UNIT-3
Part-2

DFMA tools:
DFA index, poke -yoke, lean principles, six sigma concepts,
Design for Environment (DFE)

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DFA Index (Assembly Efficiency)

- An essential ingredient of the DFA method is the use of a measure of the DFA index or "assembly efficiency" of a proposed design.
- In general, the two main factors that influence the assembly cost of a product or subassembly are:
  - The number of parts in a product
  - The ease of handling, insertion, and fastening of the parts

- The DFA index is a figure obtained by dividing the theoretical minimum assembly time by the actual assembly time.
- The equation for calculating the DFA index *E*ma is

$$E_{ma} = \frac{N_{min} t_a}{t_{ma}}$$

- where *N*min is the theoretical minimum number of parts, *t*a is the basic assembly time for one part, and *t*ma is the estimated time to complete the assembly of the product.
- The basic assembly time is the average time for a part that presents no handling, insertion, or fastening difficulties (about 3 s).

The figure for the theoretical minimum number of parts represents an ideal situation where separate parts are combined into a single part unless, as each part is added to the assembly, one of the following criteria is met:

1. During the normal operating mode of the product, the part moves relative to all other parts already assembled. (Small motions do not qualify when they can be obtained through the use of elastic hinges.)
2. The part must be of a different material, or be isolated from all other parts assembled (for insulation, electrical isolation, vibration damping, etc.).
3. The part must be separate from all other assembled parts; otherwise, the assembly of parts meeting one of the preceding criteria would be prevented.

- It should be pointed out that these criteria are to be applied without taking into account the general design or service requirements.
- For example, separate fasteners do not generally meet any of the preceding criteria and should always be considered for elimination.
- To be more specific, the designer considering the design of an automobile engine may feel that the bolts holding the cylinder head onto the engine block are necessary separate parts.
- However, they could be eliminated by combining the cylinder head with the block—an approach that has proved practical in certain circumstances.

- If applied properly, these criteria require the designer to consider means whereby the product can be simplified, and it is through this process that enormous improvements in assemblability and manufacturing costs are often achieved.
- However, it is also necessary to be able to quantify the effects of changes in design schemes.
- For this purpose, the DFA method incorporates a system for estimating the assembly cost which, together with estimates of parts cost, gives the designer the information needed to take appropriate trade-off decisions.

POKA-YOKE (Mistake Proofing)

- Poka-Yoke is designing the work process to eliminate human mistakes.
- Fool proofing system is a means to create devices that can discover defectives without the workers having to be attentive to minute detail.

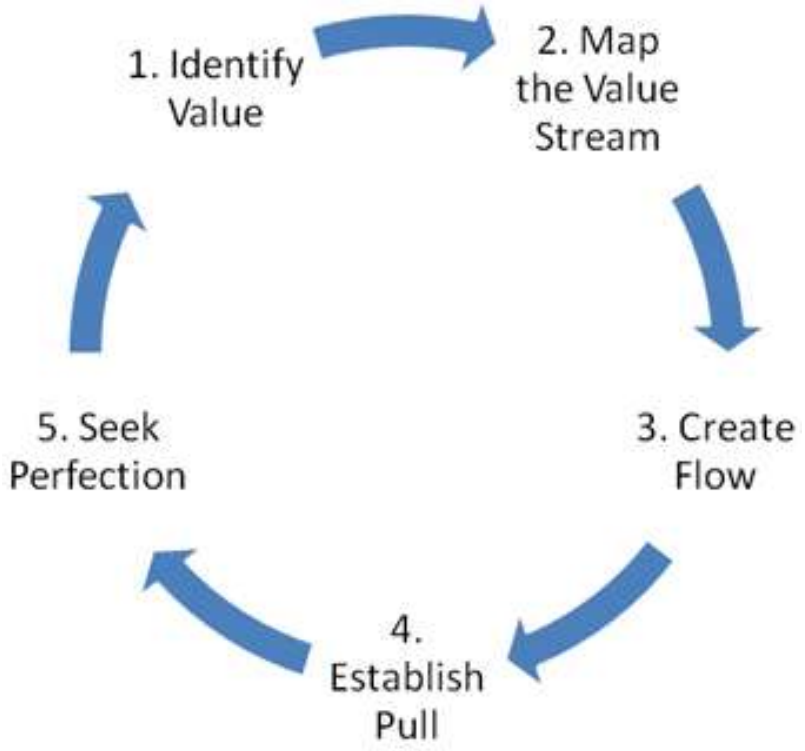
Steps

The steps for fool proofing are,

- If there is a miss step, the device does not allow goods to be mounted to jigs.
- If a disorder is found in the goods, the device does not allow the machine to start processing.
- If there is a miss step in work process or in motion, it is automatically adjusted, and the device will allow processing to proceed.
- The disorder that has occurred in preceding process is examined at the next process, and the device will stop defectives.
- If a certain operation is forgotten or stopped, the device does not allow the next operation to begin.

