TOTAL

GREEN BOOK : The Eco-innovation guide

This guide was realized by Laurie Bignalet, Maxence Plessis, Guillaume Laurent, Marine Simon and Louis Mérienne, five students from the EM Normandie business school, in collaboration with Total. It also received the support of Benjamin Lehiany working for Manadvise, a consulting firm.

SUMMARY

ACKNOWLEDGEMENTS

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Laurie Bignalet
Maxence Plessis
Marine Simon
Guillaume Laurent
& Louis Mérienne

HOW TO USE THE GUIDE?

This guide was elaborated to help the managers in their eco-innovative approach. It gives an overview of some of the eco-innovation techniques that can be used in the company environment to adapt its activity. The guide is composed of two main parts: what we classify as methods and what we classify as tools.

The methods are complete methodology that can be put in place in your service/department to accompany the development of new ideas, innovation, while respecting sustainability. Some of those methods can be used to start from scratch to build a path for a new eco-innovative project.

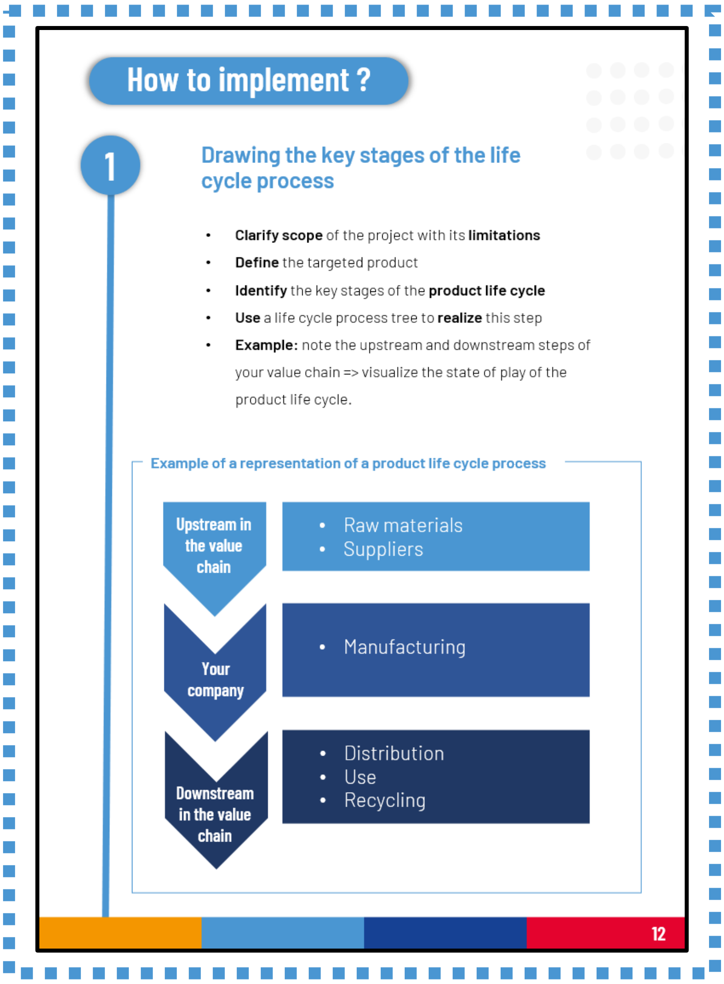
The tools are present to help the manager find solutions to challenges they are facing and as a complement to the methodology. Some of them are useful in a complete methodology and others can be used and adapted to your own project.

Thus, the first thing you should ask yourself is: What am I looking for? A complete methodology or a tool that could help me in my own method?

Methods are divided in multiple parts : **The definition, the origin, and the goals** which are giving you a global overview of the domain of application, the market application and the environmental aspects.

HOW TO USE THE GUIDE?

Following those three introductory parts of the methodology, you could find the process about how to conduct and **implement the methodology** to be successful. In this part, you will be able to find a visual representation of the method to illustrate how it can be used. Finally, as a conclusion, you will find the **pros and cons** of using such a method, looking at the part could also help you to make your choice.



At the end of the guide, you can find **cases** to illustrate applications of some methods. They are separated in three parts: **products**, **services,** and **process**. Moreover, we added a comparative table for you to choose between methods depending on your needs and requirements.

Moreover, to facilitate the navigation we built two matrices (see on next page) and we classify the method depending on their **function**. On his first page of the methodology, you will find a color code to evaluate if the method can be used for a product, a service or a process.

Product Service Process

How to use the guide?

A matrix to find the right method according to your needs

Goals / Methods	Pages	Function	Resolving environmental issues	Fostering innovation and problem-solving	Improving efficiency by reducing waste	Assessing the environmental impact of existing products	Designing eco-friendly products	Integrating eco-design process in an organization	Increasing services in an offer	Finding the right balance between people, planet and profit	Creating value for stakeholders
TRIZ	14	🟠 🔵 🔴	X	X							
TRIZ & LEAN	21	🟠 🔵 🔴	X	X	X						
Innovation Factor 4	27	🟠 🔵 🔴		X			X			X	X
Triple bottom line	34	🟠 🔵 🔴				X				X	X
LCA	40	🟠 🔵				X	X				
Environmental impact assessment	47	🟠 🔵	X							X	X
AFF	54	🟠 🔵	X				X				
PSS	60	🟠 🔵					X		X		X
Opengreen	66	🟠 🔵		X			X				X
QFDE	75	🟠 🔵					X				
MGE2	82	🟠					X				
Eco-design strategy wheel	89	🟠	X	X		X	X				
EEA	98	🟠	X			X	X				
Eco M2	106	🔴						X			

How to use the guide?

