Life Cycle Thinking in Designing Products for the Future

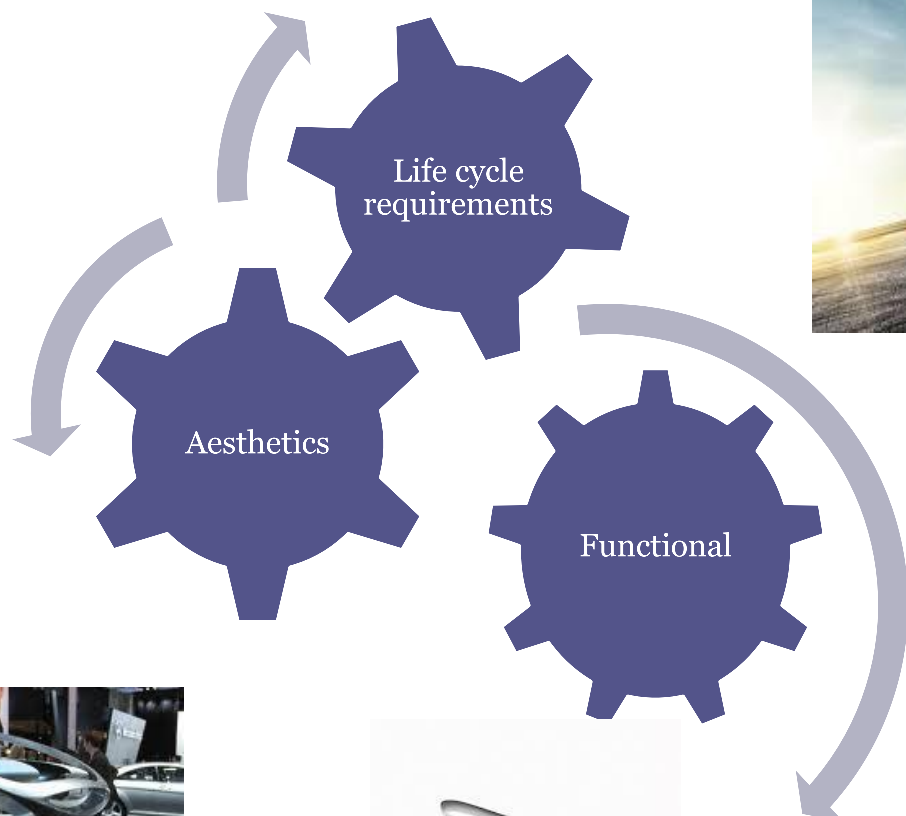
UNIVERSITI KEBANGSAAN MALAYSIA

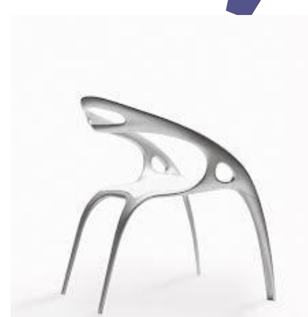
The National University of Malaysia

Prof Dr Dzuraidah Abd Wahab
Department of Mechanical and Materials Engineering
Faculty of Engineering and Built Environment
University Kebangsaan Malaysia
dzuraidah@ukm.my

To be competitive in today's market in which customer, technology and environmental requirements are fast-changing and unpredictable , products have to be innovative with clear functional purposes and market target.

Market needs





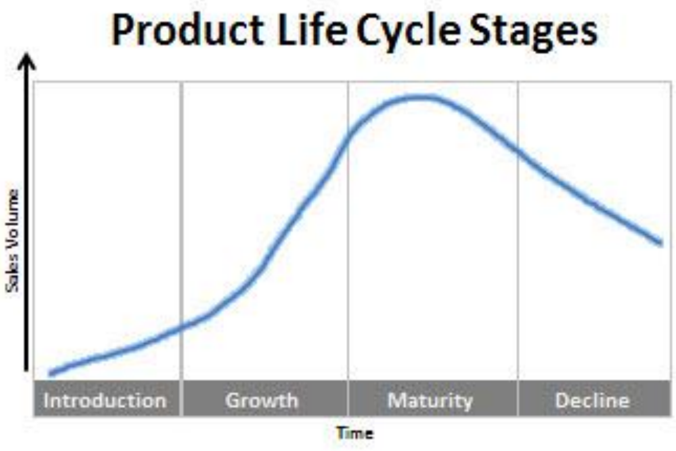
Product Life cycle

What is product life cycle?

- Product life cycle (PLC) is the cycle through which every product goes through from introduction to growth, maturity and decline.

