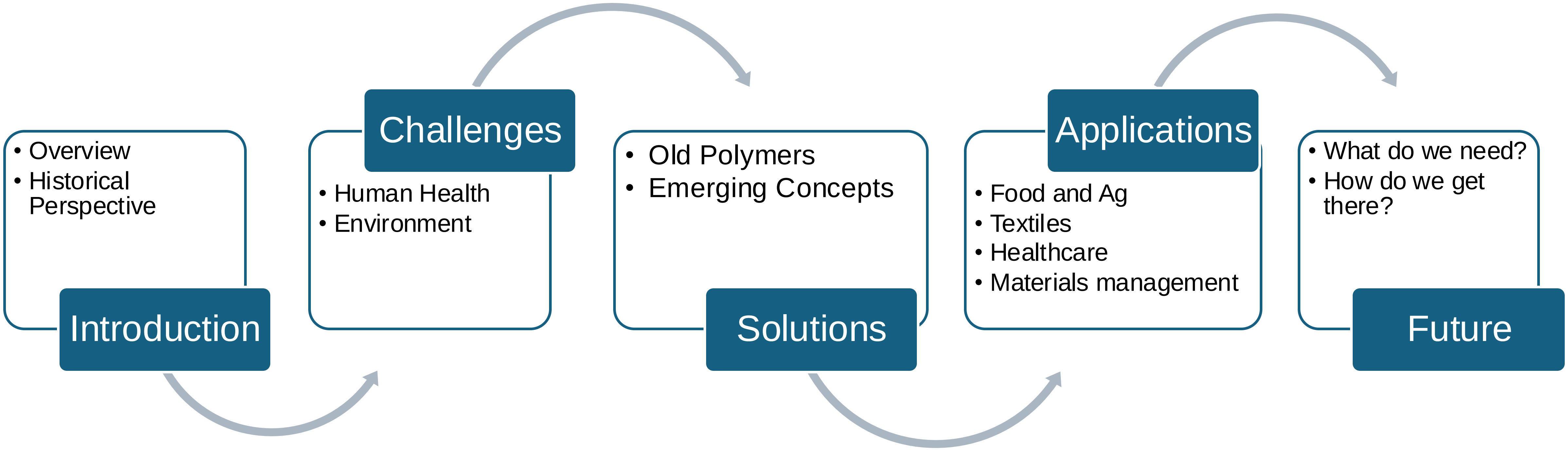
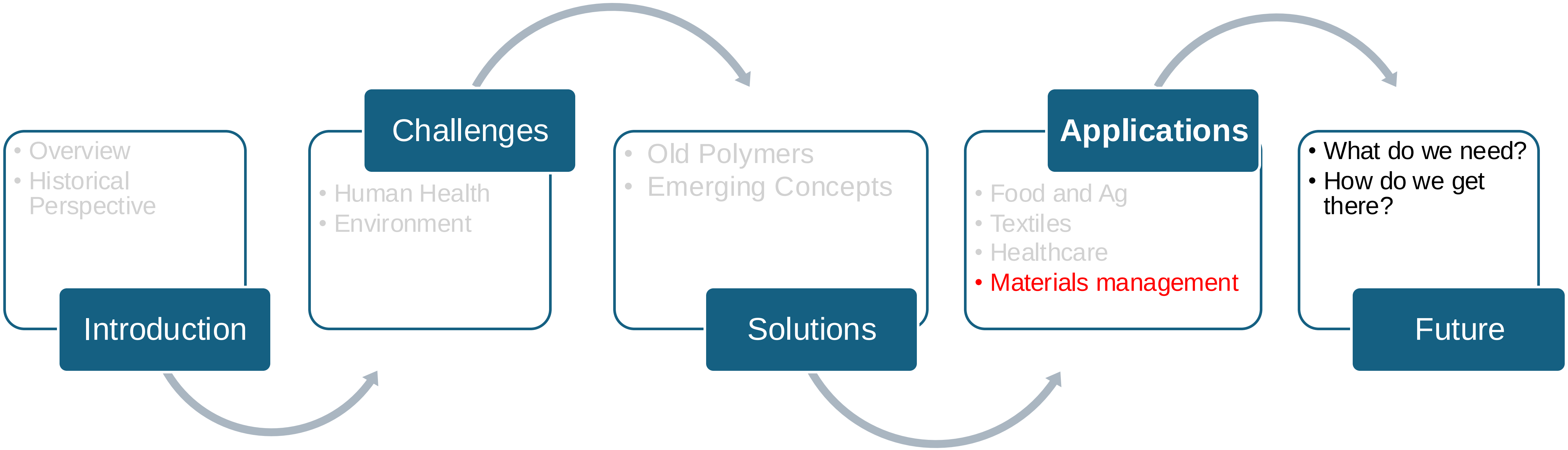
Course Overview



Lecture 16-17



Lecture 16-17

Learning Objectives:

1) Sustainable Materials Management

2) Recycling

3) Sustainable production

4) Life cycle analysis

5) Final assignment

Learning Objectives:

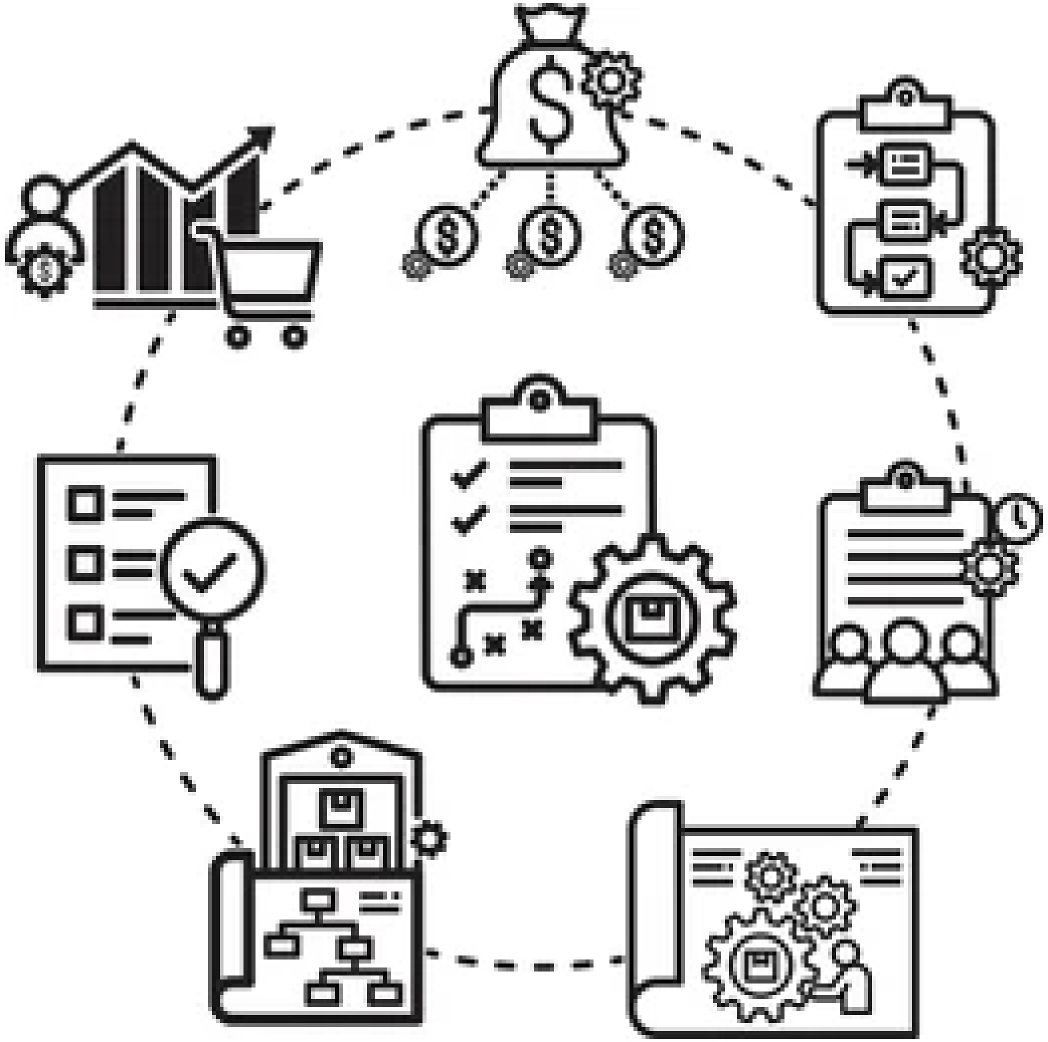
1) Sustainable production

- Introduction
- Kaizen
- 5S
- Cellular Manufacturing
- JIT/Kanban
- TPM
- Six Sigma
- 3P

2) Life cycle analysis

- Introduction
- Example

3) Final assignment



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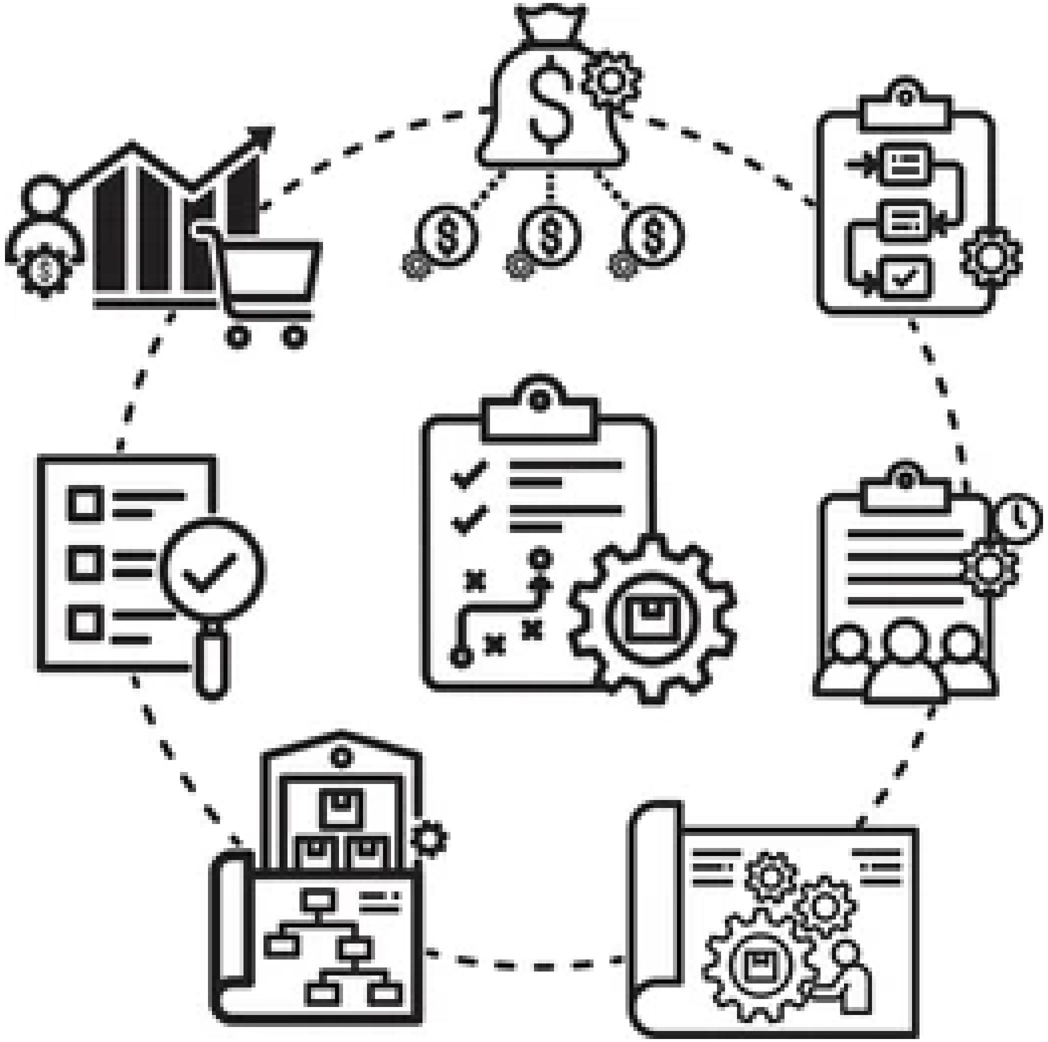
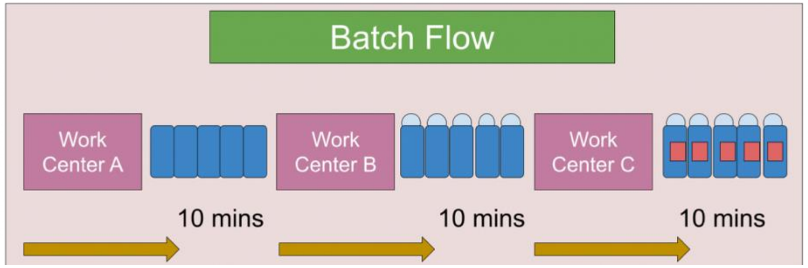


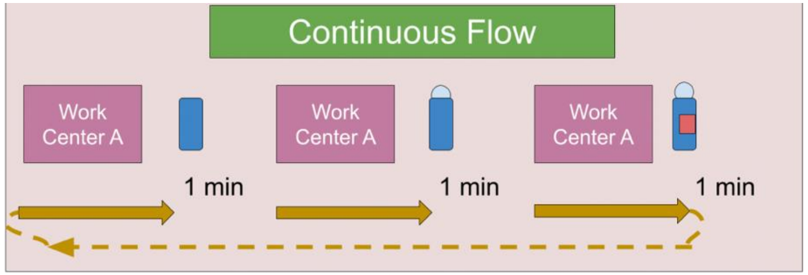
Production

Batch production



Project-based

Flow production



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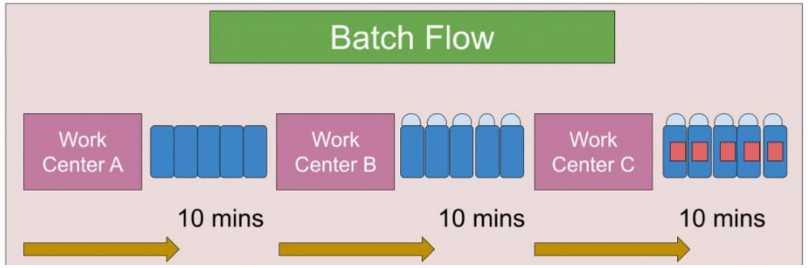
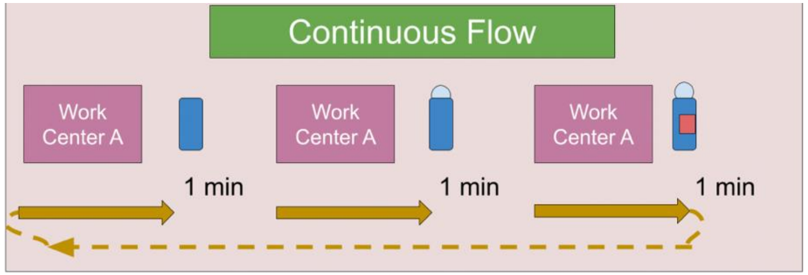


Bakery

Mass Market

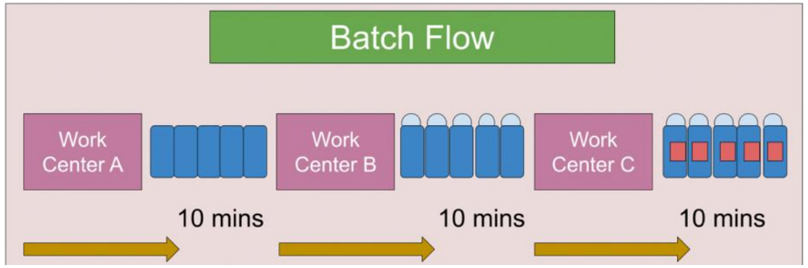
Project-based

Flow production



Production

Batch production



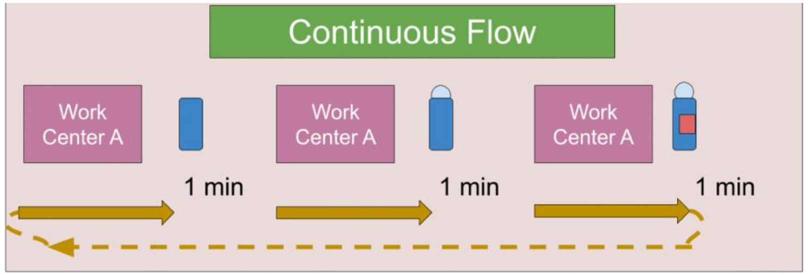
Bakery

H&M

Mass Market

Project-based

Flow production

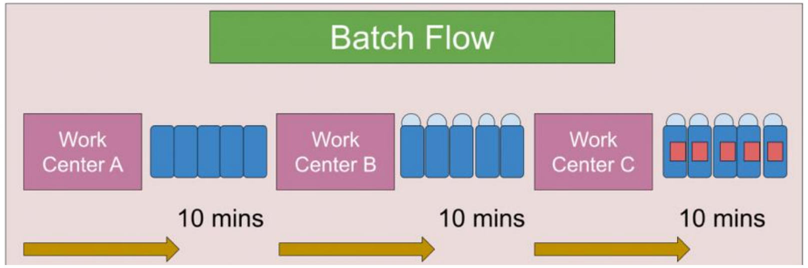


Car production

Phone production

Production

Batch production



Bakery

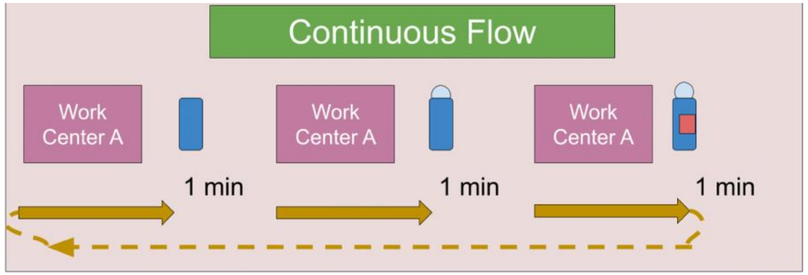
Mass Market

Project-based

Jewerly business

Research

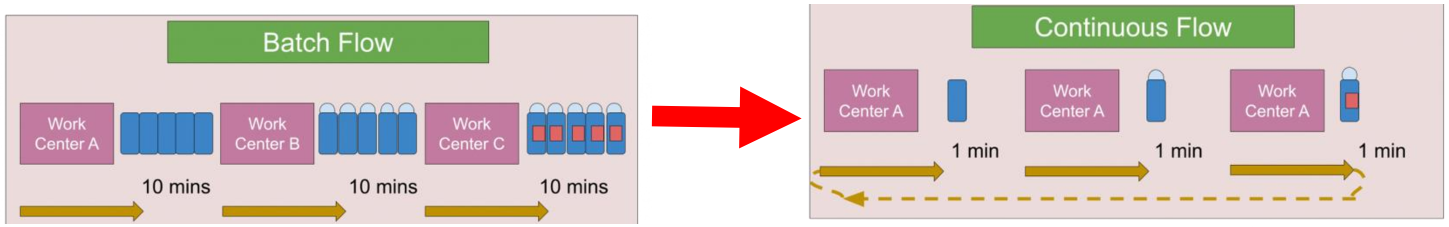
Flow production



Car production

Phone production

Lean involves a fundamental paradigm shift from conventional "batch and queue" mass production to product-aligned "one-piece flow" pull production.