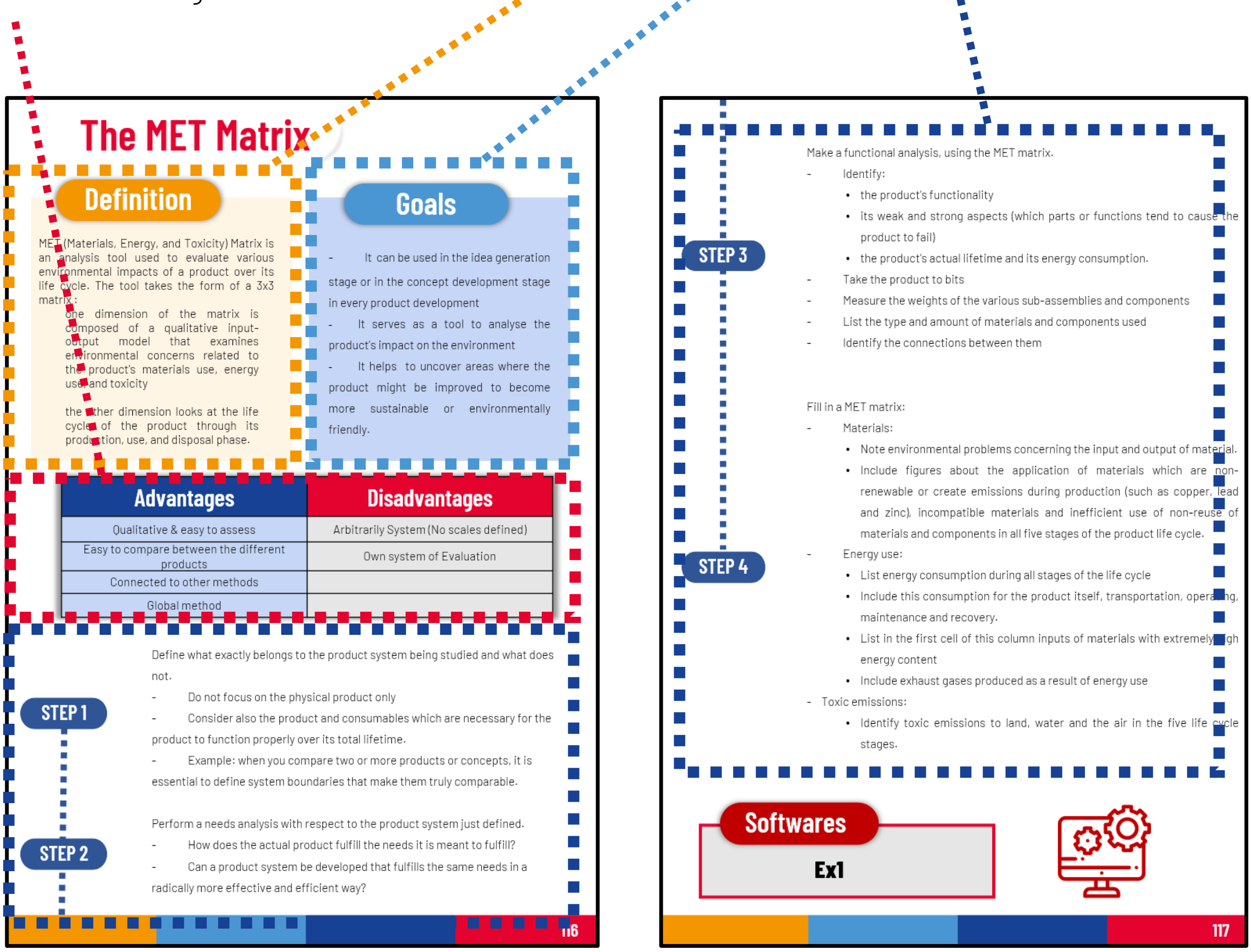
A matrix to find the right method according to the innovation life-cycle

Goals / Methods	Pages	Function	Definition of customers needs	Ideate	Prototype	Test	Implement	Review/ adjust	Growth	End of life
TRIZ	14	🟠 🔵 🔴	XX	XX	X	X	X	XX		
TRIZ & LEAN	21	🟠 🔵 🔴	XX	XX	X	X	X	XX		
Innovation Factor 4	27	🟠 🔵 🔴	X	XX	XX	X	XX	XX	X	
Triple bottom line	34	🟠 🔵 🔴	X	X	X	X		XX		
LCA	40	🟠 🔵	X	X	X	XX		XX		
Environmental impact assessment	47	🟠 🔵		XX	X	X	XX	XX	X	
AFF	54	🟠 🔵	XX	XX						
PSS	60	🟠 🔵	XX	XX			X			
Opengreen	66	🟠 🔵	XX	XX	X	X	X	X		
QFDE	75	🟠 🔵	XX	XX	X	X	X	XX		
MGE2	82	🟠		XX	X			XX		
Eco-design strategy wheel	89	🟠	X	XX	X	X	XX	XX		
EEA	98	🟠	X	XX	X	X	XX	XX		
Eco M2	106	🔴		XX			X	XX		

X : Medium impact   **XX** : Strong impact

HOW TO USE THE GUIDE?

The second part of the guide is composed of multiple tools that you could use in the method presented or to complement yours, adding the ecological view. We built the description of the tools in a more simplistic way, but we tried to reproduce as much as possible the format we use for the complete method. Then, you could find **the definition**, **the goals**, **how to use the tools**, and **the pros and cons** of using that tool.



The MET Matrix

Definition

MET (Materials, Energy, and Toxicity) Matrix is an analysis tool used to evaluate various environmental impacts of a product over its life cycle. The tool takes the form of a 3x3 matrix :

one dimension of the matrix is composed of a qualitative input-output model that examines environmental concerns related to the product's materials use, energy use and toxicity

the other dimension looks at the life cycle of the product through its production, use, and disposal phase.

Goals

- It can be used in the idea generation stage or in the concept development stage in every product development
- It serves as a tool to analyse the product's impact on the environment
- It helps to uncover areas where the product might be improved to become more sustainable or environmentally friendly.

Advantages	Disadvantages
Qualitative & easy to assess	Arbitrarily System (No scales defined)
Easy to compare between the different products	Own system of Evaluation
Connected to other methods	
Global method	

STEP 1

Define what exactly belongs to the product system being studied and what does not.

- Do not focus on the physical product only
- Consider also the product and consumables which are necessary for the product to function properly over its total lifetime.
- Example: when you compare two or more products or concepts, it is essential to define system boundaries that make them truly comparable.

STEP 2

Perform a needs analysis with respect to the product system just defined.

- How does the actual product fulfill the needs it is meant to fulfill?
- Can a product system be developed that fulfills the same needs in a radically more effective and efficient way?

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STEP 3

Make a functional analysis, using the MET matrix.

- Identify:
  - the product's functionality
  - its weak and strong aspects (which parts or functions tend to cause the product to fail)
  - the product's actual lifetime and its energy consumption.
- Take the product to bits
- Measure the weights of the various sub-assemblies and components
- List the type and amount of materials and components used
- Identify the connections between them

STEP 4

Fill in a MET matrix:

- Materials:
  - Note environmental problems concerning the input and output of material.
  - Include figures about the application of materials which are non-renewable or create emissions during production (such as copper, lead and zinc), incompatible materials and inefficient use of non-reuse of materials and components in all five stages of the product life cycle.
- Energy use:
  - List energy consumption during all stages of the life cycle
  - Include this consumption for the product itself, transportation, operating, maintenance and recovery.
  - List in the first cell of this column inputs of materials with extremely high energy content
  - Include exhaust gases produced as a result of energy use
- Toxic emissions:
  - Identify toxic emissions to land, water and the air in the five life cycle stages.