An example related to recorded television and the various stages of each method:

- Introduction - 3D TVs
- Growth - Blueray discs/DVR
- Maturity - DVD
- Decline - Video cassette



Challenges:

- **In early phases** – to capture requirements from different stakeholders that will have interests to the system many years later.
- **In late phases** – to change the design and understand their implications on the origin requirements.
- **Collaboration** on the requirements from many disciplines and in different organizations. Involves multi disciplinary efforts to address various facets of product development through Design for X.

- **Authorities' Laws and Regulations**

product safety laws, environmental laws, safety and health laws, commercial laws, etc.

- **Customer , User and Maintainer Requirements**

business requirements, performance requirements, product requirements, delivery requirements, SOW requirements,

verification and validation requirement, deployment requirements, user requirements, support requirements, etc.

- **Designer: Design Requirements**

design rules, test rules, production constraints, functional requirements, system architecture requirements, design requirements, interface requirements, integration requirements, test requirements, supporting processes requirements, production requirements, installation requirements, etc

Trends in engineering design is now focused on greener living and reduction of environmental footprint:

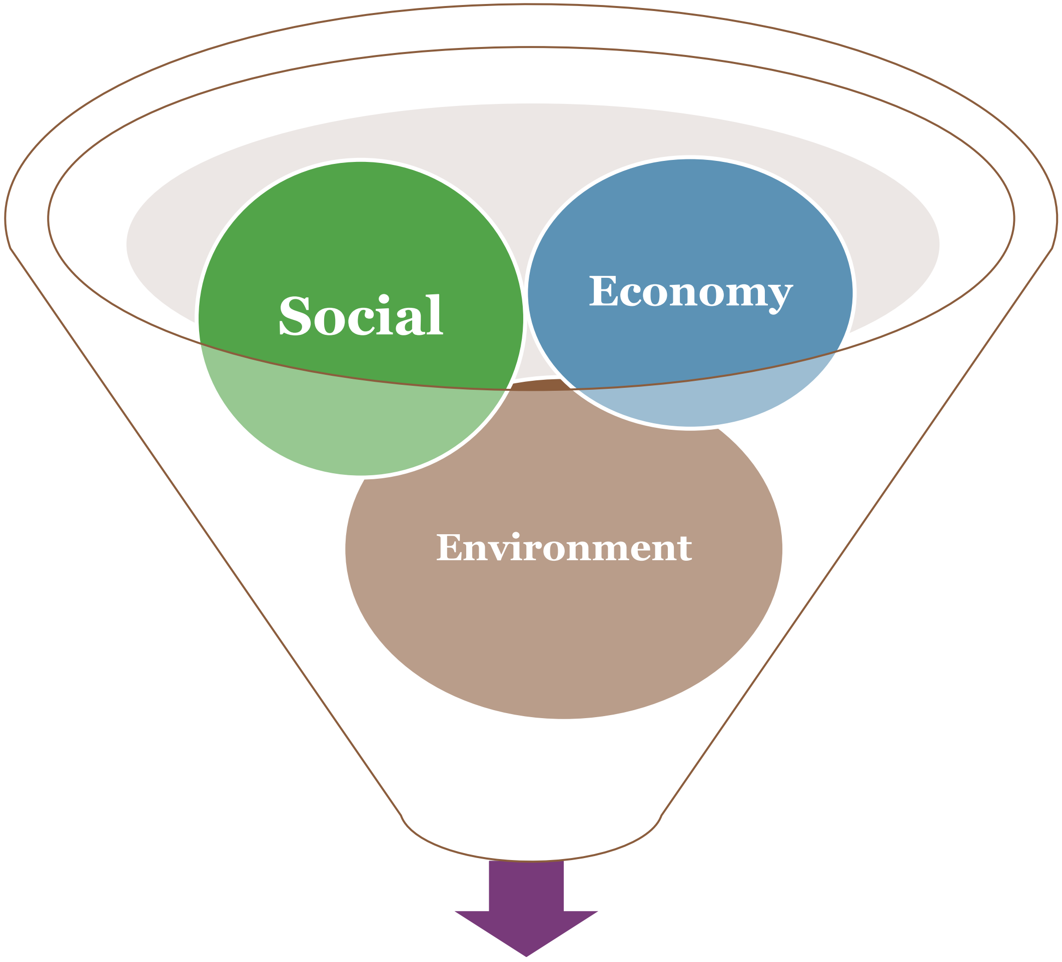
- Lowering energy consumption
- Minimizing environmental impact
- Automation

The **Brundtland Report**, from the United Nations World Commission on Environment and Development(WCED) was published in 1987. It defined sustainable development as development that

"meets the needs of the present without compromising the ability of future generations to meet their own needs."