1. **Define value** from the customer's perspective by product family.

2. Identify and **eliminate non-value steps** in the value stream.

3. Sequence value-creating steps for **smooth product flow**.

4. Let customers **pull value** from the previous step.

5. **Repeat** the process to achieve waste-free, perfect value.

Lean production methods:

- Most lean methods are **interconnected** and can be implemented concurrently.
- Organizations typically start by applying lean techniques in a **specific production area** or pilot facility.
- Over time, companies expand the use of lean methods to **other areas**.
- Companies often **customize lean methods** to suit their specific needs and situations.
- Customization may lead to the **development of unique terminology** for various lean methods.

Kaizen

5S

Cellular Manufacturing

JIT/Kanban

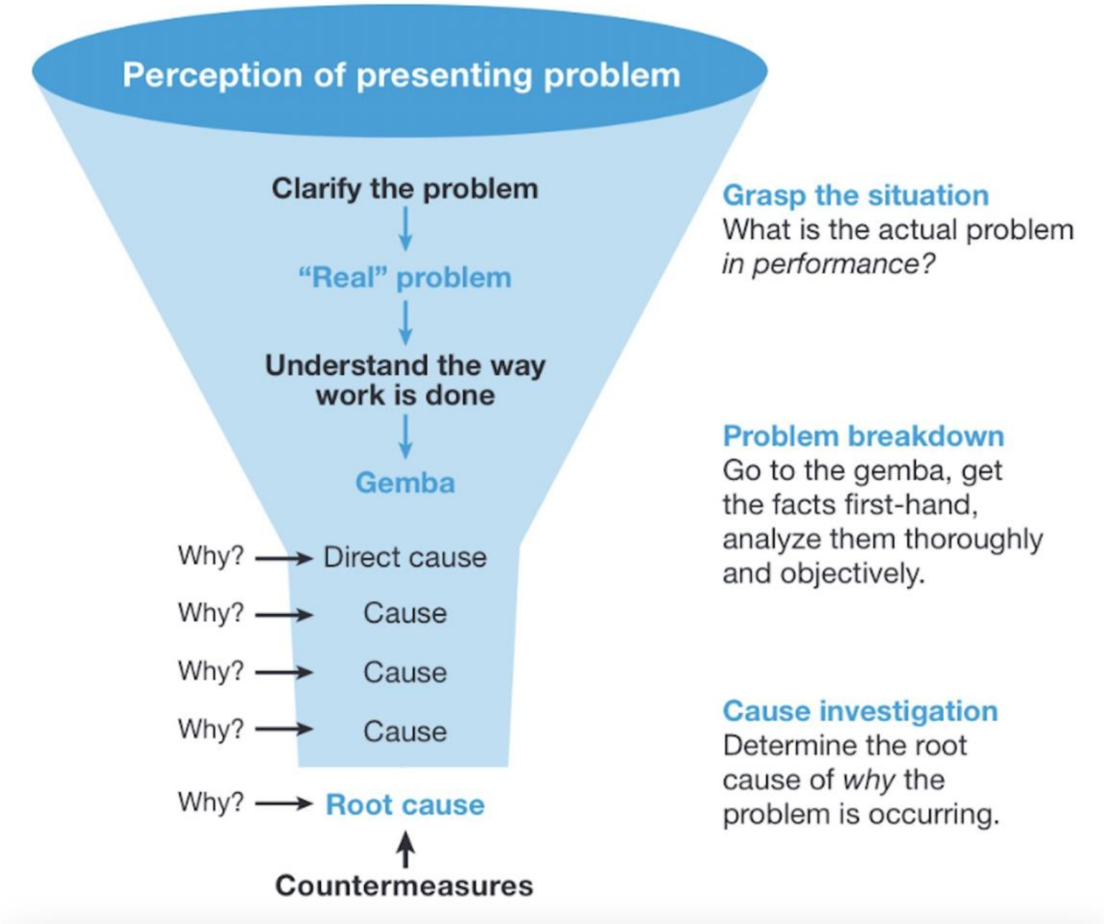
TPM

Six Sigma

3P


Hi Friends
KAIZEN
Implementation
How to implement Kaizen?
Will it give best Result or not ?
Does everyone accept it ?

Kaizen



Five Whys. Toyota developed the practice of asking "why" five times and answering it each time to uncover the root cause of a problem. An example is shown below.

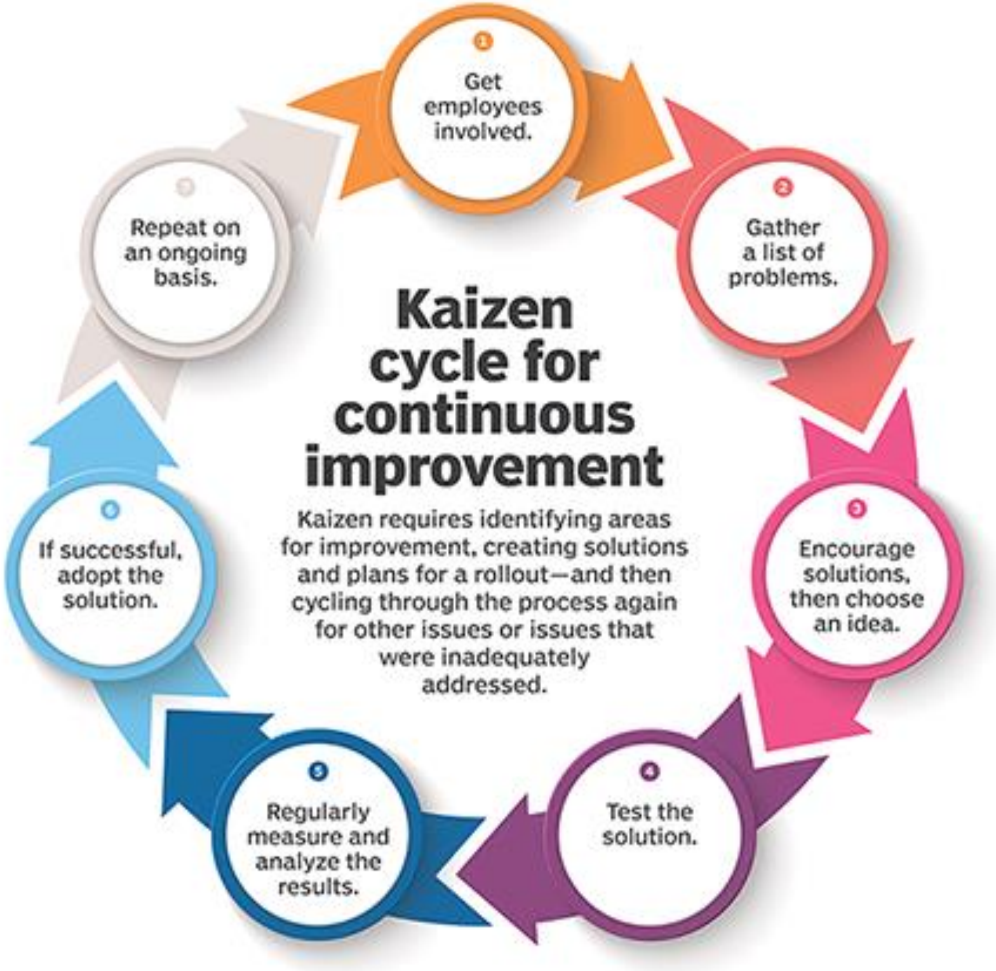
Repeating "Why" Five Times

- *Why did the machine stop?*
  There was an overload, and the fuse blew.
- *Why was there an overload?*
  The bearing was not sufficiently lubricated.
- *Why was it not lubricated sufficiently?*
  The lubrication pump was not pumping sufficiently.
- *Why was it not pumping sufficiently?*
  The shaft of the pump was worn and rattling.
- *Why was the shaft worn out?*
  There was no strainer attached, and metal scrap got in.

Potential Environmental Benefits

- **Continuous Improvement**: Kaizen drives ongoing waste reduction, similar to EMS and ISO 14001.
- **Cross-Functional Involvement**: Encourages input from workers across functions to improve processes.
- **Employee Engagement**: Helps sustain commitment to waste reduction, even in non-core activities.
- **Quick Wins**: Identifies and eliminates hidden wastes without major investments for fast results.

Potential Shortcomings



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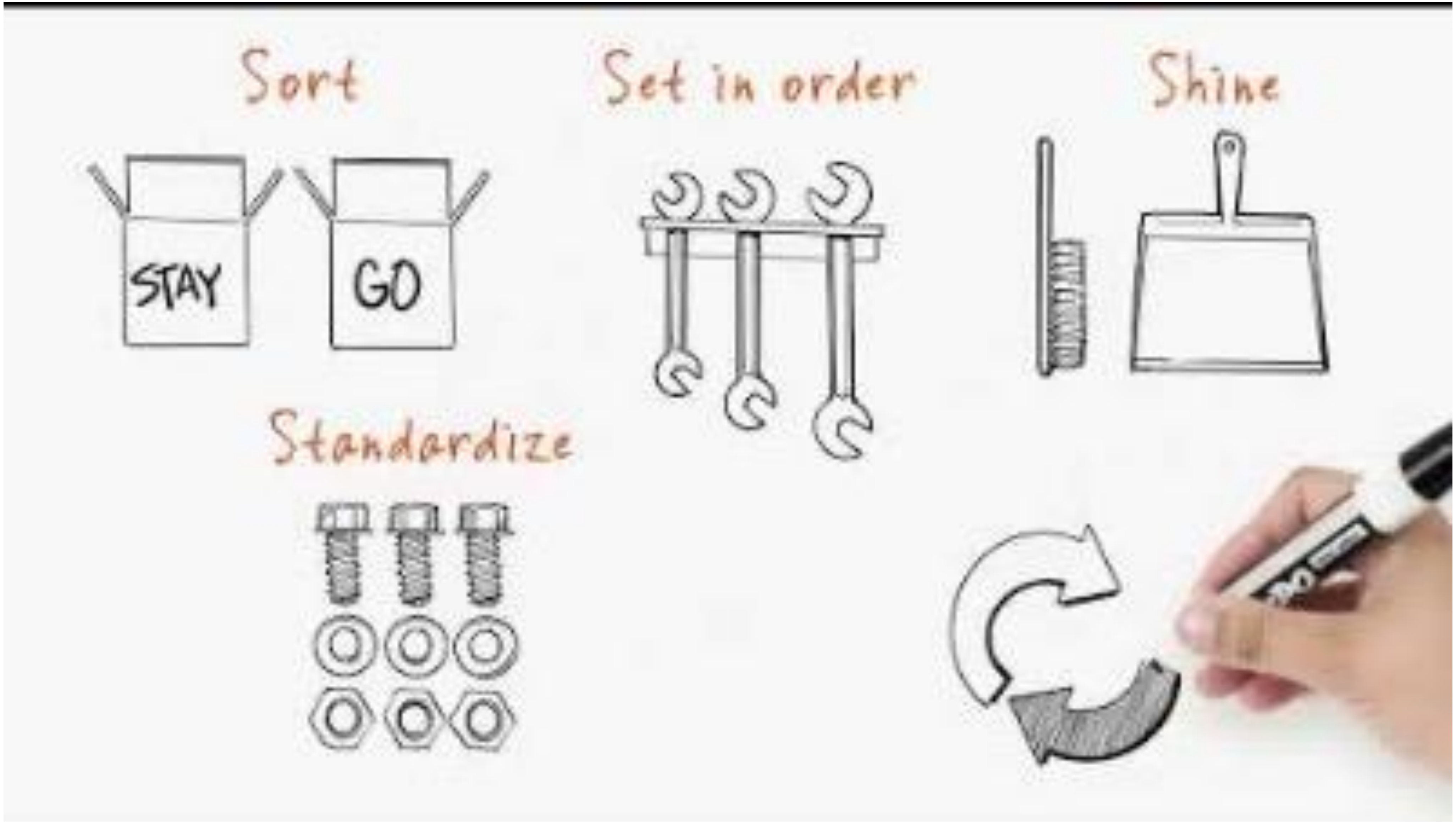
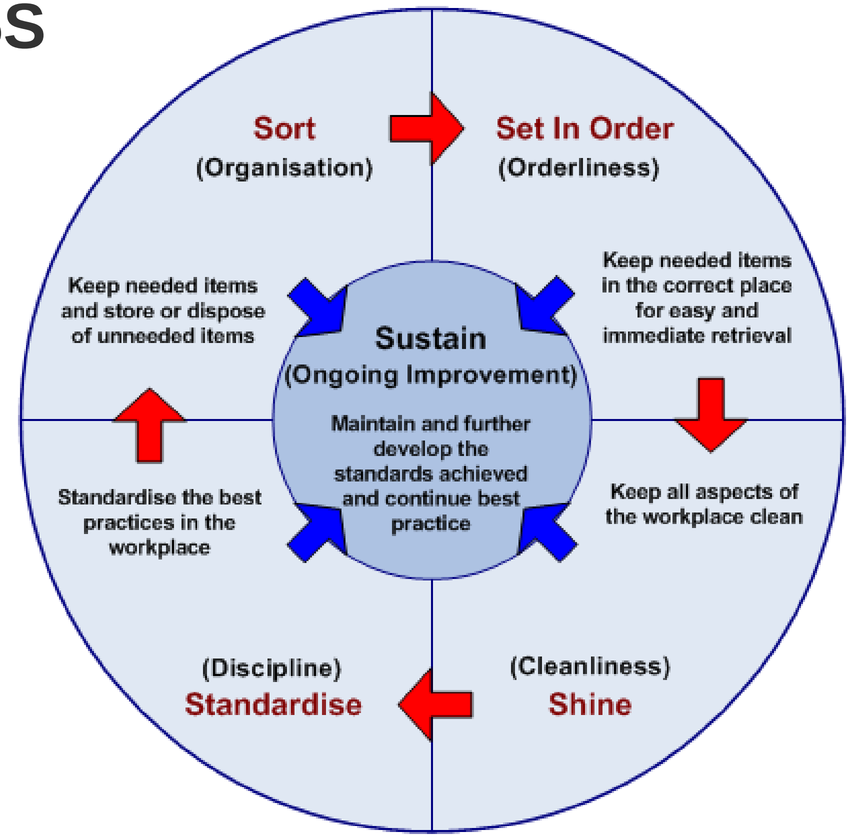
- **Quick Wins**: Identifies and eliminates hidden wastes without major investments for fast results.

Potential Shortcomings

- **Compliance Risk**: Excluding environmental staff may lead to process changes that ignore regulatory requirements.
- **Environmental Oversight**: Kaizen changes might overlook material hazards or waste impacts without environmental input.
- **Missed Sustainability**: Ignoring environmental factors could miss chances for pollution prevention and resource conservation.