Softwares

Ex1

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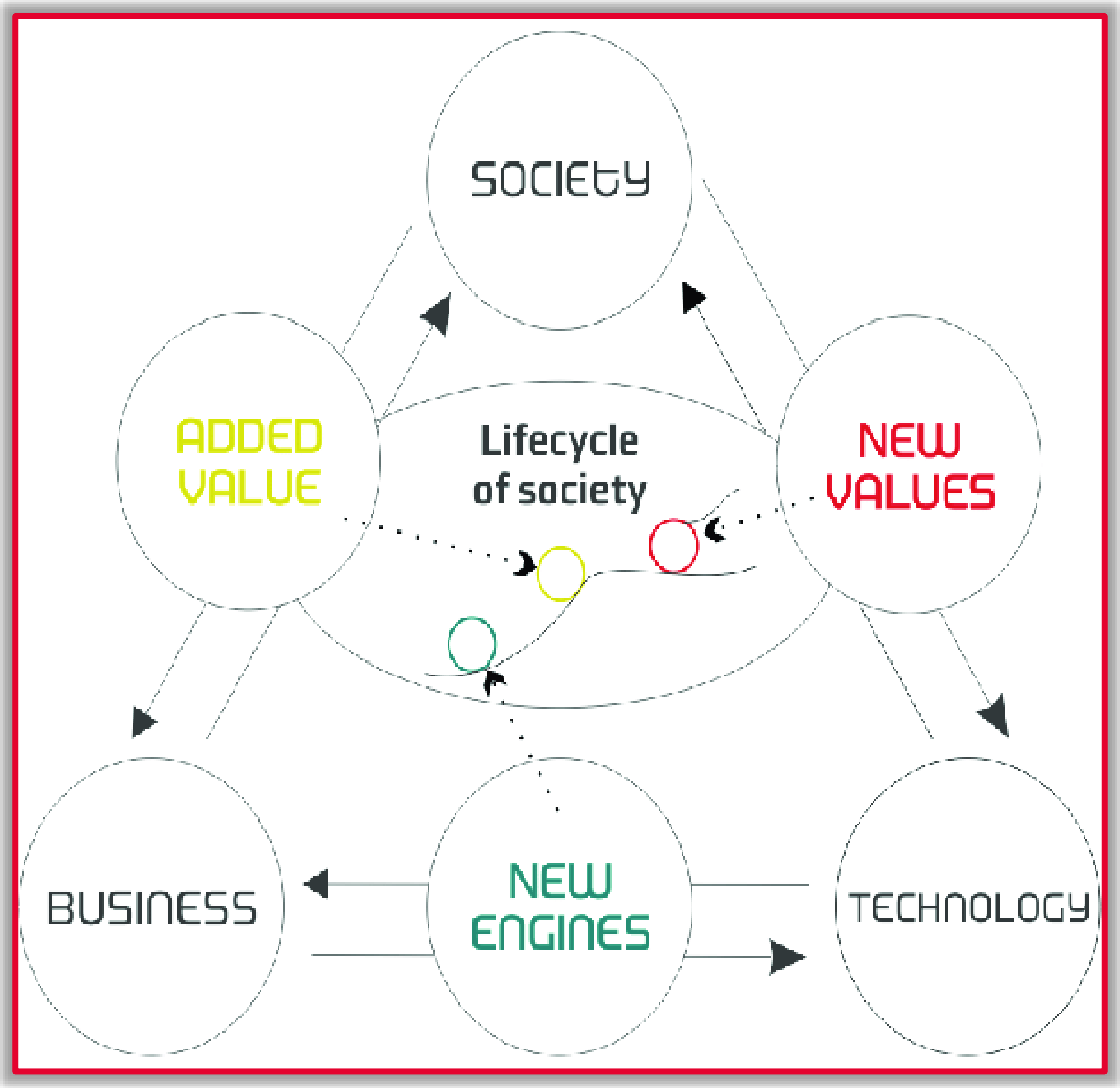
For each method and tool presented, we added at the end all the references we used to realize the guide. If you want to go further, we will recommend you having a look at those references.

INTRODUCTION

Society has greatly evolved in the last decade. Consumers have started to adopt new values and reject certain products. More and more social and environmental concerns have been pushed by customers which have forced a technological change in order to answer to the new values and demand. This transformation turns to be brought to the market by the business. Below, you can find a triangle process defined by Jan Verloop about the life cycle of society. Society adopts new values so the technology creates new engines to respond to the demand and business puts it in the market in order to create added value. It is a virtuous triangle where companies have to adapt to societal changes.



INTRODUCTION

Awareness among companies has led to the implementation of CSR principles, especially, with the arrival of the ISO 26 000 standard, which specifies the transparent and ethical behavior that a company must put in place with a contribution to sustainable development, but also the integration of the approach into the organization as a whole and in its relationships. In July 2017, France even pushed it further with a regulatory framework for the publication of non-financial information and replaced the CSR report.

The development of CSR in companies has made eco-innovation emerge. We could define it by: "Eco-innovation includes new production processes, new products or services, and new management and business methods, the use or implementation of which is likely to prevent or substantially reduce the risks to the environment, pollution and any other negative impact of the use of resources throughout the lifecycle of related activities." (European Commission). The whole concept consists of reducing the impact of something already created or upstream in order to produce a -more- sustainable product, process or service by keeping an equal or superior quality.

This concept was also partly defined in the NF X 30-264 standard in 2013:

- “Systematic integration of environmental aspects from the design and development of products (goods and services, systems) with the objective of reducing negative environmental impacts throughout their life cycle for equivalent or superior services. This approach from the very beginning of a design process aims to find the best balance between environmental, social, technical and economic requirements in the design and development of products.”