For a company to grow and secure its growth in the future, it needs to embed sustainability into all its products, services and processes.

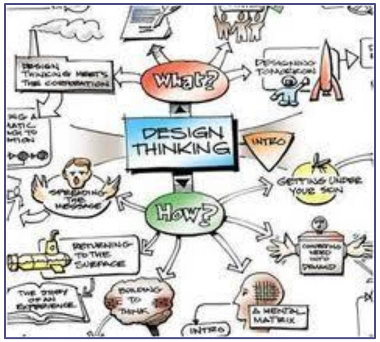
Pillars of sustainability

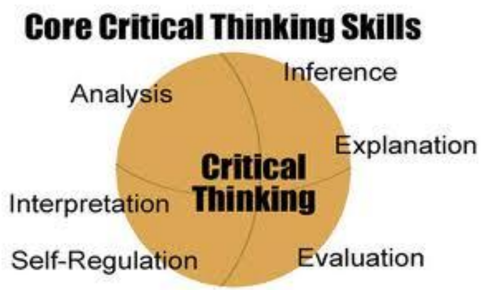


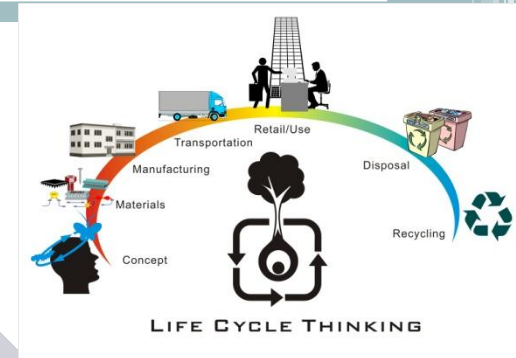
Environmental Sustainability

- The first step in designing a product for sustainability is to consider and analyse its eco-design and its life cycle impacts then minimise the largest environmental impacts form this analysis

- Ways of quantifying sustainability are carbon footprint or life cycle analysis which stems from life cycle thinking







Design thinking

Critical thinking

Life cycle thinking

Design thinking is a formal method for practical, creative resolution of problems or issues, with the intent of an improved future result.

Critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.

Life Cycle Thinking overall is a way to become more mindful of the complexities of consuming products and engaging in activities and how they affect the environment.

Life Cycle Assessment

- **Life-cycle assessment (LCA)** also known as life-cycle analysis, eco-balance, and cradle to grave analysis) is a technique to assess **environmental impacts** associated with all the stages of a product's life from-cradle-to-grave (as opposed to cradle-to-gate).

- The stages include from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling.

LCA can help avoid a narrow outlook on environmental concerns by:

- Compiling an inventory of relevant energy and material inputs and environmental releases;
- Evaluating the potential impacts associated with identified inputs and releases;
- Interpreting the results in order to make a more informed decision.

Why is LCA gaining importance?

Greater society awareness of the environment due to:

- Depletion of natural resources
- Environmental degradation.

Strategies

Generally, the approaches are:

- Use greener products
- Use greener processes

LCA refers to the major activities during a product life-span

1. Acquisition of raw material
2. Manufacture
3. Use
4. Maintenance
5. Final disposal

Input:
Material,
energy, water

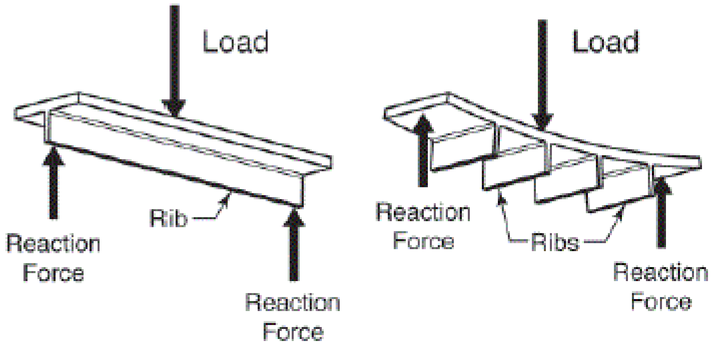
Output: Waste,
by-products,
emission, pollutants

1.Raw Materials Acquisition

- The life cycle of a product begins with the removal of raw materials and energy sources from the earth. For instance, the harvesting of trees or the mining of non renewable materials would be considered raw materials acquisition.
- Transportation of these materials from the point of acquisition to the point of processing is also included in this stage.