Lean Principles

- The goal of lean is to eliminate waste—the non-value-added components in any process.
- Unless a process has gone through lean multiple times, it contains some element of waste.
- When done correctly, lean can create huge improvements in efficiency, cycle time, productivity, material costs, and scrap, leading to lower costs and improved competitiveness.
- And remember, lean isn't restricted to manufacturing.
- It can improve how a team works together, inventory management, and even client interaction.



Five Key Principles

1. Value.

- Value is always defined by the customer's needs for a specific product.
- For example, what is the timeline for manufacturing and delivery?
- What is the price point?
- What are other important requirements or expectations that must be met?
- This information is vital for defining value.

2. Value stream.

- Once the value (end goal) has been determined, the next step is mapping the “value stream,” or all the steps and processes involved in taking a specific product from raw materials and delivering the final product to the customer.
- Value-stream mapping is a simple but eye-opening experience that identifies all the actions that take a product or service through any process.
- That process can be in design, production, procurement, HR, administration, delivery, or customer service.
- The idea is to draw, on one page, a "map" of the flow of material/product through the process.
- The goal is to identify every step that does not create value and then find ways to eliminate those wasteful steps.
- Value-stream mapping is sometimes referred to as process re-engineering.
- Ultimately this exercise also results in a better understanding of the entire business operation.

3. Flow.

- After the waste has been removed from the value stream, the next step is to be sure the remaining steps flow smoothly with no interruptions, delays, or bottlenecks.
- "Make the value-creating steps occur in tight sequence so that the product or service will flow smoothly toward the customer," advises LEI (Lean Enterprise Institute).
- This may require breaking down silo thinking and making the effort to become cross-functional across all departments, which can be one of the greatest challenges for lean programs to overcome.
- However, studies show that this will also lead to huge gains in productivity and efficiency, sometimes as high as 50-percent improvement or more.

4. Pull.

- With improved flow, time to market (or time to customer) can be dramatically improved.
- This makes it much easier to deliver products as needed, as in “just in time” manufacturing or delivery.
- This means the customer can “pull” the product from you as needed (often in weeks, instead of months).
- As a result, products don’t need to be built in advance or materials stockpiled, creating expensive inventory that needs to be managed, saving money for both the manufacturer/provider and the customer.

5. Perfection.

- Accomplishing Steps 1-4 is a great start, but the fifth step is perhaps the most important: making lean thinking and process improvement part of your corporate culture.
- As gains continue to pile up, it is important to remember lean is not a static system and requires constant effort and vigilance to perfect.
- Every employee should be involved in implementing lean.
- Lean experts often say that a process is not truly lean until it has been through value-stream mapping at least half a dozen times.

Six Sigma Concept

- The six sigma concept lays emphasis on quality.
- It aims at eliminating errors that exist in a process, product or service.
- Thereby, enhancing process, product or service improvements.
- In addition, the six sigma concept ensures customer satisfaction and loyalty.

Benefits of Six Sigma Concept

- The six sigma concept focuses on reducing variation.
- Since sigma is derived from standard deviation, the concept of six sigma seeks to reduce deviation to the barest minimum.
- When an organization reduces variation in its products, processes or services, it is able to achieve consistency. Consistency leads to quality.
- *Thus, if an organization's process is operating at a Sigma 1, it indicates that most of its products are defective. A more practical situation may be to operate at a Sigma 3 or 4. However, an ideal situation would be to operate at a sigma 6. For example, if the organization produces a million goods, at a Sigma 3, 93.32% or more of the organization's products are non-defective. This will result in 66,800 defective products. At sigma 4, 99.38% of the organization's products are non-defective. This leads to 6,210 defective products. Whereas, at a Sigma 6, 99.99% of the organization's products are non-defective. This will result in only 3.4 defective products*

Pros of six sigma

- Six sigma helps to measure process quality.
- The main aim of six sigma is to improve the final product by eradicating all forms of defects in the process.
- However, it is data driven so it depends heavily on management strategies.
- The goal of the six sigma concept is to work smarter, not harder.
- It uses data collated to improve the process, reduce/ eliminate mistakes and increase sigma rating.