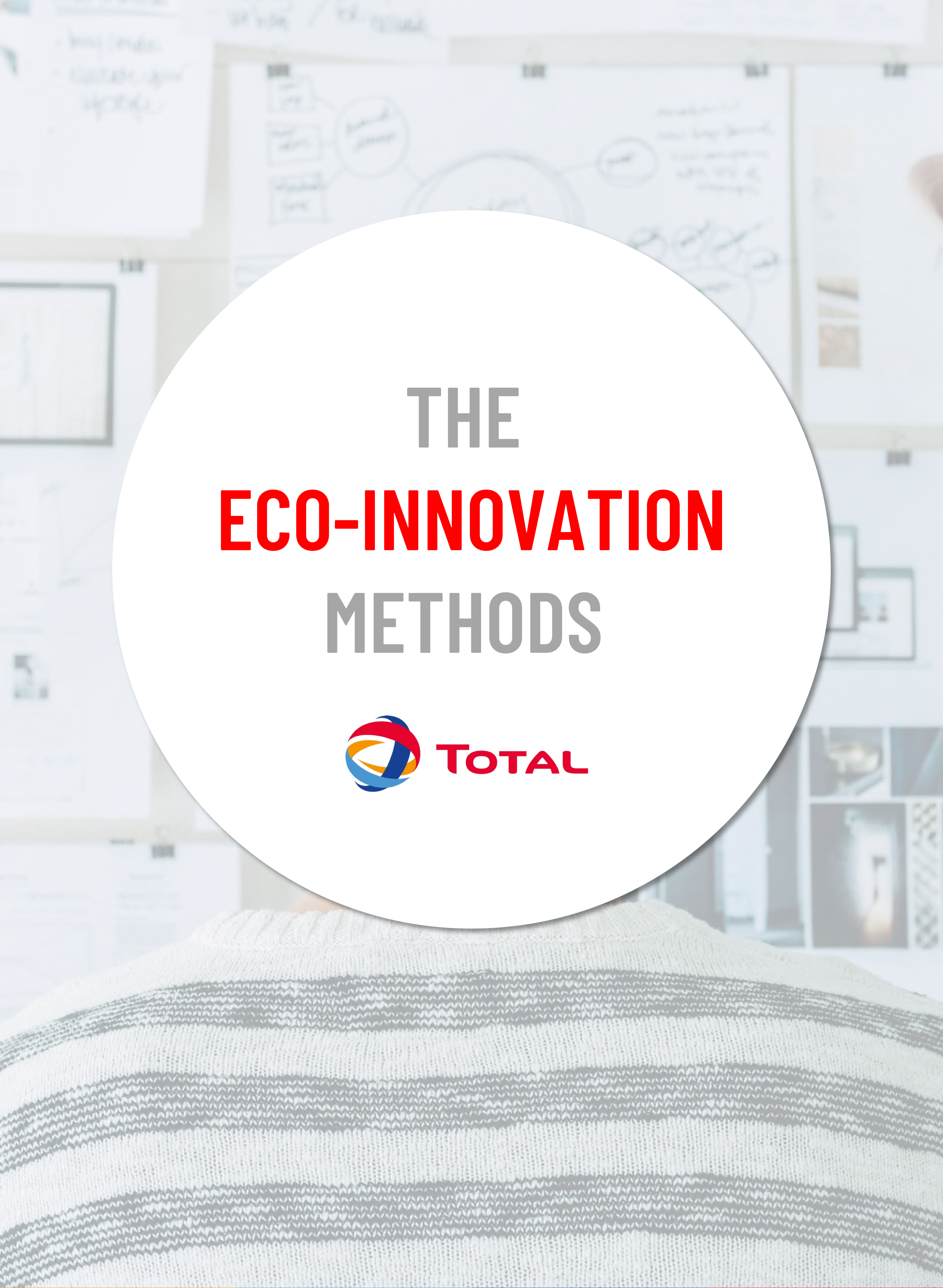
INTRODUCTION

It has 4 approaches. The first one is a preventive approach driven by decisions that are made at the source. The second one is a multi-criteria approach by taking into account many areas (raw materials, energy, human health...). The third one is a circular approach which takes into account all stages of the life cycle. Finally, the last approach and, perhaps, the most important one, is a global approach which integrates ALL the environmental impacts throughout the product's life cycle in order to realize a successful eco-conception.

For a company using this kind of method, it is no longer a hypothesis but must become an obligation as the benefits are important cornerstones in companies' CSR impacts:

- Reduce its environmental impacts
- Better control the risks and costs linked to the products' life cycle
- Anticipate customers' expectations and meet the growing demand for environmentally friendly products and services
- Make the environment a new factor of dynamism and creativity in the product creation and design process
- Improve its image and differentiate itself in the market
- Achieve economic gains
- Anticipate the increasingly strict requirements set by governments and the market

In this book, we provide you several eco-innovation methods and tools which will allow you to build your projects by respecting the environment and stakeholders as well as keeping a competitive advantage over your competitors by implementing innovation throughout your mission.



THE ECO-INNOVATION METHODS

The TRIZ methodology

Genrich Altshuller

Soviet engineer, inventor, and writer
President of the **TRIZ association**

Definition

It is a **systematic methodology** that provides a **logical** approach to developing **creativity** for **innovation** and inventive **problem thinking.**

Method used in **problem solving** thanks to **logic**, **data** and **research** and presents different tools to emphasize on systematic creativity by **facilitating decision-making.**

It assumes that **inventions** can be predicted and are **influenced** by certain **rules.**

- We can find **3 concepts** in any of **TRIZ** problem solving process:

Contradictions : Which are **indicative** of inventive problems arising from the apparent **incompatibility** of desired **features** within a system. Issues can be solved by firstly **finding** a **solution** for the problem:

- **Technical contradiction**
- **Physical contradiction**

Ideality: it is a **measure** which indicated how close a system is to the most **excellent** and **suitable** it can possibly be (i.e. the **ideal** machine). **Ideality** of a system can be expressed in **mathematical** terms as

$$Ideality = \frac{\Sigma\, Benefits}{(\Sigma\, Costs + \Sigma\, Harms)}$$

Patterns of evolution of systems: Technical systems have **similarities** in their **development**. They are required for creating **suitable answers** to issues and imagine the **evolution of systems**.

Origin

Also called 'theory of **the resolution of invention-related tasks**' or '**Theory of Creative Problem Solving'**

This method has been created by **Genrich Altshuller**, a Russian **scientist** and **engineer**, around the **1960's**

He investigated thousands of patents from several field of studies to **identify patterns** and arrived to the conclusion of that patents can be related to **improvements in systems**

Initially, it was applied **for technology-related problems**; but, nowadays, we can find it in many **other areas**

Goals

- Use it to solve **problems** on **sustainability**
- Identify, understand, and **solve** the **issues**
- Eliminate **contradictions**
- Foster **eco-efficiency**
- Can be applied in **Processes**, **Products** and **Management**
- Help **corporations** to adopt an ongoing **improvement process**

Aligned with: **Reducing** the material, enhancing the **recyclability** of **materials,** maximizing the use of **renewable** resources, extending the **durability** of products; and, **increasing** the **service** intensity

How to implement it?