Sort
STAY
GO
Set in order
Shine
Standardize

5S



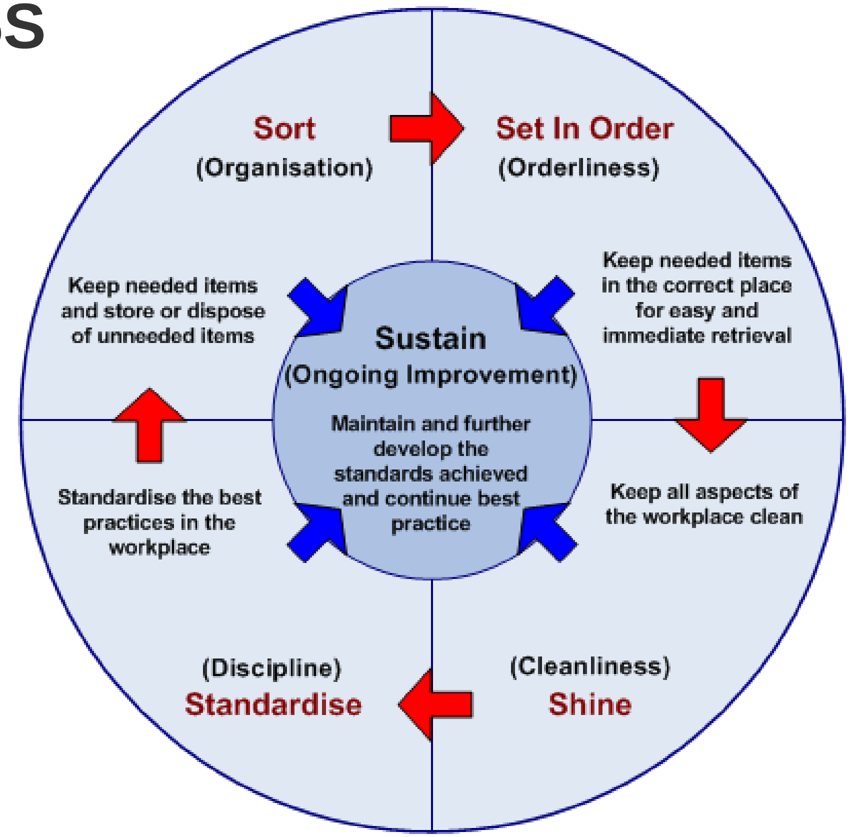
The 5S pillars, **Sort** (*Seiri*), **Set in Order** (*Seiton*), **Shine** (*Seiso*), **Standardize** (*Seiketsu*), and **Sustain** (*Shitsuke*), provide a methodology for organizing, cleaning, developing, and sustaining a productive work environment

Potential Environmental Benefits

- **Energy Efficiency**: Light-colored equipment and clean windows reduce lighting energy needs.
- **Quick Spill Detection**: Clean, organized areas make spills and leaks easier to spot, minimizing waste from cleanup.
- **Accident Prevention**: Clear paths and obstacle removal reduce spill risks and hazardous waste from accidents.
- **Reduced Contamination**: Regular cleaning prevents buildup of debris, lowering defect rates and environmental waste.
- **Material Management**: Organized storage prevents premature disposal of unused chemicals/materials.
- **Enhanced Environmental Awareness**: 5S visual cues improve waste handling, hazard awareness, and emergency readiness.

Potential Shortcomings

5S



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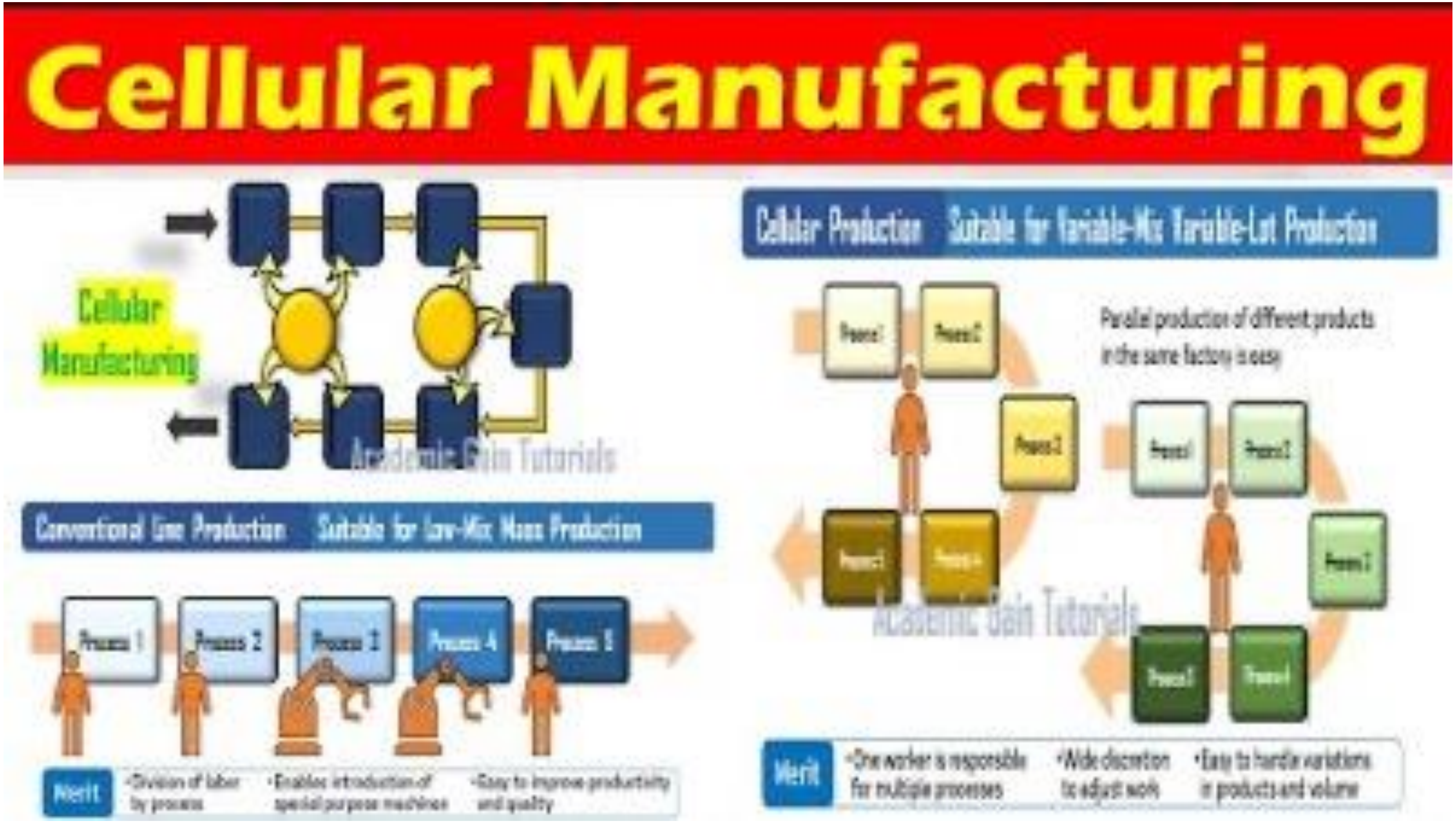
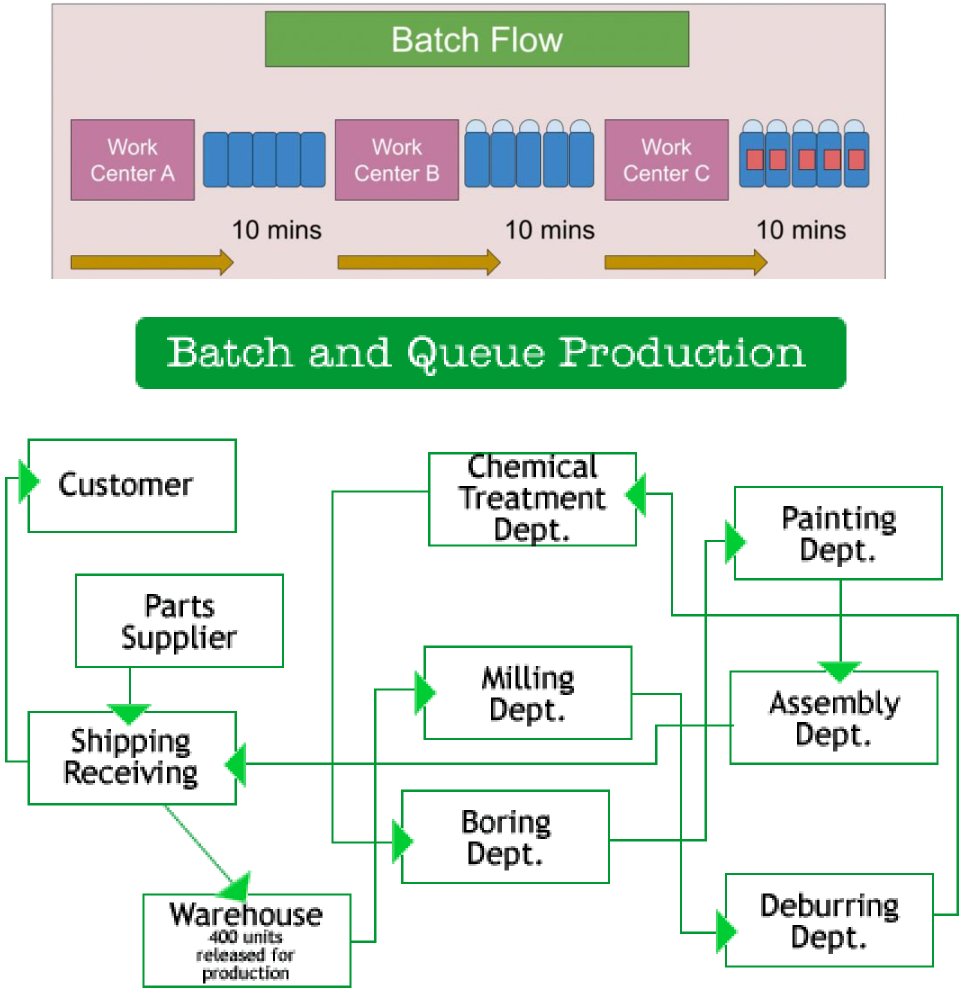
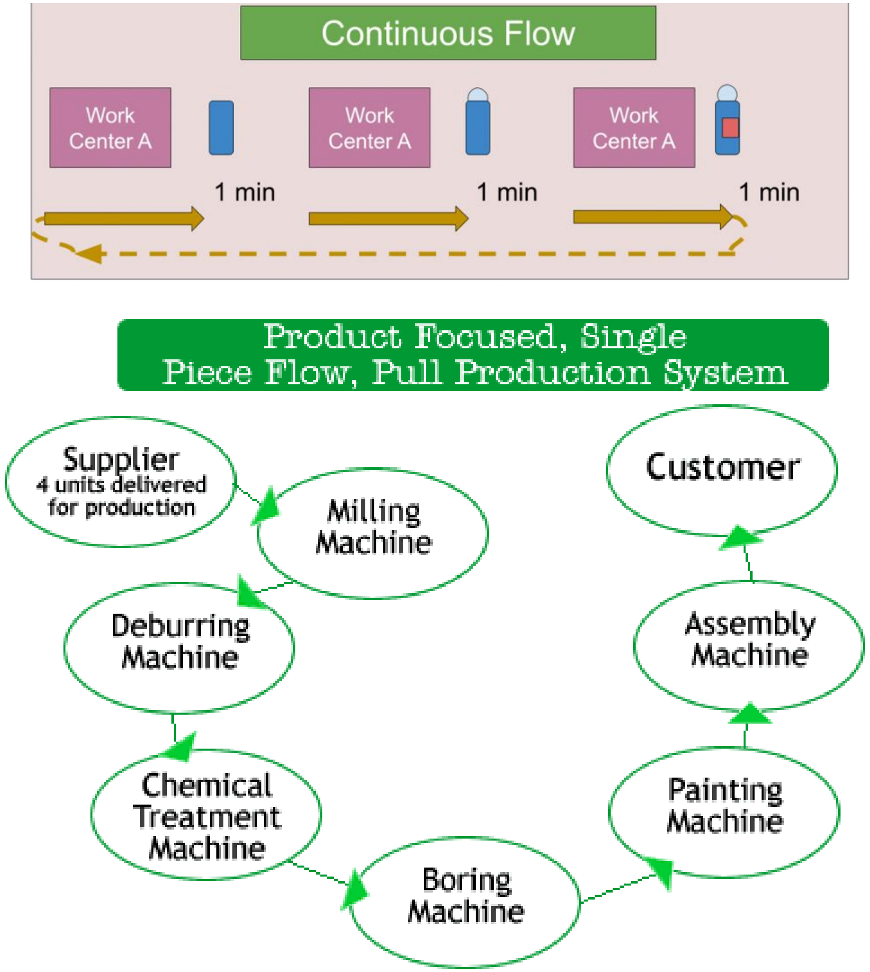
Potential Shortcomings

- **Increased Supply Use**: Frequent painting and cleaning may lead to higher use of solvents and chemicals, increasing emissions and waste.
- **Waste Surge**: Disposing of unneeded items can create a temporary increase in waste, potentially including hazardous materials.

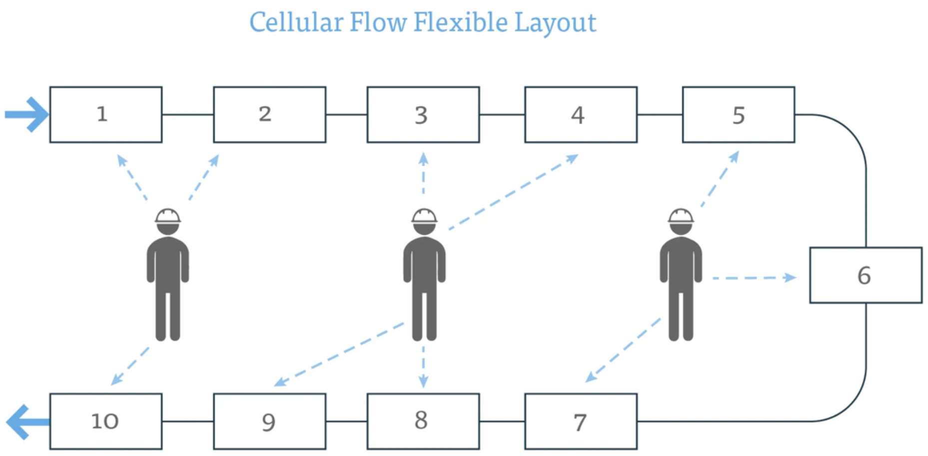

Cellular Manufacturing
Cellular Manufacturing
Academic Gain Tutorials
Conventional Line Production
Suitable for Low-Mix Mass Production
Process 1
Process 2
Process 3
Process 4
Process 5
Merit
•Division of labor by process
•Enables introduction of special purpose machines
•Easy to improve productivity and quality
Cellular Production
Suitable for Variable-Mix Variable-Lot Production
Parallel production of different products in the same factory is easy
Academic Gain Tutorials
Merit
•One worker is responsible for multiple processes
•Wide discretion to adjust work
•Easy to handle variations in products and volume

Cellular Manufacturing





Cellular Manufacturing

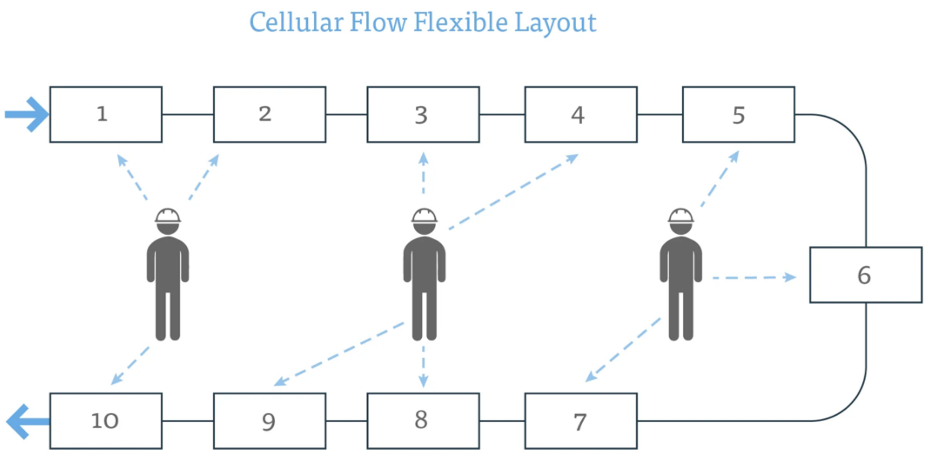


Potential Environmental Benefits

- **Reduced Overproduction**: Cellular production minimizes excess output, cutting raw material, energy use, and waste generation.
- **Fewer Defects**: Quick defect detection reduces scrap, conserving materials, energy, and waste from re-worked products.
- **Right-Sized Equipment**: Smaller, optimized equipment lowers material and energy use per unit of production.
- **Space Efficiency**: Compact layouts reduce energy for heating, lighting, and maintenance, lowering environmental impact.
- **Improved Maintenance**: Frees workers to focus on equipment care and pollution prevention, reducing spills and accidents.