Cons of six sigma

- Nonetheless, six sigma is very rigorous to implement.
- It involves a somewhat difficult process that takes a long time to achieve.
- By so doing, it ensures that everyone involved in the process is following closely enough to realize the value of six sigma.
- For this reason, six sigma is performed by a selected team of trained and certified professionals.

Six Sigma Process

FMEA

- FMEA is an acronym for Failure Mode Effects Analysis.
- This six sigma technique is also known as potential failure and effects analysis or Failure Modes, Effects and Criticality Analysis (FMECA).
- It is used to detect likely errors that might occur in a product, service, process or design.
- There are two types of FMEA; they are Process FMEA (PFMEA) and Design FMEA (DFMEA).
- FMEA can be used in the Analyze or Design phase of DMAIC, depending on what it intends to achieve.

5Why

- 5Why is a six sigma technique that helps to ascertain the root cause of defects by asking "why" questions.
- Similarly, Fault Tree Analysis (FTA) is a technique used in the six sigma process to identify potential causes of errors, before they occur.
- This technique employs statistical and analytical strategies to determine the highest causes of errors.

Voice of the customer

- The voice of the customer is a proactive technique used to gather feedback from customers.
- It is applied to both the internal and external customers of an organization.
- This technique is used in the six sigma process to understand customer's needs, expectations and experiences.
- By so doing, process improvements can be tailored in a way that meets and exceeds customer's expectations.
- The best way to know the "voice of the customer" is through direct conversations and interviews.
- Group discussions and surveys are other methods of determining the voice of the customer.