1 Define your problem/situation

- Define the problem/situation briefly
- **Assess** the amount of **resources** you can mobilize for the project

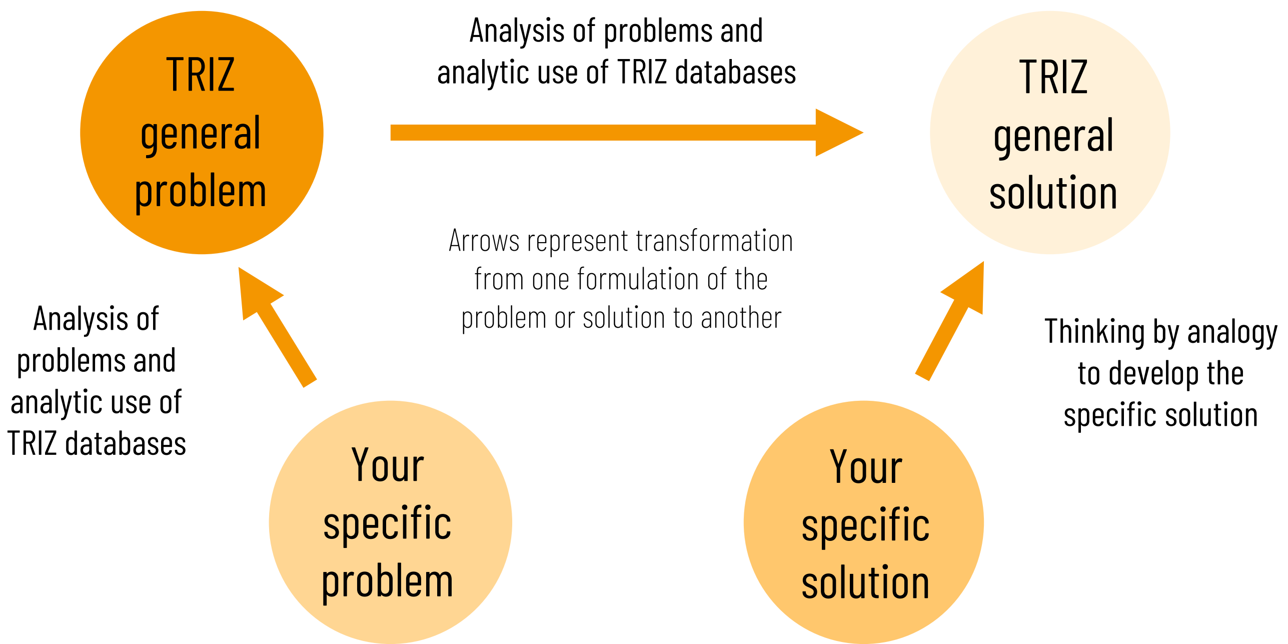
2 Try to find solutions to this problem

- Identify solutions and evaluate them
- **Criteria**: **satisfaction level** and **importance** of the problem
- If you have resolved this problem thanks to **a problem-solving activities**, you are not obliged to go **further**
- If your solutions do **not satisfy** you or if you do not find any, go to the **third step**

3 Generalize Problems and Solutions

- **Observe** the patterns of issue and solution
- **Represent** the current situation as a 'contradiction'
- **Predict innovative solutions** to that problem by using a **scientific approach**
- **Use** the **general patterns** to the specific situation with which you struggle, and find a **generalized form** of the problem

The TRIZ Problem-Solving Method



4 Eliminate the contradictions identified in the previous step

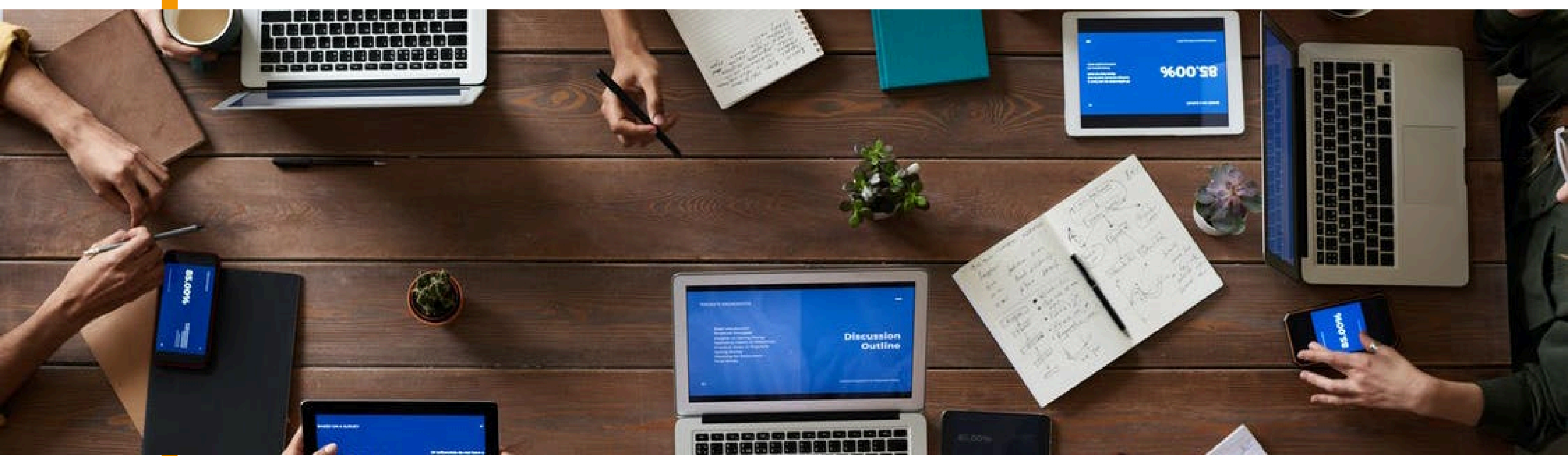
- **Identify** which kind of contradictions it is
- **Find solutions** to erase it