Potential Shortcomings

Cellular Manufacturing



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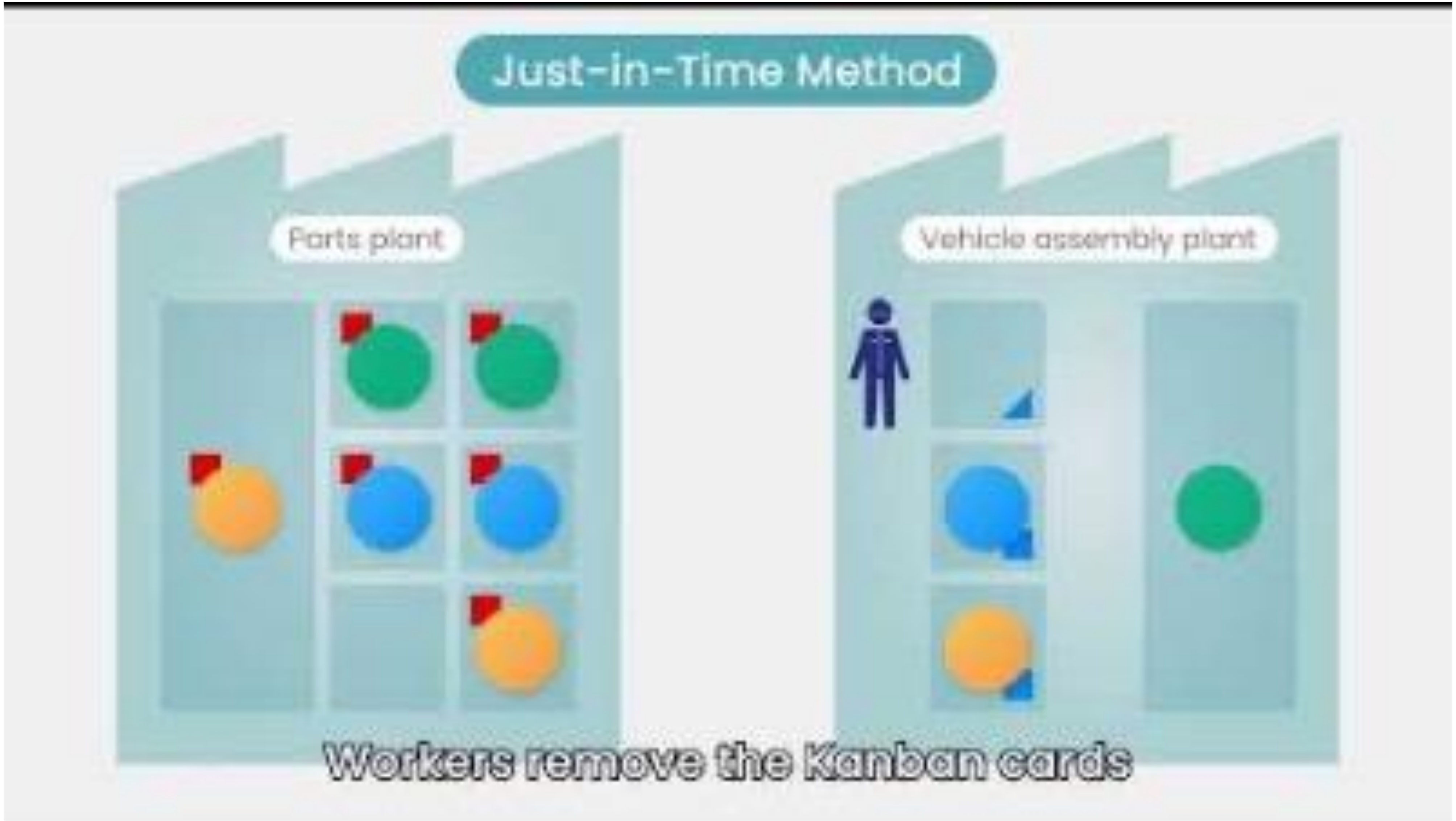
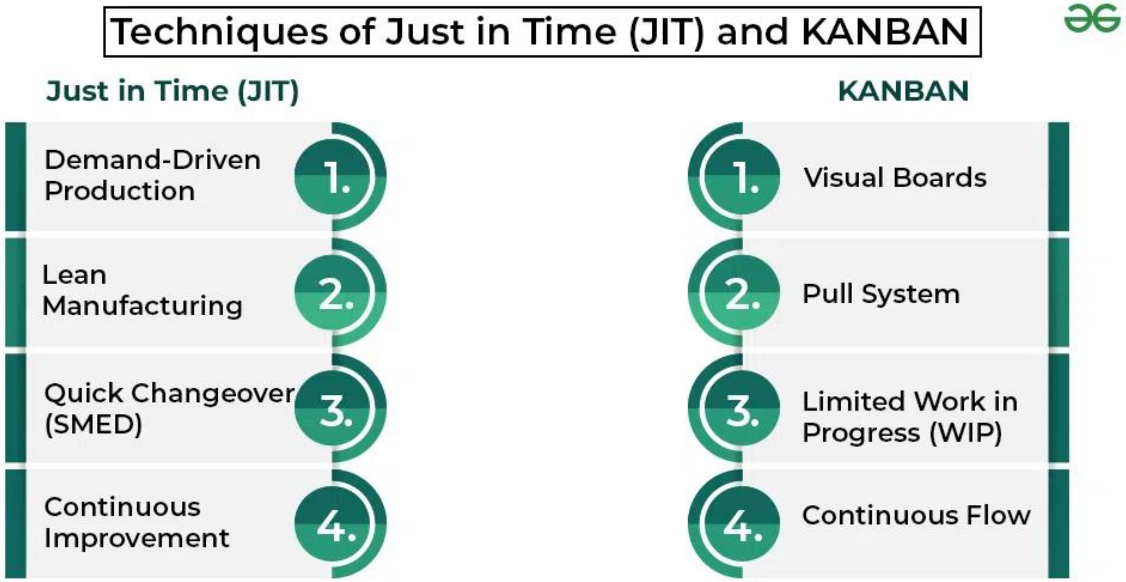
Potential Shortcomings

- **Equipment and Waste**: Transitioning to cellular systems may require scrapping old equipment, creating recycling and waste challenges.
- **Environmental and Compliance Risks**: Dispersing processes can disrupt pollution controls and, without proper adjustments, may lead to regulatory non-compliance.


1. Build a board


Just-in-Time Method
Parts plant
Vehicle assembly plant
Workers remove the Kanban cards

Just in Time/KANBAN

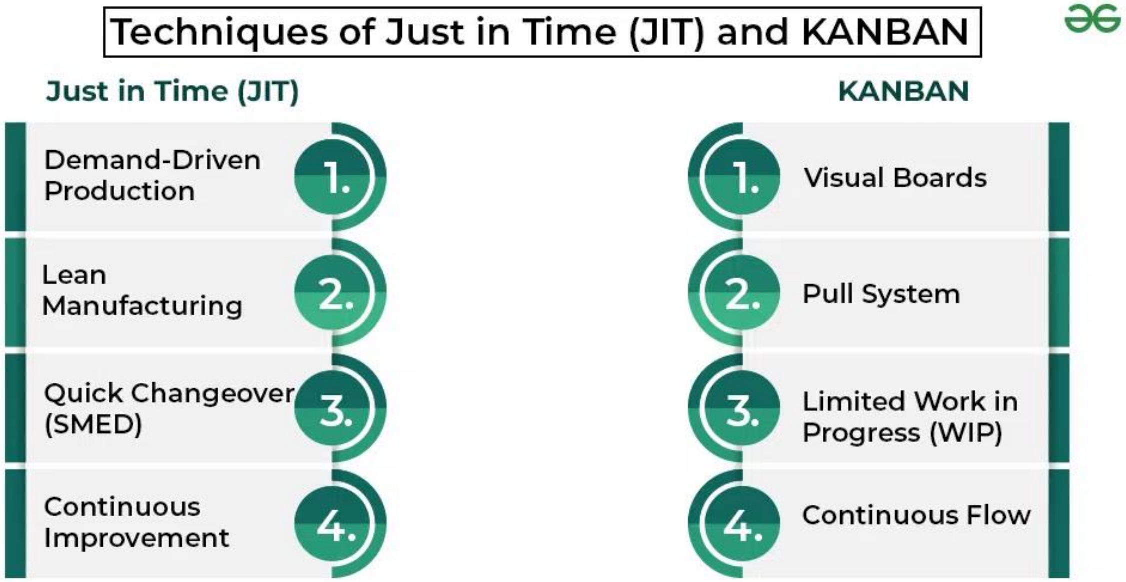


Potential Environmental Benefits

- **Reduced Overproduction**: JIT/kanban minimizes excess output, cutting waste, raw material use, and emissions.
- **Lower Inventory Waste**: Less inventory reduces risk of damage or spoilage, decreasing solid and hazardous waste.
- **Space Efficiency**: Compact layouts lower energy needs for heating, lighting, and maintenance, reducing environmental impact.
- **Encourages Improvements**: Minimal inventory motivates worker-led process improvements and product quality.
- **Lower Transport Needs**: Reducing excess inventory decreases energy for transport and reorganization.

Potential Shortcomings

Just in Time/KANBAN



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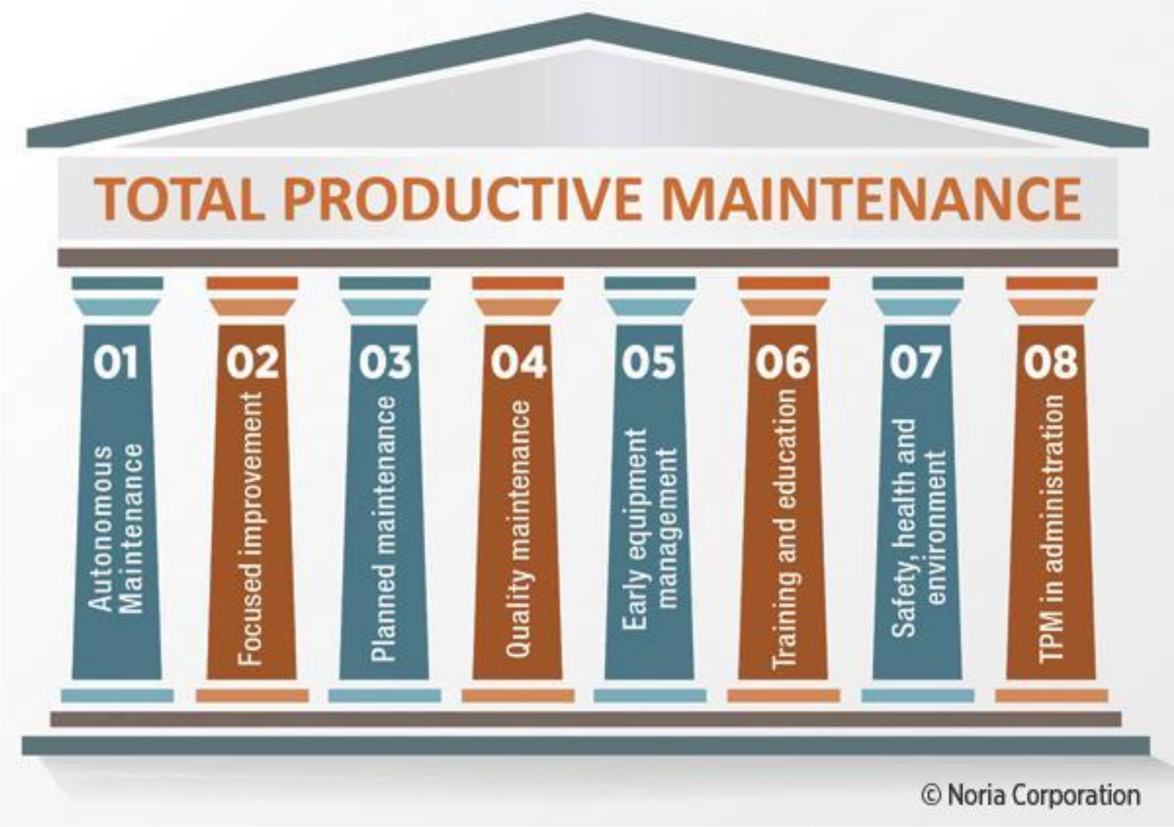
Potential Shortcomings

- **Increased Transport**: More frequent deliveries can raise fuel use and emissions but can be reduced with efficient load planning.
- **Market Fluctuation Risk**: JIT may struggle to cut overproduction waste if demand is unpredictable.


Total Productive Maintenance
8 Pillars of TPM | 5-s Methodology
educationleaves.com

Total Productive Maintenance

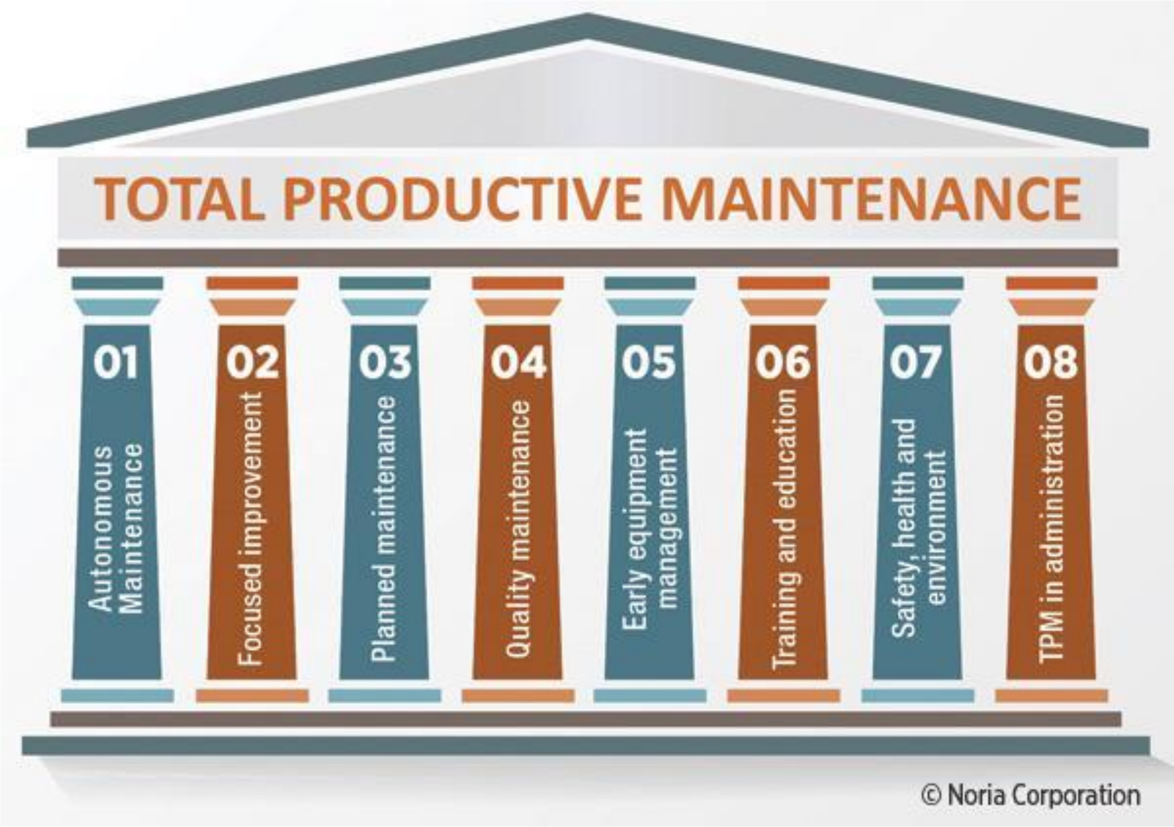


Potential Environmental Benefits

- **Fewer Defects**: Reducing defects cuts waste, saving materials, energy, and scrap disposal.
- **Extended Equipment Life**: TPM increases equipment longevity, reducing environmental impact from new manufacturing.
- **Less Waste from Leaks**: Improved maintenance lowers spills and leaks, reducing hazardous cleanup waste.