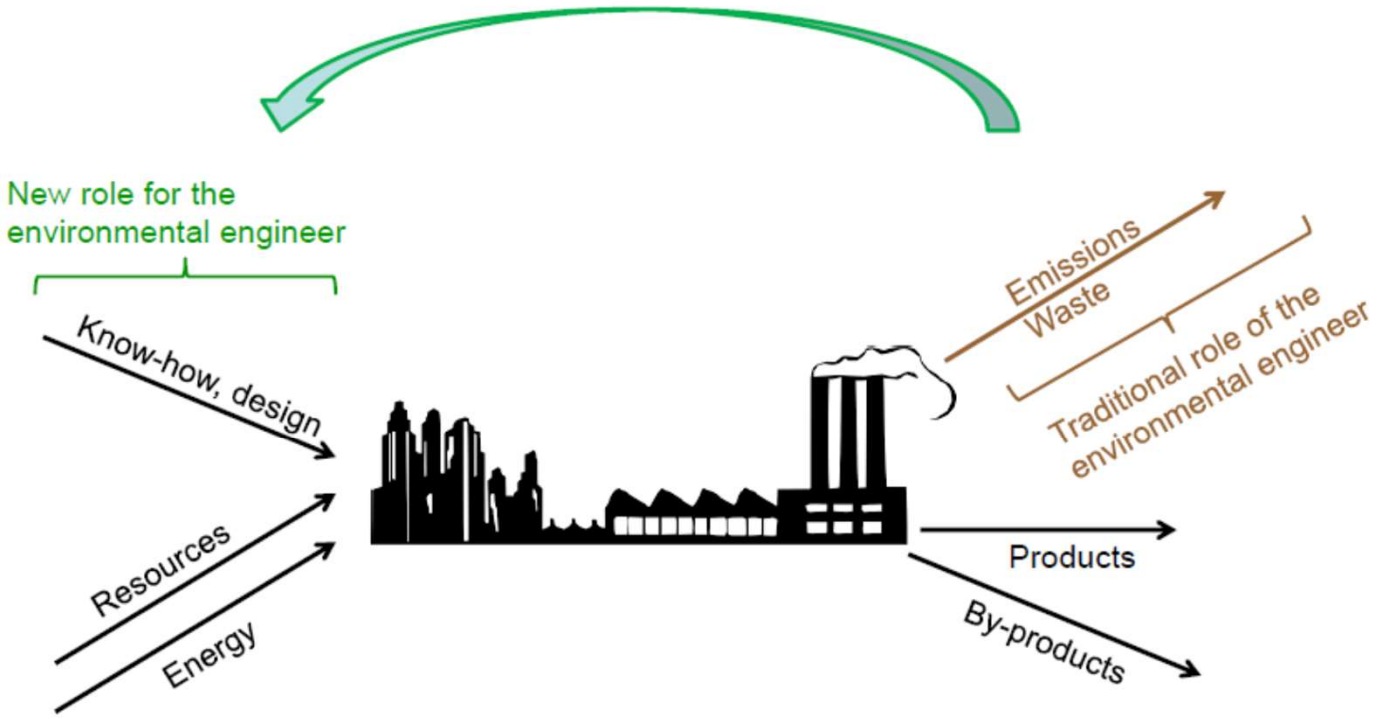
SIPOC

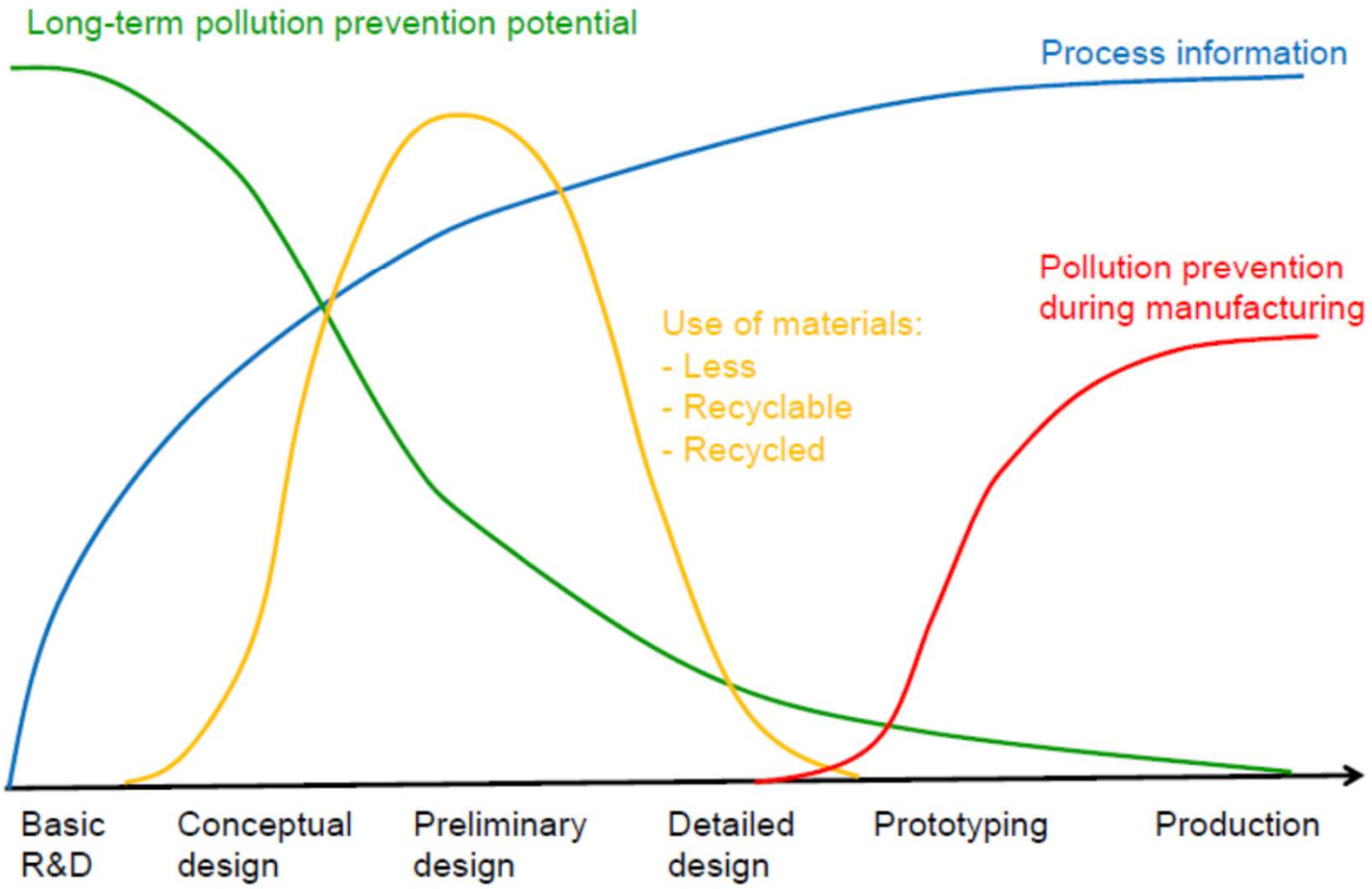
- SIPOC is a technique used in six sigma processes to understand the scope and function of the process under review.
- SIPOC is an acronym for Suppliers – Inputs – Process – Outputs – Customers.
- These elements are connected in one way or the other.
- First of all, suppliers provide inputs for the process.
- These inputs are in the form of resources, services or information.
- Secondly, the process requires inputs to generate outputs.
- The process is a flow of activities that modify the inputs to produce valuable outputs that give value to customers.
- Thirdly, outputs are the end products, service or information.
- Finally, customers are the end-users of the outputs generated by the process.
- Usually, SIPOC technique is applied during the Define phase of DMAIC.