5 Choose the TRIZ tools

- Firstly, **classify** them as **analytical** (e.g., Substance-Field Analysis, Functional Analysis, ARIZ), **knowledge-based** (e.g., 40 inventive principles, 76 standards solutions) or **psychological** tools (e.g., Smart Little People, Size-time-cost Operator).
  - **Analytical tools**: Identify, formulate and represent the issue
  - **Knowledge-based tools**: Give solutions for improvements
  - **Psychological tools**: Help and support the problem-solving process
- **Choose** between the **TRIZ tools** in function of your needs
- You can find the different **TRIZ tools** in the green toolbox

6 Apply the TRIZ tools

- **Find** the **specific application** of the chosen tools in the literature
- It exists **software** to help you at the **TRIZ tools** implementation, e.g. **Goldfire** (Invention Machine), **Innovation Workbenchs** (Ideation International), **Guided Innovation ToolkitTM** (Pretium Innovation), **TriSolver** (TriSolver Group), **Creax Innovation Suite** (Creax)



7 Re-evaluate your solutions: Are they satisfying?

- **Establish** the moment when the **TRIZ activities** can stop because your **solutions** are the **best** as possible for your problem
- **Take** the **criteria** assessed in the **STEP 2**

8 Implement the solutions

- **Formulate** specifically the **solutions**
- **Realize** a **Work Breakdown Structure** and job assignments
- **Review** your solutions effectiveness **compared** to the initial system

Strengths & Weaknesses

Systematic approach

Can improve the quality of conceived solutions

Large choice of possible tools

Able to provide useful outcomes in almost every field

Provide a structured approach to problem-solving

Provide useful new solutions

Generate more innovative ideas

Identify problems quickly

Effective teamwork

Allow deconstruction of patents

Can represent a competitive advantage

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Time and cost consuming

Generally, it is needed to combine it with other methods

Not really known and used by firms

Do not provide a specific application of the tools

Difficult to understand all TRIZ tools

Diversity of methods which can lead to confusion

Slow pace

Some of the tools are time consuming and low effective and efficient

Lack of standardized good practices

Need previous experience to have good results

Not always accepted within organizations

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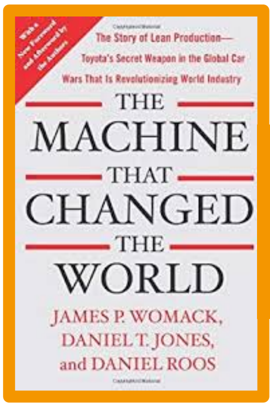
The TRIZ-Lean



"The machine that changed the world' J.Womack & D.Jones **(1991)**

James Womack

Director of the **International Motor Vehicles Program** in Cambridge
Founder of the **Lean** Entreprise **institute**

Daniel Jones

Founder of the **Lean** Enterprise **Academy**
PhD in **Science** at Buckingham

Definition

- See the **definition** of **TRIZ** which can be found in the specific section.

- Lean manufacturing **comprises activities** in which the **waste produced** by the process functioning is **identified.**

- We can find five principles:
  - **Grasp** the added value consumers want
  - **Understand** the value stream
  - **Suppress** any waste to fluidify value flow
  - **Allow** customers take value from the manufacturer
  - Constantly **improve** to achieve perfection

Origin

TRIZ : See the appropriate section

LEAN : have a look to that section

A way to answer **customers' wishes**: more products' **customization**, lower **process time**, more **qualitative goods**, lower **prices**

1950's: Toyota Production System (**TPS**), the **precursor** of **Lean** manufacturing, has been developed by Taiichi **Ohno** et Eiji **Toyoda**

1991: James **Womack** and Daniel **Jones** have designed **Lean** in their **book** called '**The machine that changed** the **world**'

Goal: producing in an **ongoing flow** by **maximizing** the quantity of **products sold** and **minimizing** the **resources** used

Motto: 'Doing **more** with **less**': less **human efforts**, less **defects**, less **manufacturing** space, less **stocks** and less **time** spent to develop new products

Goals

Identify and **solve** problems

Reduce industrial waste thanks to **innovative** solutions

TRIZ serves to complete **Lean** methodology by **solving** the happening of **technical contradictions**

Improve the twelfth goal called '**Responsible consumption and production**' from the United Nations Sustainable Development Goals

TRIZ tools are useful to implement **Lean methodologies** and complete **Lean instruments**

TRIZ and **Lean** methods have the **same direction**: resolve firms' issues by answering to **customers**, **social** and **environmental** needs

Reduce all kinds of **waste** such as environmental waste and improve the **efficient use** of **natural resources**

How to implement it?

1

Define the problem

- Use the **checklist** (see in the toolbox)
- Use the **5Whys** technique (see in the toolbox)
- **Brainstorm** with your team

2

Analyze the company state of play

- You can use the **value stream mapping**
- **Collect** current **KPIs**

3

Select tools from the Lean instruments

- **Choose** them according to your **needs** *(See Appendix at the end)*
- They have to be in **accordance** with your **findings** in the **STEP 2**

4

Use TRIZ tools to support Lean methodology

- **Support innovation** and teamwork
- **Improve** the natural resources use
- **Identify** causes and effects
- Useful **TRIZ tools** *(See Appendix of the TRIZ Methodology)* :
    - Nine-windows tools
    - Contradictions matrix
    - 40 principles
    - Resources
    - Ideality
    - Functional analysis
    - Smart Little People
    - Size-Time-Cost

5

Optimize the use of available resources

- According to your findings, **elaborate** solutions
- **Select priority** and impactful actions
- **Assess** the intended **results**

6

Evaluate your improvements

- Re-evaluate **KPIs**
- **Implement** new **KPIs**
- **Follow-up** measures
- **Re-use** the method if new **problems** are occurring
- Use other **methodologies** to complete your **assumptions**