Potential Shortcomings

Total Productive Maintenance



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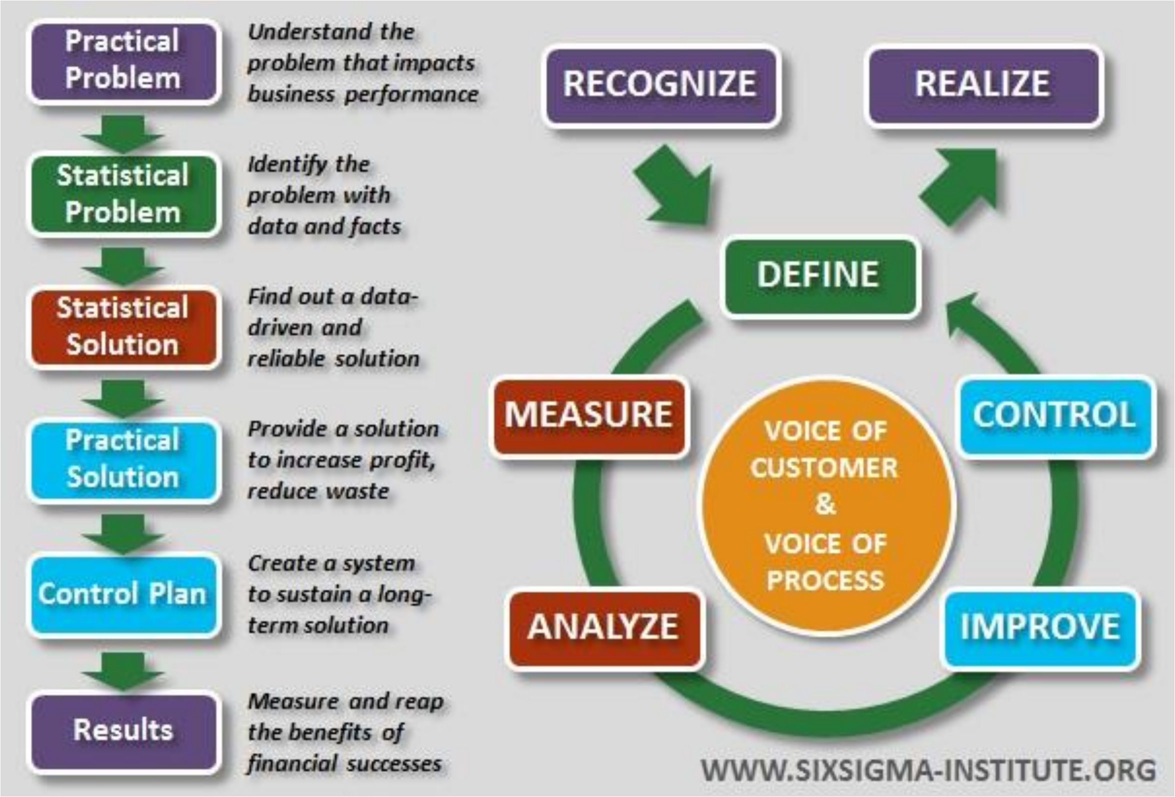
Potential Shortcomings

- **Missed Waste Reduction**: Ignoring environmental factors in equipment upgrades can miss chances to cut waste.
- **More Cleaning Waste**: Extra cleaning supplies can add emissions and waste if root issues aren't fixed.


1 MILLION+ VIEWS
What is Six Sigma?
And guess what?
simplilearn
LEAN

Six Sigma



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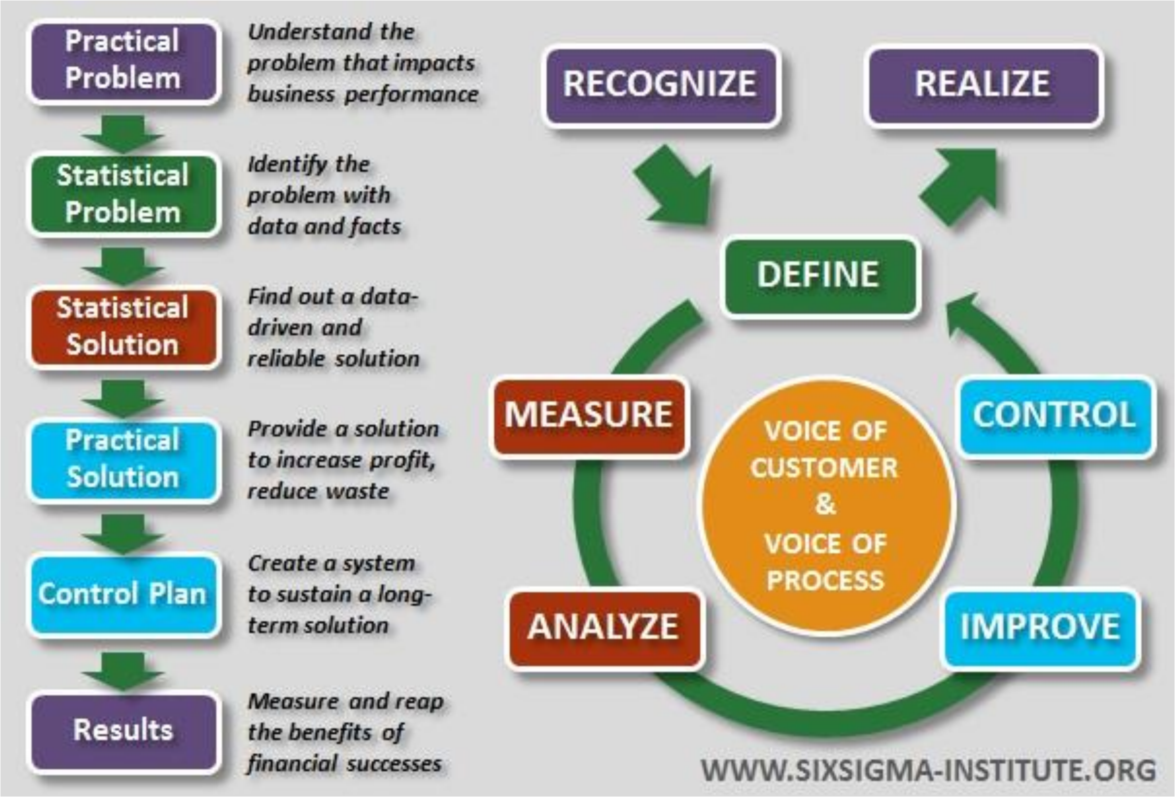
- **Increased Product Lifespan**: Improved durability reduces replacements, cutting environmental impact.

Potential Shortcoming

Six Sigma



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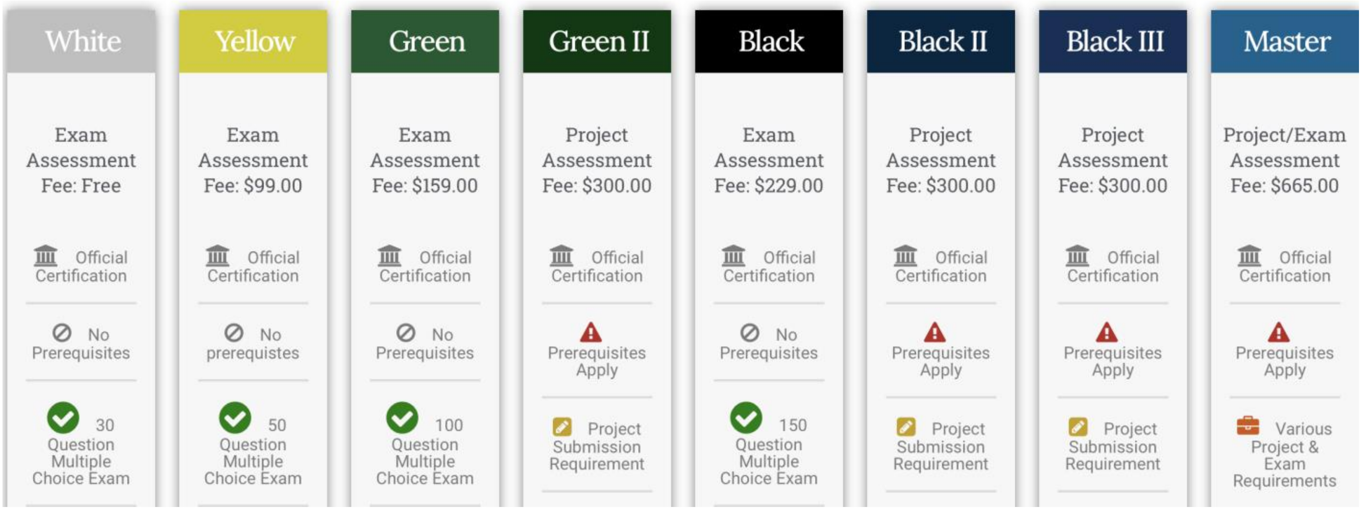
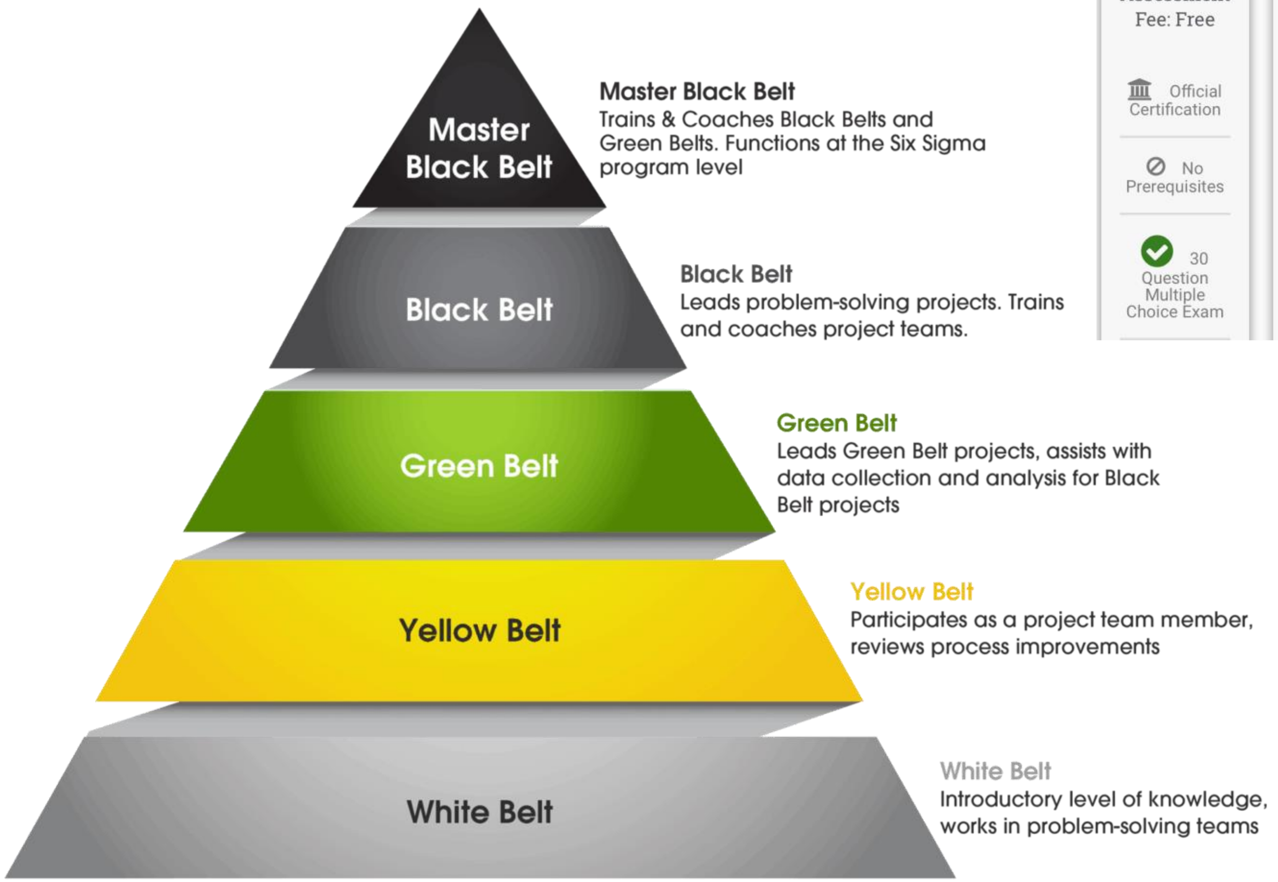
Potential Shortcoming

- **Unexpected Waste**: Lack of technical capacity to effectively utilize Six Sigma tools can potentially decrease effectiveness of the strategy, and/or result in unexpected waste if inappropriately applied.

Six Sigma



White	Yellow	Green	Green II	Black	Black II	Black III	Master
Exam Assessment Fee: Free	Exam Assessment Fee: $99.00	Exam Assessment Fee: $159.00	Project Assessment Fee: $300.00	Exam Assessment Fee: $229.00	Project Assessment Fee: $300.00	Project Assessment Fee: $300.00	Project/Exam Assessment Fee: $665.00
Official Certification	Official Certification	Official Certification	Official Certification	Official Certification	Official Certification	Official Certification	Official Certification
No Prerequisites	No prerequisites	No Prerequisites	Prerequisites Apply	No Prerequisites	Prerequisites Apply	Prerequisites Apply	Prerequisites Apply
30 Question Multiple Choice Exam	50 Question Multiple Choice Exam	100 Question Multiple Choice Exam	Project Submission Requirement	150 Question Multiple Choice Exam	Project Submission Requirement	Project Submission Requirement	Various Project & Exam Requirements

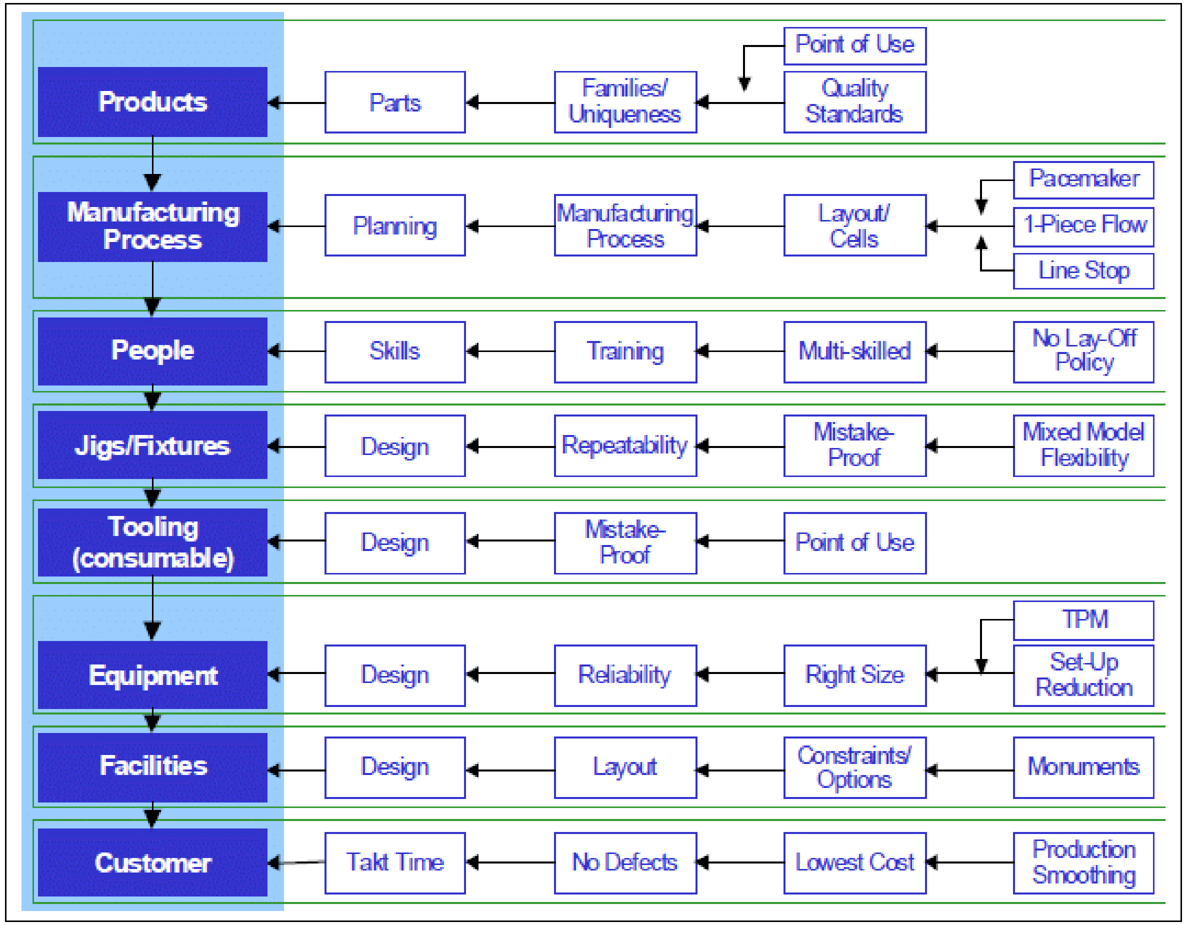


Benefits of having 6 sigma belts:

- **Boosts Efficiency**: Reduces waste and streamlines processes.
- **Enhances Career Prospects**: Valued by employers for quality expertise.
- **Improves Customer Satisfaction**: Ensures high-quality, defect-free products.
- **Promotes Data-Driven Decisions**: Leads to better, more accurate decisions.