Process maps

- These are used in the six sigma process to outline an existing process in a simplified way.
- Process maps require two steps.
- One step describes the process as the team thinks it is, while the other describes the process as the team desires it to be.
- Therefore, a process map can be defined as a think flow chart.
- This is one of the most common techniques used in six sigma process.

Design for Environment (DFE)





Adapted from Hertz (1995) and Bishop (2000)

Major design considerations:

An anonymous designer starting work

Industrial designers need to mind:

- Functionality and performance (product must do the job)
- Manufacturability, logistics (one should be able to make the product)
- Reliability, safety (there must be some quality standard)
- Cost, market penetration (product needs to be competitively priced)

The various levels of **DESIGN for ENVIRONMENT**: **DfX**

DfM	Design for Manufacturability	To enable pollution prevention during manufacturing For less material For fewer different materials For safer materials and processes
DfEE	Design for Energy Efficiency	For reduced energy demand during use For flexible energy use Design for use with renewable energy Design for Zero Emission Design for Carbon Neutrality
DfZT	Design for Zero Toxics	
DfD	Design for Dematerialization	
DfP	Design for Packaging	Minimize packaging – Rethink selling method
DfL	Design for Logistics	Use of local materials – Less Transportation Arrange outsourcing to minimize transportation
DfL	Design for Longevity	Design for Modularity Design for Serviceability
DfMo	Design for Modularity	To ease upgrading → Delay replacement To ease serviceability and, later, disassembly
DfS	Design for Serviceability	For ease of repairs → longer life For recapture of used/broken parts

The various levels of **DESIGN for ENVIRONMENT**
(continuation)

DfRMV	Design for reduced material variety	
DfRM	Design for use of recycled materials	
DfD	Design for Disassembly	To promote re-use of components For quicker and cheaper disassembly For more complete disassembly For dismantling by simple tools
DfR	Design for Recycling	For greater materials recovery Use of materials that can be locally recycled For easier materials identification For safer disposal of non-recyclables
DfER	Design for Economic Recycling	To enable and promote recycling
DfC	Design for Compostability	
DfER	Design for Energy Recovery	For safe incineration of residues For composting of residues
DfC	Design for Compliance	To meet regulations more easily To prepare for future regulations

Major questions arising in
DESIGN FOR ENVIRONMENT

1. Product or process?

Automotive examples:

Make essentially the same product, but with different materials

Steel → aluminum chassis

Make the same product in a different way

ex: as to minimize energy consumption or generation of by-products

Gas car → hybrid car

Make a different product that fulfills the same function

Personal cars → public transportation

2. At which level?

Microscale: Part of a product
A unit of production

Mesoscale: The entire product
The entire factory

Macroscale: Meeting the function (service) in a new way
Rethinking the industry-environment relation (social concerns)