Strengths & Weaknesses

Increase efficiency

Ongoing evolution

Provoke viable and sustainable synergies

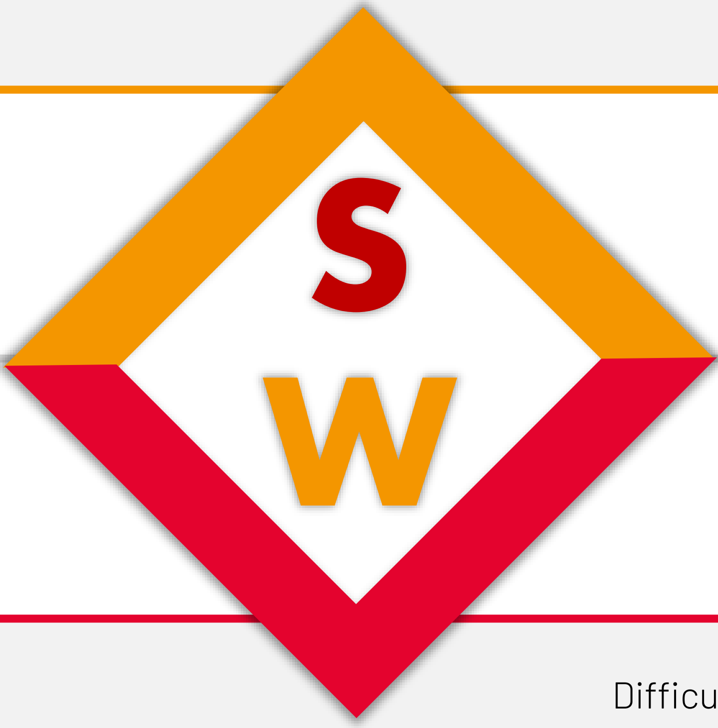
Collective effort: reinforcing teams

Bring operational excellence by combining creative and efficient techniques

Fast results

Long-term perspective

Increase agility



People have to be motivated

Need a transformational corporate culture

Difficulty to understand how to use them

Put suitable KPI's to control the performance and not destroy it

Difficult to apply

Real, constant and visible commitment needed at the top management level

Demanding process

Need constant effort to keep results and not lose them

Do not expect spectacular results

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Factor 4

"Factor 4 innovation Framework" Daniel Kaplan & Renaud Francou, **2017**

Daniel Kaplan

General Delegate of the **Fing**
Member of the **National Digital Council** (CNNum)

Renaud Francou

Previous member of the **Fing**
Responsible for **territories** of **experimentation** (TEX)

Definition

- The innovation **Factor 4** model develops new ways of innovation, whose "**value proposition**" incorporates a deep, broad (scaling up), and long-term ecological impact (e.g. "factor 4", "zero emissions / waste", "positive energy").
- The term "**Factor 4**" illustrates the extent of the transformations needed to limit climate change: **reduce greenhouse gas emissions** to one quarter of their current levels by 2050, through a combination of **reducing energy requirements** and substituting fossil fuels with **renewable energies.**
- It proposes a new method of **analyzing innovative projects** likely to produce a major ecological **impact**, describing both their **economic viability** and their **potential** for impact.
- **Factor 4 Innovation** is therefore defined both by its **intention** (to produce a positive ecological impact) and its **ambition** (a "radical" impact by its depth and/or ladder).

Origin

2016: Beginning of the project

2017: Publication of the "**Factor 4 Innovation Framework**"

Collaborative work with Walter Bouvais, Damien Demailly, Yan Thoinet and Benjamin Tincq

It tooks its roots from **three actual streams of innovation**:

- **Green and social innovation**: Actors want to create socio-environmental positive impacts, but they are still on local and sector scale.
- **Digital innovation**: Focus on transformation and « disruption » for sectors and activities but without social and environmental awareness. The goal is to maximize profit.
- **Innovation factor 4**: The emergence of new innovators' generations who want to change by methods from digital cultures (agility, co-production with their users, collaboration, open innovation, even open source) with social and ecological intention.

Goals

Propose a **new method** of **analyzing** innovating projects

Economically viable

Limit impacts on other **sectors** and **actors**, as well as the possible "rebound effects" likely to reduce the net ecological benefits which they entail

Logically **link** the search for **impact** to **innovative activity**, the products and services it offers and the business model

Formalize the way to produce an environmental impact and **verify** their **progress** towards this **objective**

The **search** for the **impact** is located the very **origin** of the project

Produce a major **ecological impact** (deep, positive and lasting)

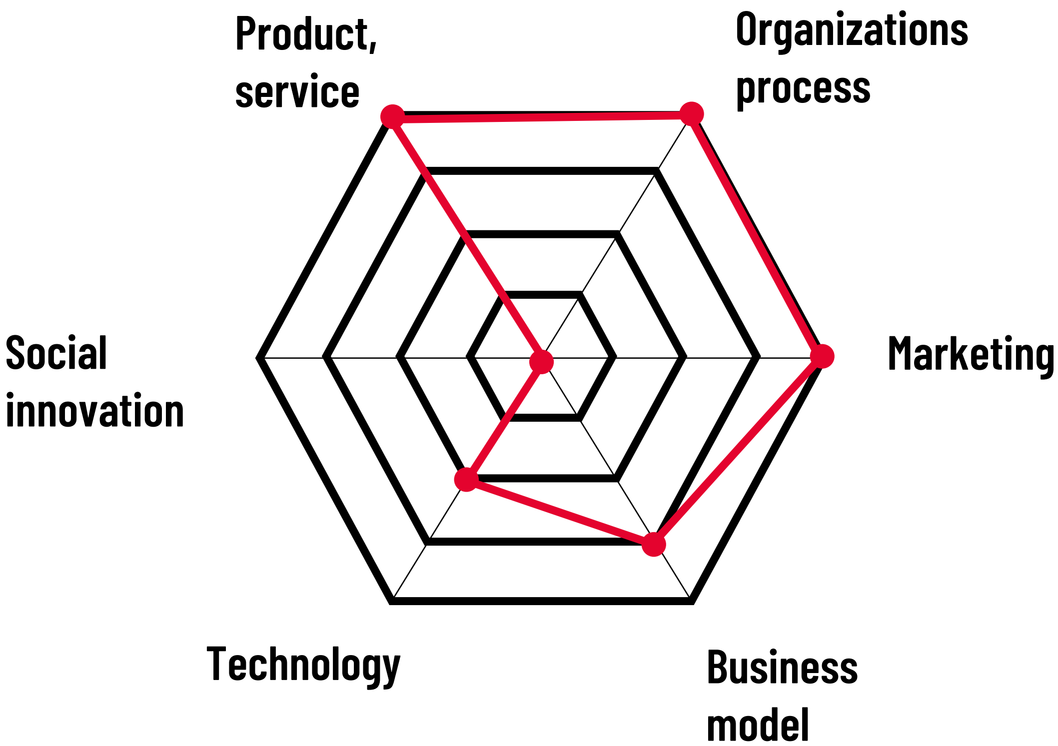
Concern "**radical**" innovations

How to implement it?