Basic rules in material selection for sustainability:

- follow the simple hierarchy - Reduce, Reuse, Recycle
- use as few **types** of materials as possible
- reduce the **quantity** of material used in the manufacture of a product through sensible ribbing design (to avoid changing material or increase sectional properties in order to improve stiffness)



- choose renewable material
- select materials which are compatible for recycling where possible

Materials Reduction

- Reducing the amount of material used in a product minimises manufacturing costs, reduces waste going to landfill, and conserves resources.
- It can be achieved by:
  - identifying and designing out any excess material
  - using precision cutting equipment to ensure the maximum use of raw materials
  - replacing bulk material with webbing*

***Webbing** *is a strong fabric woven as a flat strip or tube of varying width and fibres often used in place of rope e.g seatbelts*

Biodegradable materials

- Biodegradable materials can be broken down to their constituent parts by naturally occurring chemical compounds at the end of their useful life.
- Biodegradable materials are currently used in the manufacture of bags, cutlery, pens, clothing, credit cards, food packaging, agricultural films, teabags, coffee filters, diapers and napkins

Renewable materials

- Renewable materials such as wood, wool, paper, leather, sisal, jute, cotton and bio-plastics are harvested from sources which are naturally replenished by nature.
- Favourable to use over metals and plastics which are mined from ore and oil reserves

Using mainstream materials

- Most mainstream products are made from plastics such as polypropylene (PP), polyethylene (PE), PET, ABS, polystyrene (PS), glass or metals such as aluminium and steel.
- These materials are recyclable.

2. Manufacturing

- **Materials Manufacture** - The materials manufacture step involves the activities that convert raw materials into a form that can be used to fabricate a finished product.
- **Product Fabrication** - The product fabrication step takes the manufactured material and processes it into a product that is ready to be filled or packaged.
- **Filling/Packaging/Distribution** -It includes all of the manufacturing and transportation activities that are necessary to fill, package, and distribute a finished product.

Strategies include:

- **Reduce Packaging**

Minimising packaging, and using recyclable or recycled materials creates a good impression.

- **Reuse or recycle packaging**

Encourage customers to reuse packaging, make it so useful that customers do not want to throw it away or sell refills

3. Use/Reuse/Maintenance

- Consumer's actual use, reuse, and maintenance of the product.
- The product or material may need to be reconditioned, repaired or serviced so that it will maintain its performance. When the consumer no longer needs the product, the product will be recycled or disposed.

Energy Reduction

- A popular way of reducing the environmental impact of a product is to reduce the amount of energy it uses.
- Studies have shown that the use phase has the largest environmental impact across the product lifecycle. For this reason, reducing the energy during use is a popular approach for companies wanting to consider eco-design.

Durability

Making a product last longer can have positive impacts on the environmental and enhance brand value.

- Select materials carefully:
  - specify strong materials which can resist wear and withstand prolonged use
  - use materials and finishes which do not damage easily

- Ensure the product is manufactured to a high quality

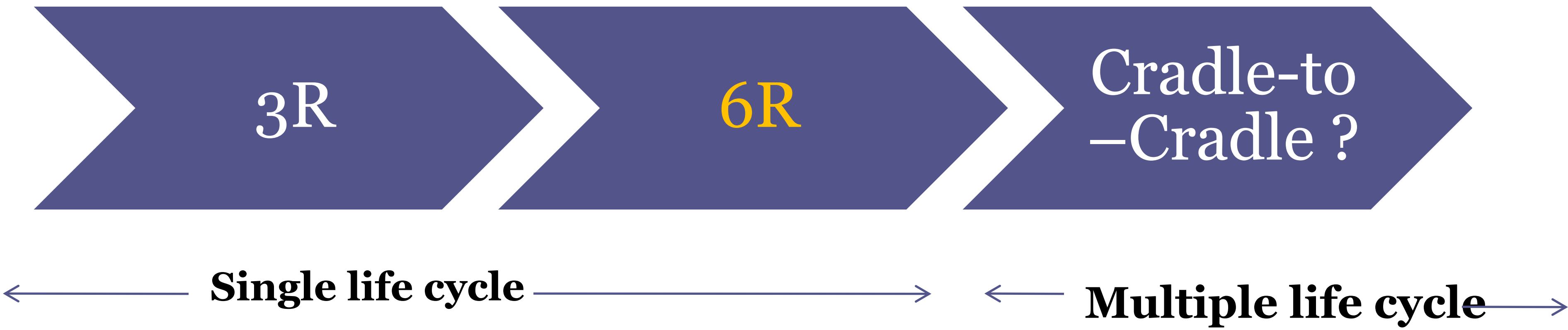
5. Recycle/Waste Management

- The recycle/waste management stage includes the energy requirements and environmental wastes associated with disposition of the product or material.