Production
Preparation
Process
3P
LEANVLOG

Production Preparation Process

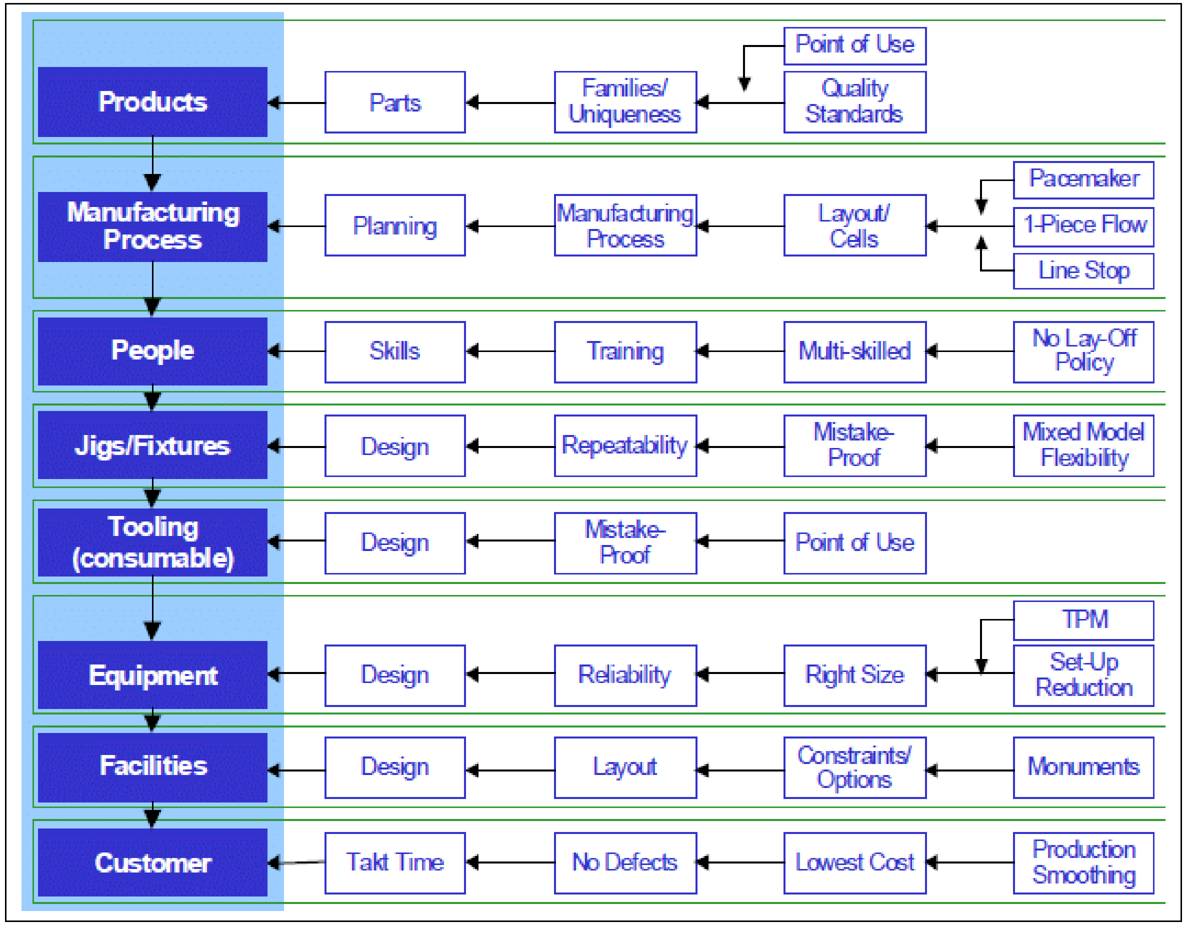


Potential Environmental Benefits

- **Waste-Free Design**: 3P minimizes waste at design stage, inspired by nature.
- **Right-Sized Equipment**: Lowers material/energy use, reduces environmental impact of space.
- **Streamlined Production**: Simplifies steps, often replacing resource-heavy processes (e.g., using colored molding instead of painting).
- **Simpler Product Designs**: Fewer parts and materials, aiding disassembly and recycling.

Potential Shortcoming

Production Preparation Process



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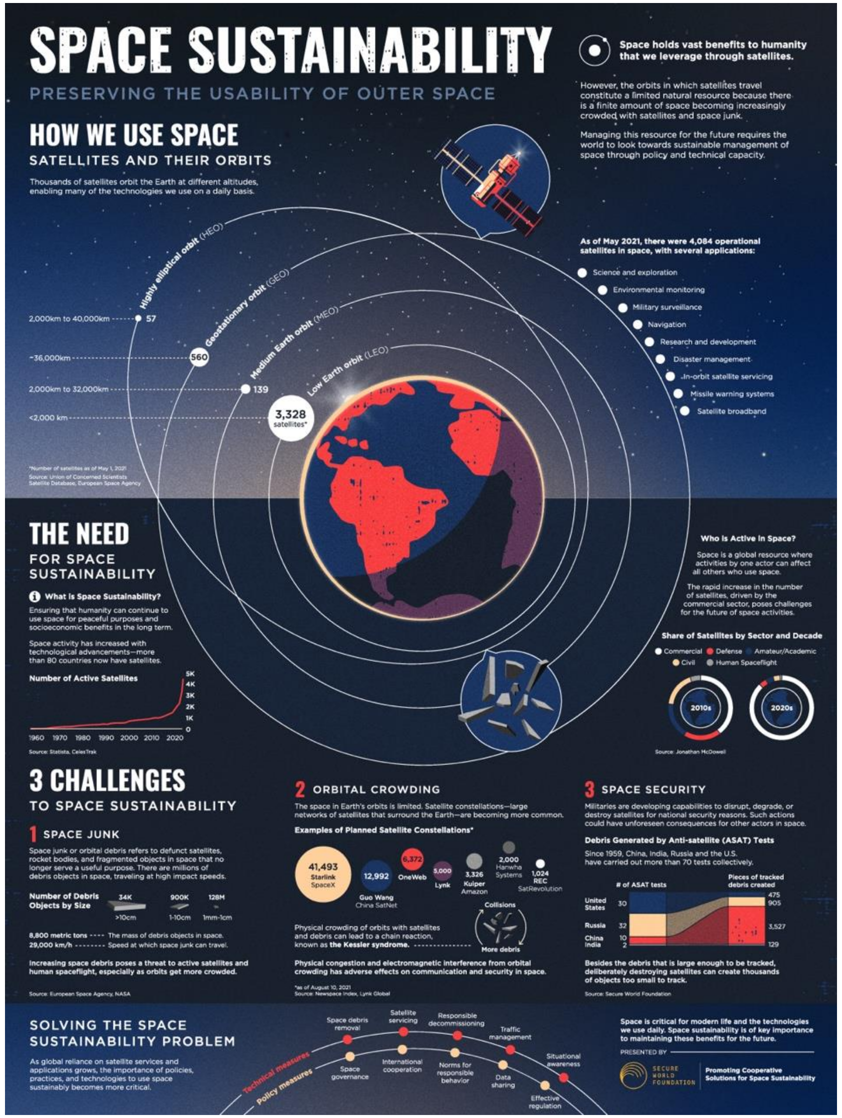
Potential Shortcoming

- **Environmental Impact**: Ignoring design risks can lead to unnecessary harm.
- **Missed Green Options**: Leaving out environmental goals may skip pollution prevention steps.

Best lean production method?

Best lean production method?

No one knows!



Space Junk

According to the European Space Agency (ESA), the mass of all debris objects in space summed up to **8,800 tonnes** as of December 2020. This includes:

•**34,000** objects greater than 10cm in size
•**900,000** objects between 1cm and 10cm
•**128 million** objects between 1mm and 1cm

Space Security

Since 1959, China, India, Russia, and the U.S. have carried out more than 70 anti-satellite (ASAT) tests collectively. These tests generated over **5,000 pieces** of debris that are currently being tracked, in addition to the thousands of smaller objects that are too small to track.

Orbital Crowding

Company	Constellation Name	Number of Satellites
SpaceX	Starlink	41,493
China SatNet	Guo Wang	12,992
OneWeb	N/A	6,372
Lynk Global	N/A	5,000
Amazon	Kuiper	3,326
Hanwha Systems	N/A	2,000
SatRevolution	REC	1,024

Learning Objectives:

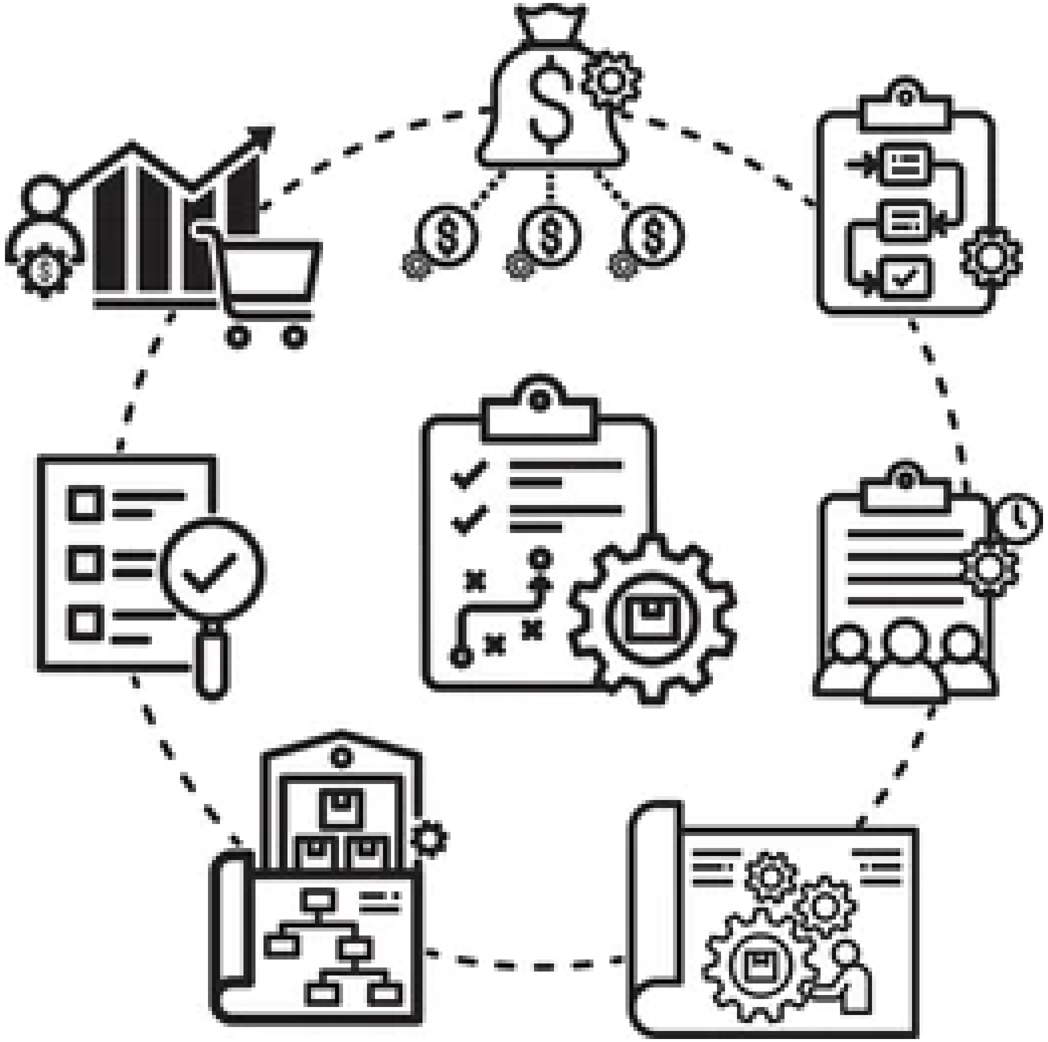
1) Sustainable production

- ❖ Introduction
- ❖ Kaizen
- ❖ 5S
- ❖ Cellular Manufacturing
- ❖ JIT/Kanban
- ❖ TPM
- ❖ Six Sigma
- ❖ 3P

2) Life cycle analysis

- ❖ Introduction
- ❖ Example

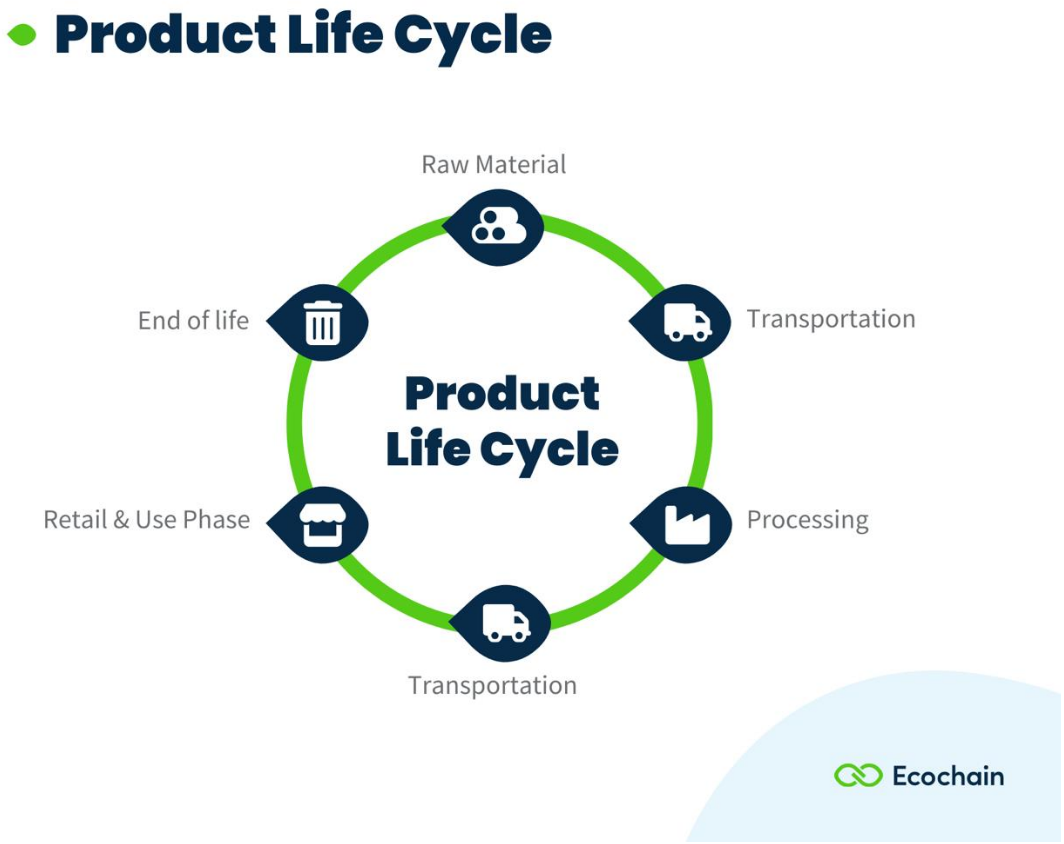
3) Final assignment



Life Cycle Assessment (LCA) is a technique to make more informed decisions through a better understanding of the human health and environmental impacts of products, processes, and activities.

What Are the Benefits of Conducting an LCA?

- Develop a systematic evaluation of the environmental consequences associated with a product.
- Analyze environmental trade-offs of specific products/processes to gain stakeholder acceptance for a planned action.
- Quantify environmental releases to air, water, and land across each life cycle stage.
- Assess the human and ecological effects of material use and environmental releases on local, regional, and global scales




1
Phase 1
Define

LCA impact ranges

Global Impacts

- **Global Warming**: Polar melt, soil moisture loss, longer seasons, forest loss/change, and changes in wind and ocean patterns.
- **Ozone Depletion**: Increased ultraviolet radiation.
- **Resource Depletion**: Decreased resources for future generations.

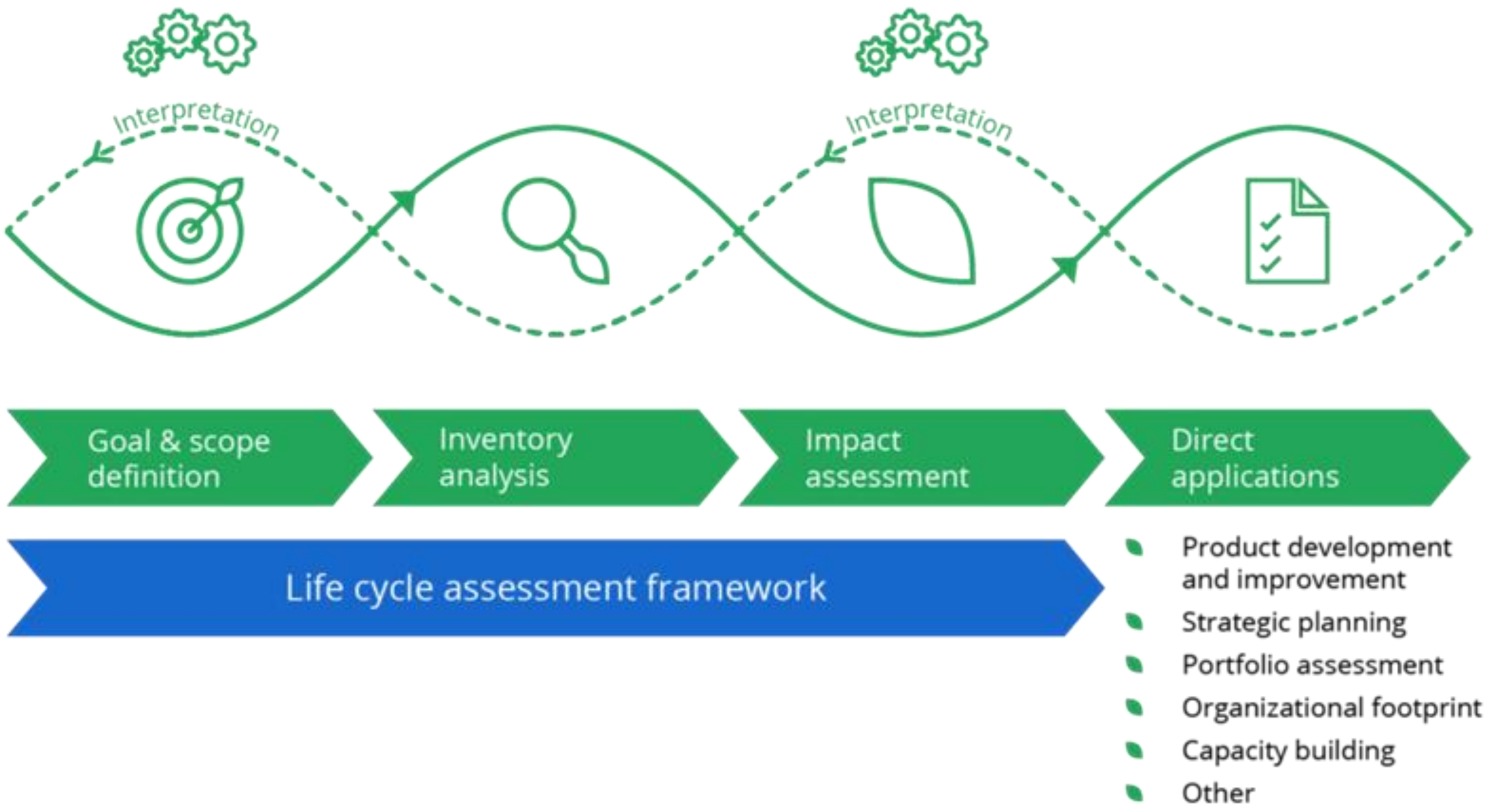
Regional Impacts

- **Photochemical Smog**: "Smog," decreased visibility, eye irritation, respiratory tract and lung irritation, and vegetation damage.
- **Acidification**: Building corrosion, water body acidification, vegetation effects, and soil effects.