Example of Design for Environment applied to a manufacturing process

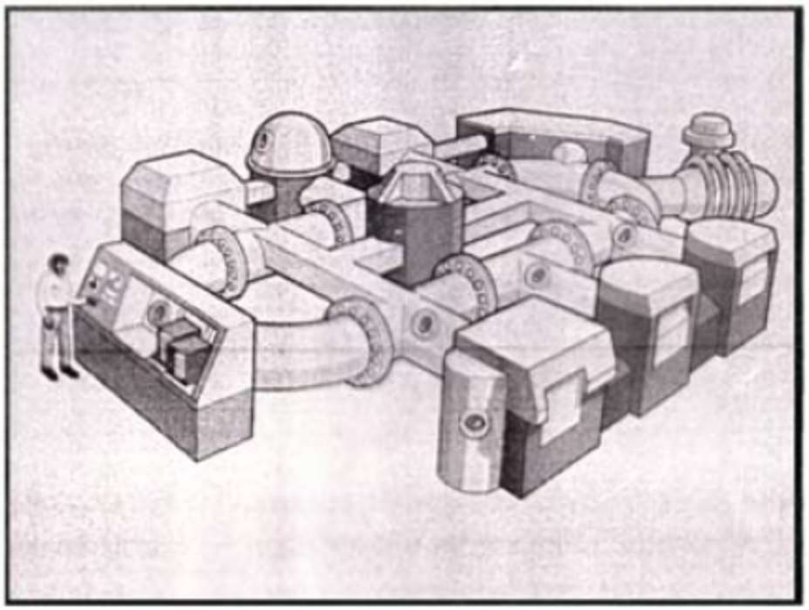


Figure 23.4 A concept for the manufacture of electronic circuits by "cluster processing" techniques. (Courtesy of C. K. N. Patel, University of California, Los Angeles)

Advantages:
- Less air to be dust-free and less chance of dust intrusion
- In the absence of personnel inside the controlled volume, freedom to have an oxygen-free atmosphere (pure nitrogen) to reduce oxidation or other undesirable side effects

Option 2: REDESIGN of PRODUCTS

- Consider function rather than the object:
  Can this function be met with a smaller product, with a more benign product?
  Or, at the limit, could it be met as a service without any material product?

- Don't forget: Package is part of product
  → Rethink the packaging of the product, too

Barriers: - Technological (alternative is not technically feasible)
- Ergonomic, Safety (alternative may be a misfit or unsafe)
- Societal (people may not be prepared for the alternative)

Examples of radical redesigns
(unfortunately having little to do with environmental considerations…)

Note how in each instance,
the function is met by a radically different product,
which happens to use less material and/or
consume energy.

"Great horse manure crisis of 1894"

Prediction around that time based on continued growth:

In New York City, about 100,000 working horses will produce roughly 2.5 million pounds of manure a day.

Residents will be exposed not only to the stench but also to biohazards like anthrax.

Roughly 20,000 New Yorkers will die each year from diseases related to horse waste.

Now, let's see what actually happened…

Analogy between then and now:

Horse generating manure → Automobiles spewing CO_2

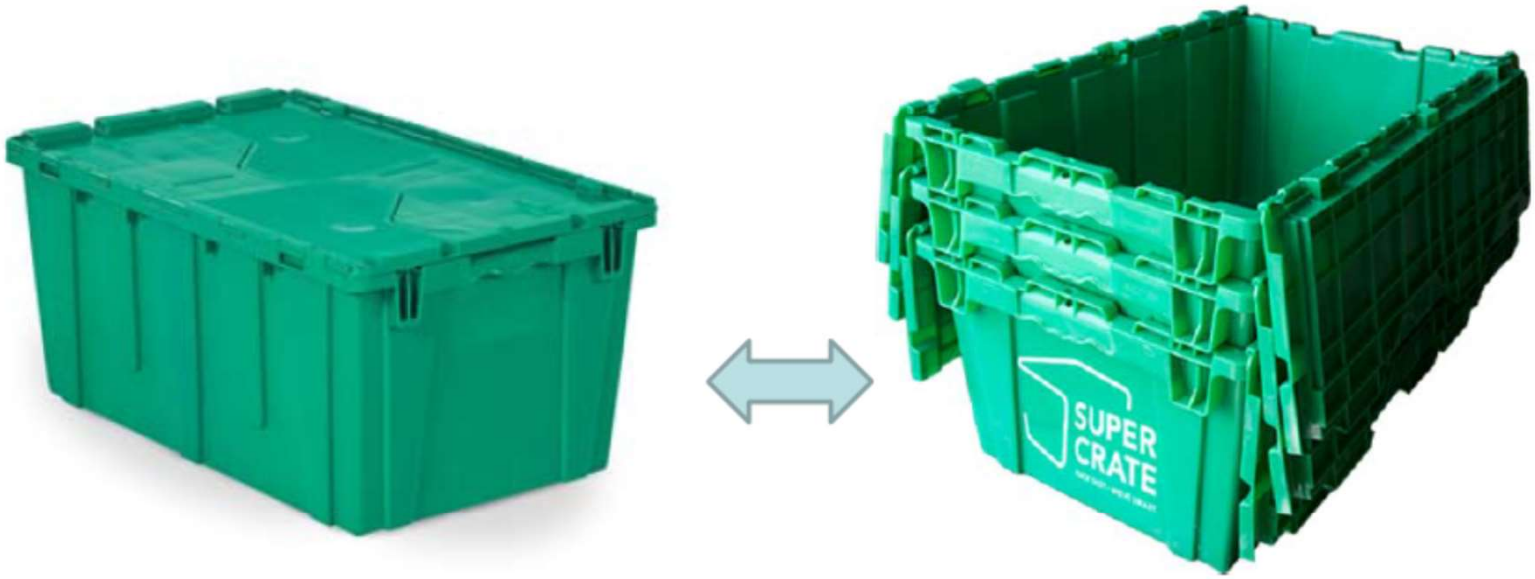
Unsanitary conditions → Climate change

Switch from horses to gas engines
→ Switch from gas engines to electric and driverless cars?

Smart use of material and modularity

Glass-filled Durethan polyamide-6 resin from Miles Polymers Division, injected on and around a perforated piece of metal, solidifies to cribbed a ribbed, securely bounded, interlocked composite structure.

Reusable crates



The Equator EZ 3612CEE is a washer/dryer combination that meets the strict energy efficiency requirements of Energy Star's Tier 4B.

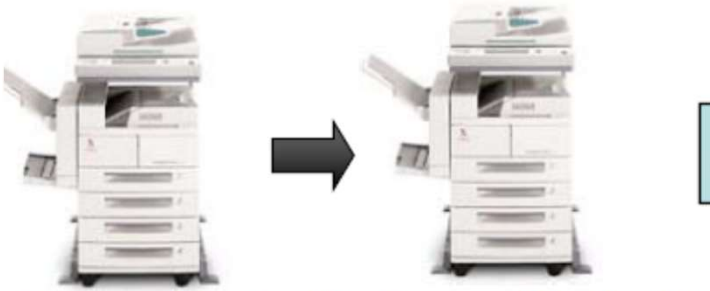
This great little machine is not only two machines in one and compact; it also requires no venting. The 3612CEE offers the perfect solution for apartment dwellers who are unable to vent a standard-type dryer.

The downside of this option is that this type of drying, called condensing, is much slower than a vented dryer. Many users find the best way to do laundry with this machine is to put it in before they go out for the day. It is then completed by the time they return home.

An added benefit is that this machine operates on standard electrical power and does not require 220-volt electrical service like a regular dryer. It does, however, require a water source and a drain.

(http://products.howstuffworks.com/equator-ez-3612cee-review.htm)

XEROX:
Parts Reuse and Equipment Remanufacturing



Document Centre 220 **Document Centre 220**

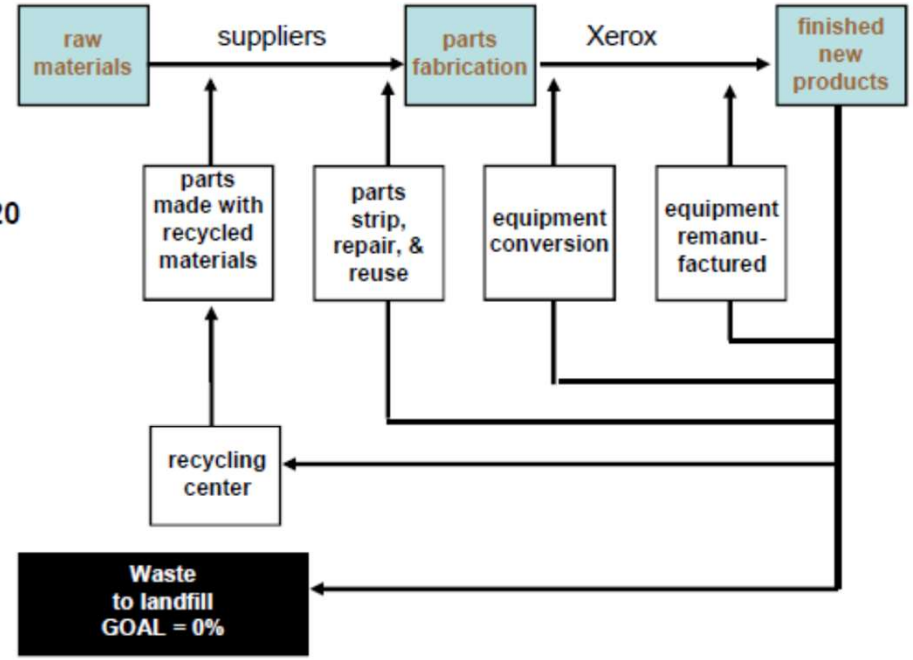
"newly manufactured" "remanufactured"