Take Back

- The WEEE Directive places responsibility for products at the end of their useful life in the hands of the producer.
- EU End of Life Vehicle Directives

Designing products for environmental sustainability



Cradle-to-cradle design is to develop multiple regenerative product life-cycles where byproducts can be cleanly metabolized by natural systems or fed back into original processes (McDonough and Braungart 2002).

Design strategies

- Ease of disassembly and reassembly
- Designing for Modularity (Product Architecture)
- Ease of Maintenance and Servicing
- Upgradability

Types of LCA tools

- Software packages intended for practitioners for e.g. GaBi Software, developed by PE International and SimaPro, developed by PRé Consultants,

- There are LCA tools that provide LCA-based results without having to develop the LCA data and impact measures e.g. at the product level:
    - U.S. National Institute of Standards and Technology (NIST) makes its BEES (Building for Environmental and Economic Sustainability) tool freely available,
    - Solidworks CAD software (DassaultSystèmes) presents LCA-based environmental information to the user through an add-on called SustainabilityXpress, and PTC's Windchill

Eco indicator 99

- Eco-Indicator 99 is a life cycle impact assessment tool developed by PRé Consultants B.V.

- Eco-Indicator 99 helps designers to make an environmental assessment of a product by calculating eco-indicator scores for materials and processes used. The resulting scores provide an indication of areas for product improvements.

- The Eco-Indicator is split into three sections:
  - production of raw materials (e.g. polystyrene), processing & manufacture (e.g. injection moulding)
  - transportation of product (e.g. shipping), energy in use (e.g. electricity), consumables in use (e.g. paper)
  - disposal

Eco labels

Energy Star

The EPA Energy Star programme aims to reduce energy consumption in electrical goods by putting in place measures to reduce energy wasted during idle. The EPA Energy Star is most widely used within the personal computer, printer, fax machine, copier and scanner markets. To obtain an EPA Energy Star manufacturers must demonstrate a 10-25% increase in efficiency above the level required by the federal standard.

Energy Saving recommended

The most efficient products can also display the Energy Saving Recommended logo. This label is applied to energy efficient products which reduce energy wastage, cost less to run and help the environment.

European Eco-label

Illustrated by the flower logo, the European Eco-label aims to help consumers make more informed choices by enabling them to easily identify products with a reduced environmental impact. The scheme is voluntary

Related past and on-going research on design sustainability:

The Sumitomo Foundation (Japan Fiscal 2011 Grant)- Reg. No. 118404

How Successful Can Remanufacturing Strategies Be Implemented For Automotive Manufacturing Sustainability? – A Comparison of Sociotechnical Perspectives between Japan And Malaysia (J¥ 800,000) 01/04/2012 – 31/3/2013

GUP-2013-042

Optimisation of Design and Process Parameters for Upgradability of Sustainable Engineered Components. 01/11/2013-31/10/2015 RM60,000

FRGS/2/2013/TK01/UKM/01/1

Assessment of Design Criteria for Optimum Multiple Generation Life Cycle, 16/12/2013 - 15/12/2015 RM83,000

ERGS/1/2012/TK01/UKM/02/7

Assessment of Energy and Process Efficiency in the Remanufacturing of Local Automotive Engines for Sustainable Design Considerations
01/06/2012 - 31/05/2015 RM 50,000

UKM-GUP-BTT-07-25-149

A New Methodology For Enhancing Component Re-Use In Locally Manufactured Automotive Component 01-10-2007 – 30-09-2011

UKM-KK-02-FRGS0198-2010

Development of a Design for Remanufacturing Index for end-of-life Recovery of Locally Manufactured Automotive Components 20/08/2010- 9/08/2012

UKM-GUP-2011-041

Modularity metrics for predicting design obsolescence in end-of-life automotive components for recovery purposes 08/08/2011 – 07/08/2012

- Product life cycle requirement management http://www.pdteurope.com/media/4290/13b_product_lifecycle_requirement_management_plrm.pdf
- Images from www.google.com.my
- Life Cycle Thinking http://en.wikipedia.org/wiki/Life_Cycle_Thinking
- Defining Critical Thinking https://www.criticalthinking.org/pages/defining-critical-thinking/766
- Design Thinking http://en.wikipedia.org/wiki/Design_thinking