Local Impacts

- **Human Health**: Increased morbidity and mortality.
- **Terrestrial Toxicity**: Decreased production and biodiversity, reduced wildlife for hunting or viewing.
- **Aquatic Toxicity**: Decreased aquatic plant and insect production, reduced commercial or recreational fishing.
- **Eutrophication**: Nutrients (phosphorous and nitrogen) enter water bodies, causing excessive plant growth and oxygen depletion.
- **Land Use**: Loss of terrestrial habitat for wildlife and decreased landfill space.
- **Water Use**: Loss of available water from groundwater and surface water sources.

Life Cycle Assessment (LCA) Framework

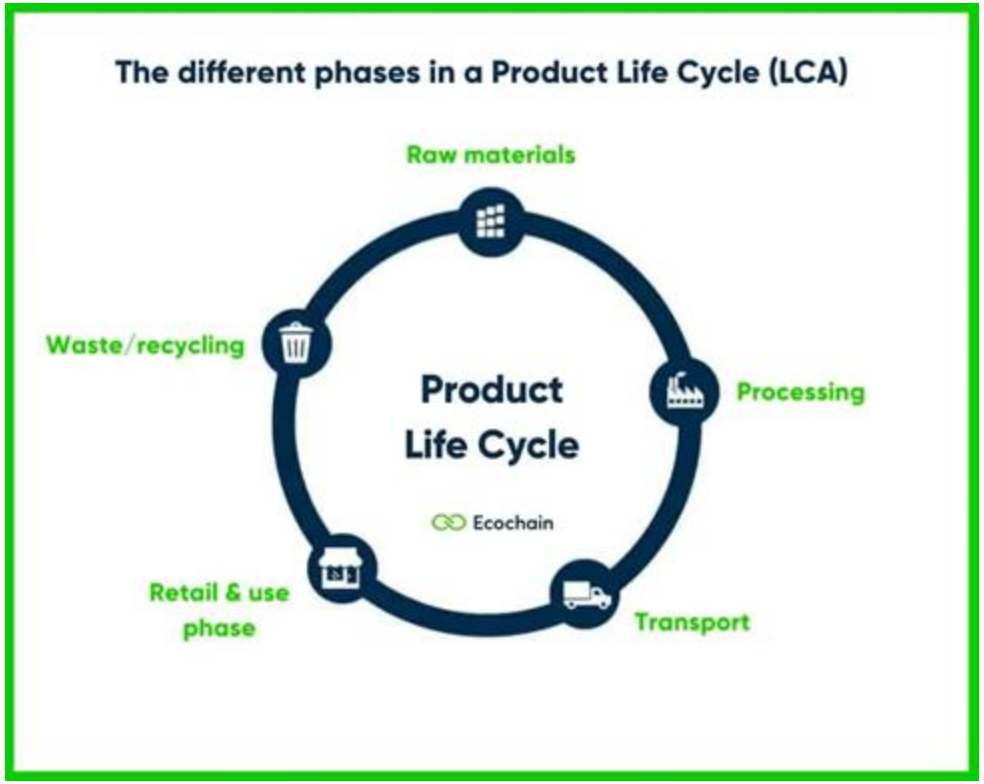


Life Cycle Assessment (LCA)

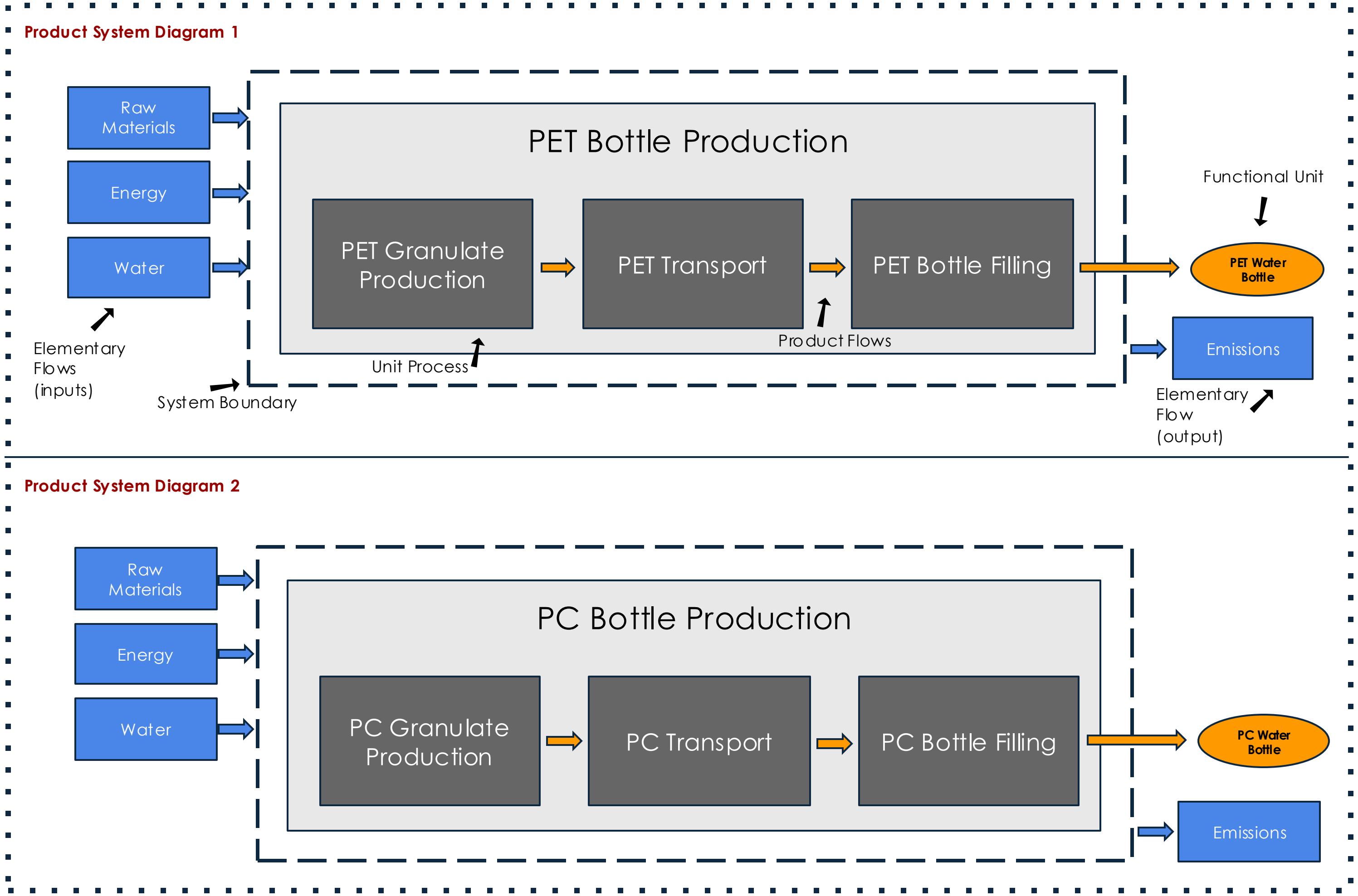
Main Types:

- Cradle-to-gate
  up to production, before leaving the factory gate
- Cradle-to-grave
  includes all 5 life stages
- Cradle-to-cradle

  replaces waste stage with recycling/upcycling process



Project: PET vs PC Water Bottles



Life Cycle Inventory (LCI)

For each unit process, you need:

Inputs

- Product flows from other processes
- Elementary flows directly from the environment (ground, water, or air)

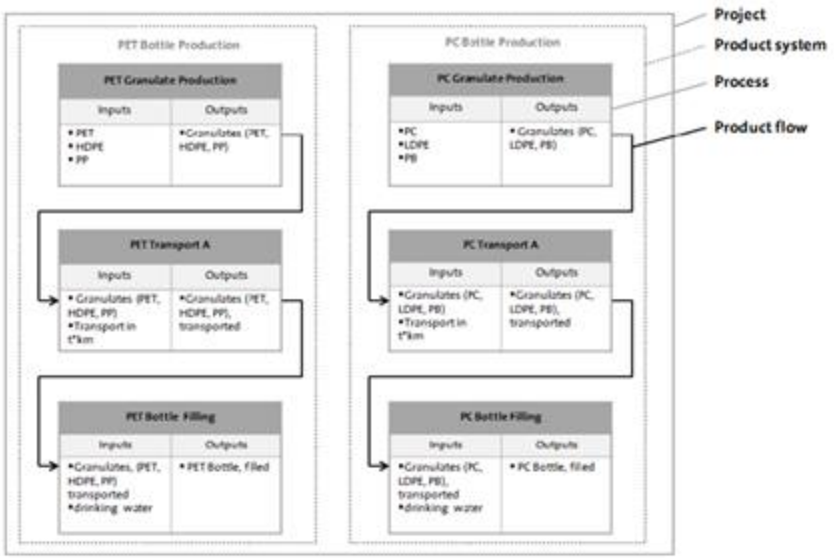
Outputs

- Product flows (products) to other processes
- Co-product flows (if applicable)
- Elementary flows to the environment
- Wastes to other processes (management)

Questions to ask

- What do I need to produce the output for each process?
- What is that made of?
- What are the outputs of each unit process?

PET vs PC water bottle example



How do I get/represent that information?

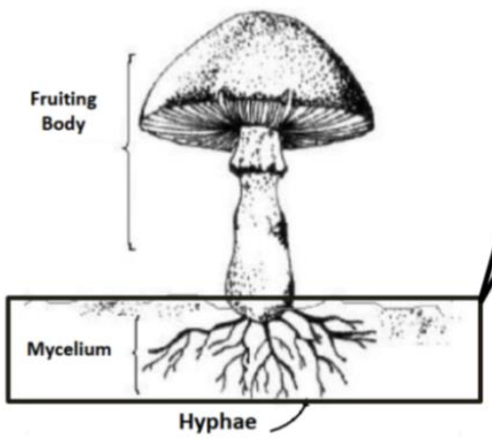
- Primary data (collecting data yourself – physical measurement, surveys)
- Secondary data (literature – reports, surveys, government datasets, industry, databases)
- Proxies (substitute processes, expert opinion, estimations)

Mycellet

***Vision**: Blend style with sustainability while prioritizing compassion for all living beings.

“We are **crafting a greener future** with our vegan leather wallets made from mushroom mycelium.
Join us in redefining fashion for a better world!”

CEO, CTO, etc. | Bomi Park



Mycelium Leather

Mycelium is a root-like structure of a fungus consisting of a mass of branching, thread-like hyphae. Through the mycelium, a fungus absorbs nutrients from its environment.

✓**Environmentally Sustainable**

✓**Cost Effective**

Species	*Ganoderma lucidum & Pleurotus ostreatus*
Substrate	By-products such as wheat straw

Ganoderma lucidum

Pleurotus ostreatus

Wheat straw

By-product of wheat grain

↑ **Strength & Durability**

1. Sustainable raw material sourcing

■ The amount of mycelium for 1 wallet

- Volume of the wallet = 7.5cm*10cm*0.5cm = **37.5 cm³**
- Density of the wallet = **0.23-0.27 g/ cm³** (Basak et al., 2023)

$$37.5\ cm^3 \times 0.25\,{}^{g}/_{cm^3} = \mathbf{9.375\ g\ Mycelium/1Wallet}$$

■ The amount of substrate for 1 wallet

Table 1. Effect of different substrates on mycelium growth and yield of *Ganderma lucidum* (Atila et al., 2020)

Substrates	Yield (g/kg)	Spawn running time (days)
Oak sawdust	86.1	16.0
Popular sawdust	79.4	14.8
Wheat straw	57.9	14.2
Sunflower Meal	42.7	18.0
Cotton Seed Meal	28.6	18.2
Soybean straw	54.8	14.6
Bean straw	62.0	15.2
Average	*57.8*	*15.85*

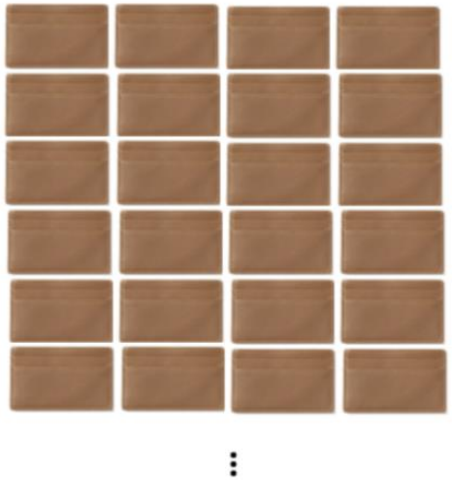
$$\frac{9.375\ g\ Mycelium/_{1\ Wallet}}{57.9\ g\ Mycelium/_{1kg\ Wheat\ straw}} = \mathbf{0.1619\ kg\ Wheat\ Straw}/_{1Wallet}$$

1. Sustainable raw material sourcing

1 Wallet

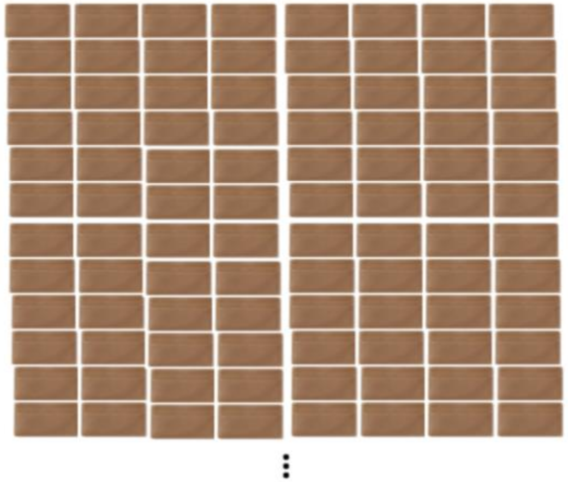
- 9.375 g Mycelium
- 0.1619kg Wheat Straw

200 Wallets / Month



- 1.875 kg Mycelium
- 32.38 kg Wheat Straw

2,400 Wallets / Year



- 22.5 kg Mycelium
- 388.56 kg Wheat Straw

1. Sustainable raw material sourcing

350 million tons of wheat straw are produced annually (Tufail et al., 2021).
Therefore, it is considered that the **supply is sufficient** to meet the demand.