Document Centre 440

Conversion

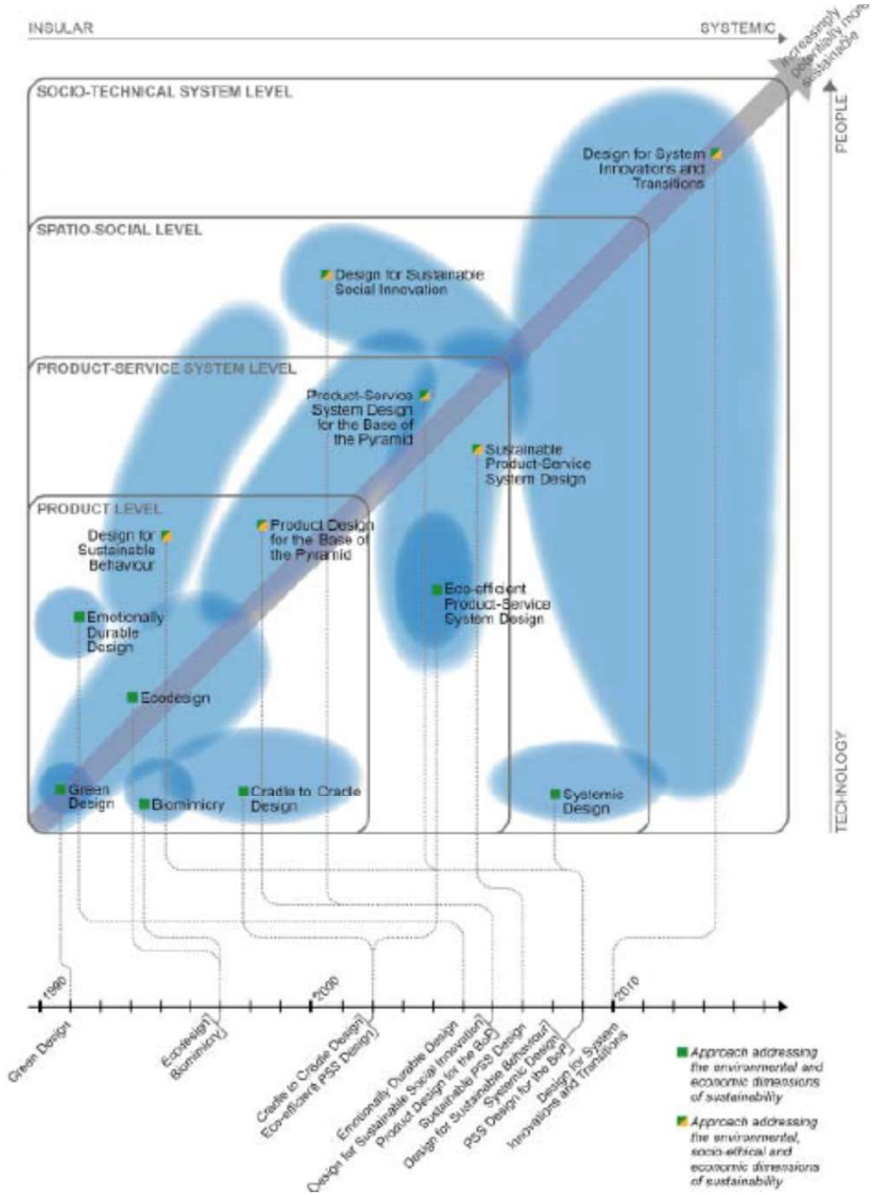
"Factory Produced New Model"

Reuse/Recycle Process



Goal: optimize financial and environmental benefits...

From object to system
and
From technology to people



Source:
Fabrizio Ceshin & Idil Gaziulusoy, 2016:
Evolution of Design for Sustainability.
Design Studies, **47**, 118-163.