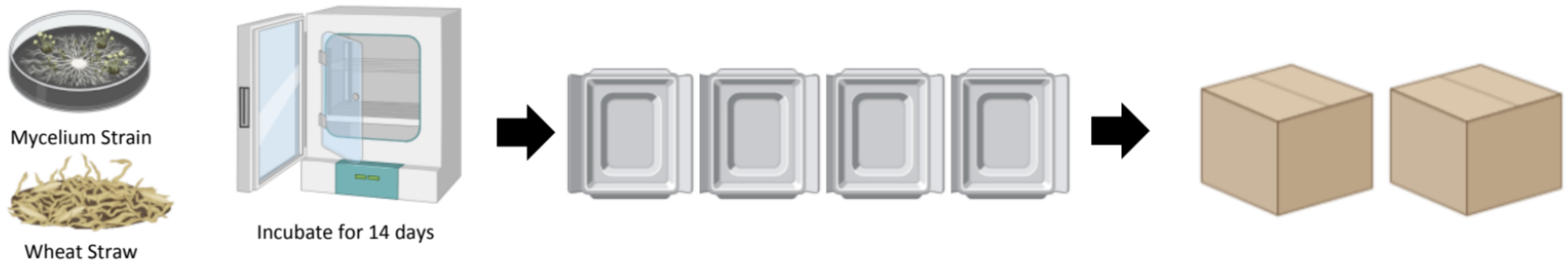
- 9.375 g Mycelium
- 0.1619kg Wheat Straw

- 1.875 kg Mycelium
- 32.38 kg Wheat Straw

- 22. [illegible] m
- 388.56 kg Wheat Straw

2. Process Design

■ Unit operations



	Mycelium Inoculation & Incubation	Molding & Drying	Packaging
Input	**1) Energy**: Incubation room (temperature & humidity) **2) Sterilize substrate**	**1) Energy**: Pressure & Heat 2) Mold, drying facility, adhesive & coating agent: corn zein	**1) Packaging Material (Box)** **2) Energy**: Electricity
Output	1) Mycelium 2) Fungal biomass 3) Residue of wheat straw	1) Mycelium wallet 2) Residue of mycelium leather	1) Packaged product

2. Process Design

- **LCA: Water**

Steps

- Substrate Washing: $16.19\ kg\ wheat\ straw\ \times 4 = \mathbf{64.76\ kg\ Water}$
- Mycelium Cultivation: $947.5\ g\ mycelium \times 65\%\ humidity \times 14.2\ days$ **Water**

73.505 kg Water / 100 Wallets

- **LCA: Energy**

Steps	User	kw	Batch Time (hr)	kwh
Sterilizing substrate (wheat straw)	Autoclave	7.5	3	22.5
Mycelium Cultivation (14.2 days)	Incubator (Chamber volume 120L)	1.4	340.8	477.12
Drying	Drying incubator	1.45	1	1.45
			Total	**501.07**

2. Process Design

■ **Hotspots, design changes to be implemented**

- **95% of Energy** was consumed during the **mycelium cultivation stage**.
- **Reducing cultivation time** should be needed.

Steps	User	kw	Batch Time (hr)	kwh
Sterilizing substrate (wheat straw)	Autoclave	7.5	3	22.5
Mycelium Cultivation (14.2 days)	Incubator (Chamber volume 120L)	1.4	340.8	**477.12**
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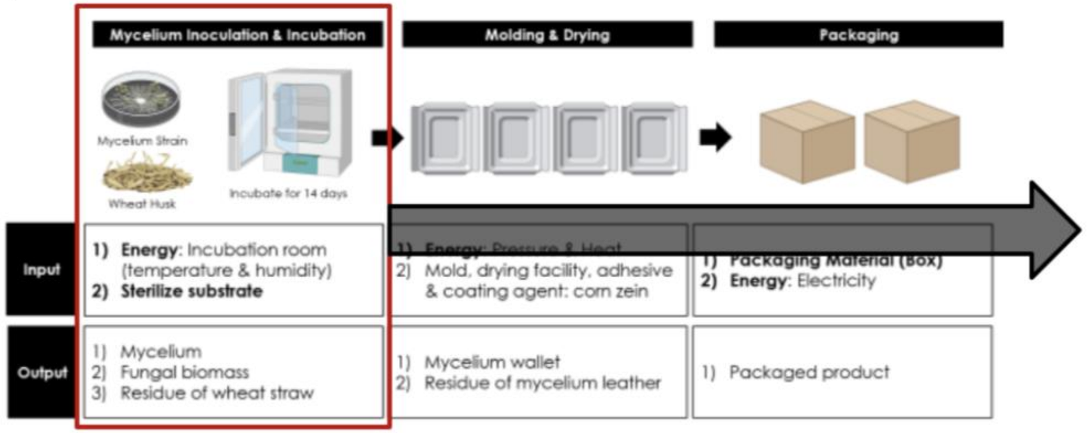


Changing Strain or Substrate that can produce more mycelium in a shorter cultivation period.

3. End-of-life scenarios

■ Cradle-to-Grave

- **Substrate, mushroom spawn, and mycelium** are natural and renewable, so the final products are **biodegradable** (Silverman et al., 2020).

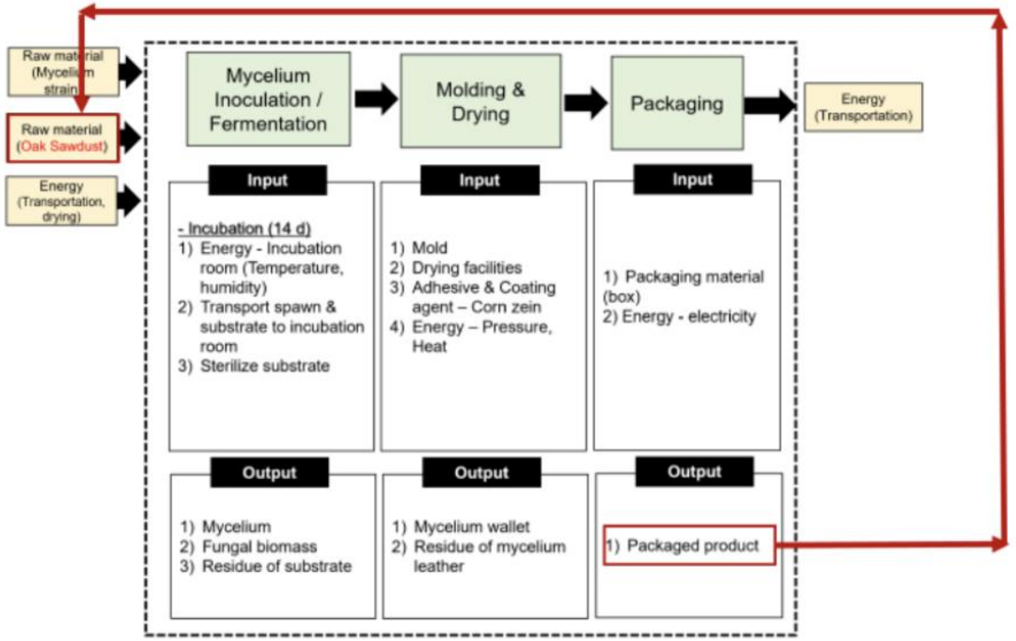
- After consumer's use, the mycelium wallet can be **composted to return their nutrients to the earth for agricultural production** (McDonough & Braungart, 2002).

- Mycelium can serve as a **source of nutrients for organisms** when decomposed in the soil (Raffie et al., 2021).

- However, this only applies if mycelium wallets are made without the addition of synthetic adhesives.

■ Cradle-to-Cradle

- Substrates can be recycled.



Sustainability in Process Design

BME 0194-04

Kirsten Trinidad

Learning Objectives:

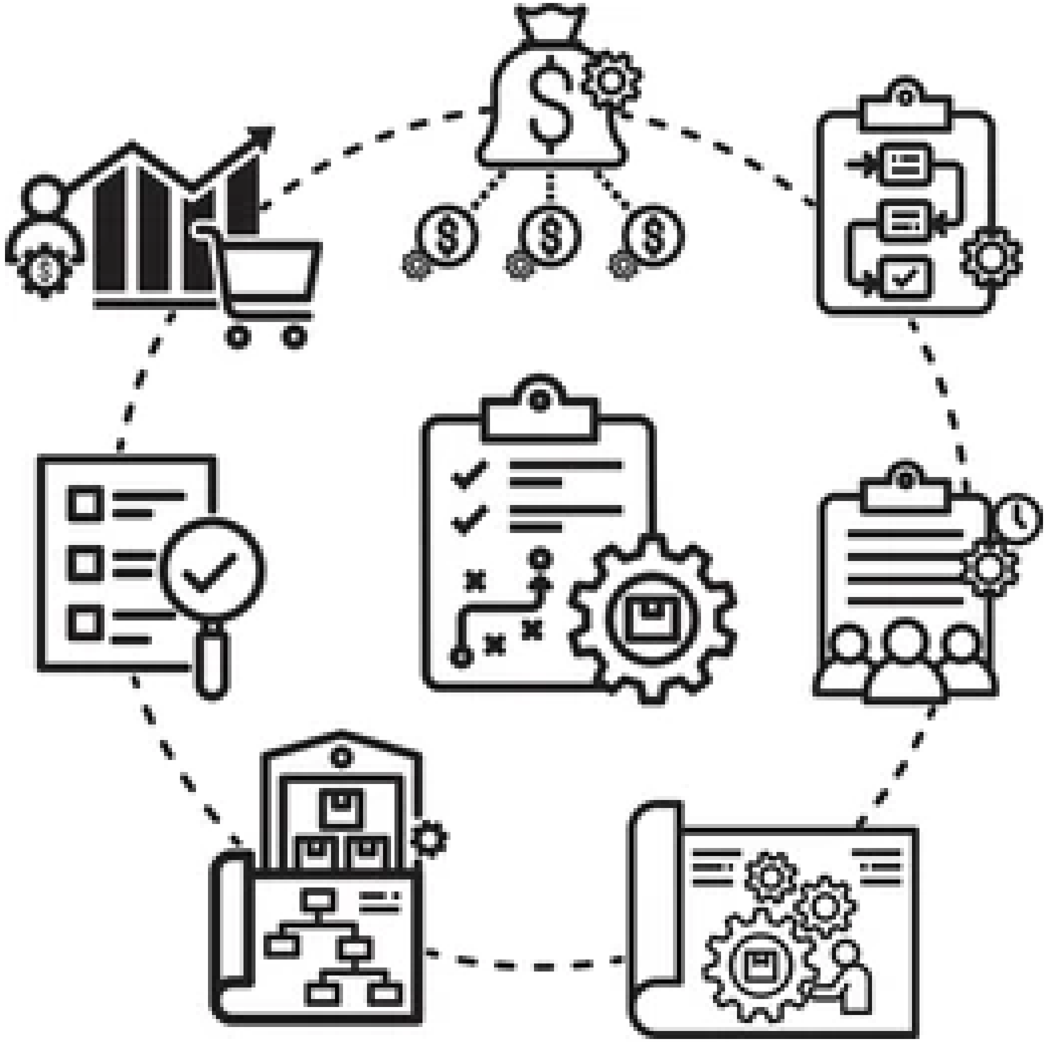
1) Sustainable production

- ❖ Introduction
- ❖ Kaizen
- ❖ 5S
- ❖ Cellular Manufacturing
- ❖ JIT/Kanban
- ❖ TPM
- ❖ Six Sigma
- ❖ 3P

2) Life cycle analysis

- ❖ Introduction
- ❖ Example

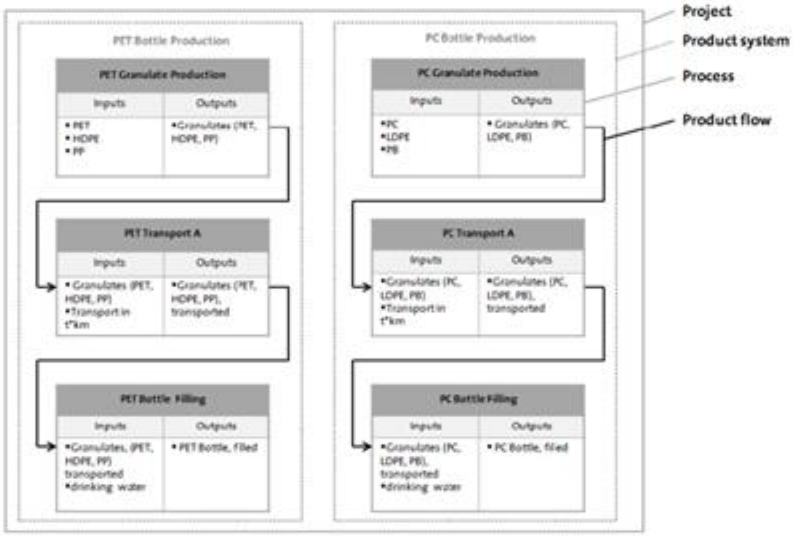
3) Final assignment

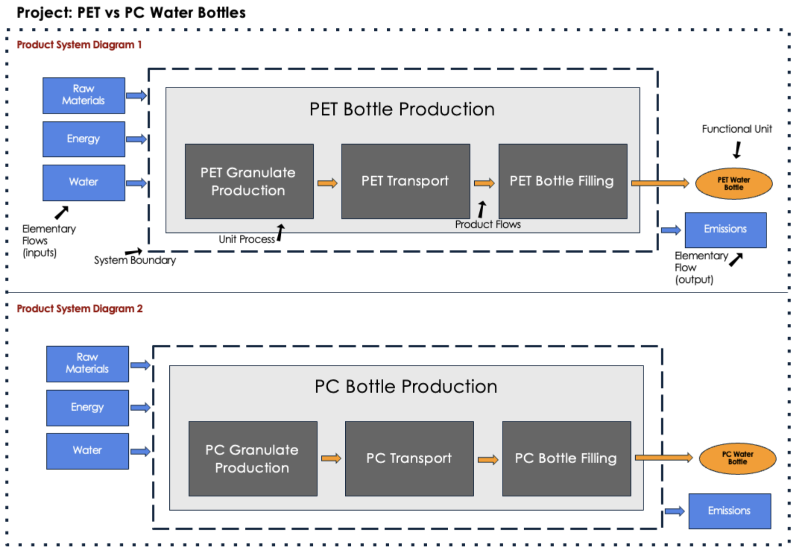


Goal: Estimate an LCA of your product, to find priorities for sustainability and make fair comparisons between alternatives. You should compare it with conventional solution and prove that your solution can be more sustainable (like a start-up pitch).

Task: 2 LCA, one for non sustainable conventional solution and one for your chosen material.

Minimum requirements: Water LCA and Energy LCA for both solutions.





Learning Objectives:

1) Sustainable production

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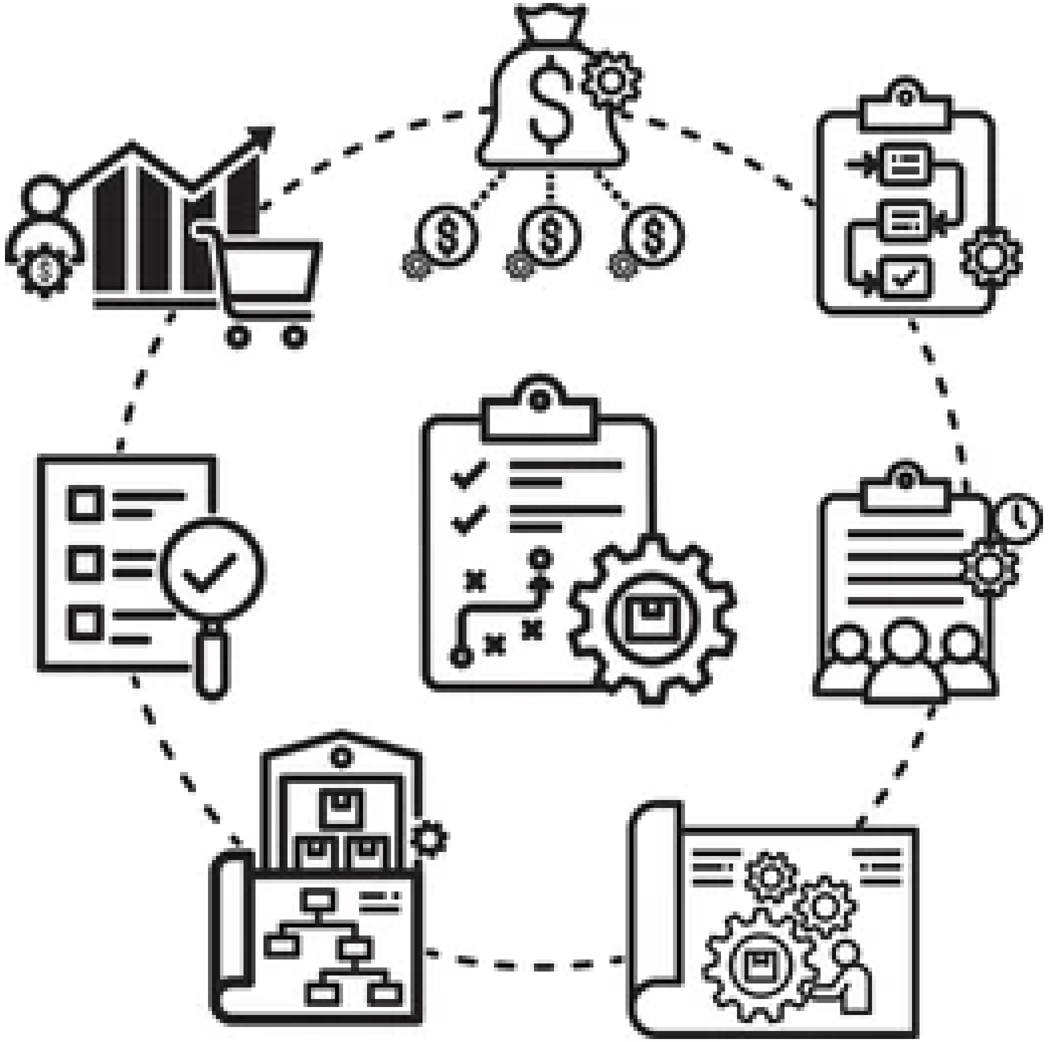

Lecture 16-17

Learning Objectives:

1) Sustainable Materials Management

2) Recycling

3) Sustainable production

4) Life cycle analysis

5) Final assignment