1 Describe and analyze the innovative nature of the project

- It seeks to answer two simple questions :
  - What does the project **bring** new to its **customers**, **users** and **beneficiaries**?
  - How can the project **differentiate** the company from what exists and/or from its competitors?
- **Evaluate** the **innovation intensity** by measuring it on a scale going from 0 (not innovative) to 4 (radical/disruptive innovation) thanks to **BPIFrance referential**

The combination of innovation types / degree of innovation enables producing an easy-to-read "radar":

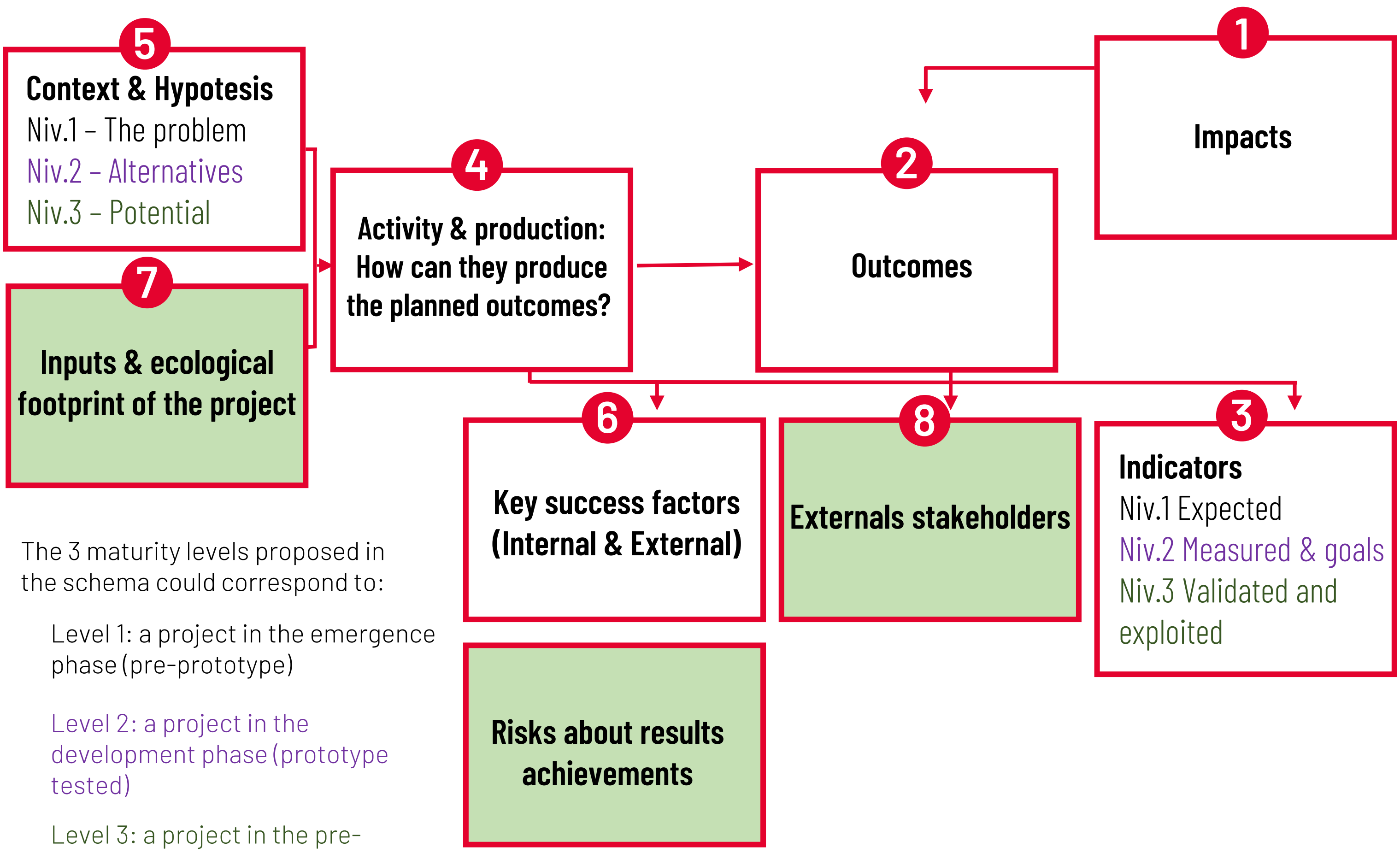


2

Describe or analyze at the same time the economic viability and the impact potential of the project

- **Link** the **creation** of **value** for the organization itself and for others (externalities or impacts)
- Based on the "**Theory of Change**", which develops models on the daily activities of an organization and the impacts it wants to achieve
- Start from the **impact** to go towards the **activity** proposed by the **organization** to achieve them
- Link this analysis with your "**business model**" thanks to tools such as the **Business Model Canvas**
- Assess your impact thanks to methods such as **LCA**, **Carbon Impact Analytics** and **GRI Standards**
- To sum up:
    - Use the **Business Model Canvas** to assess your business model
    - Use the **Theory of Change** to validate the impact
    - Use the **Key Success Factors** to check that all is aligned

Example of "Theory of Change" within the framework of this method



The 3 maturity levels proposed in the schema could correspond to:

Level 1: a project in the emergence phase (pre-prototype)

Level 2: a project in the development phase (prototype tested)

Level 3: a project in the pre-launch phase

3 Describe or analyze at the same time the growth path of the company and the impact

- **Identify** if the **environmental** and **social impacts** are at the heart of your corporate mission to **guide** the development of your **project**

- **Maximizing impact** may come into tension with **maximizing growth** or return on capital

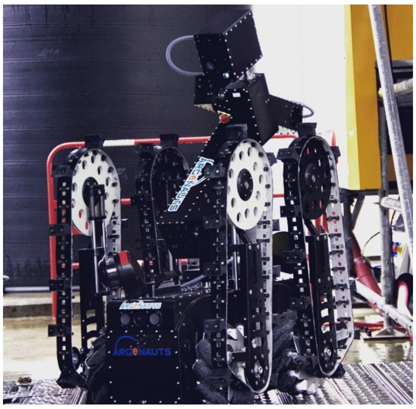
- **Realize arbitrations** around 4 questions:

  - Dissemination of knowledge, methods, and techniques: draw a scale between protection and sharing and identify your position
  - Competition vs Cooperation
  - Control vs Network (value chain)
  - Growth in activity (endogenous vs duplication)










Strengths & Weaknesses

Concrete

Continuous improvement

Facilitate the dialogue between the leaders of "Factor 4" projects and their potential partners and investors

Difficult to "read" by the usual interlocutors of innovators

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Innovation factor 4

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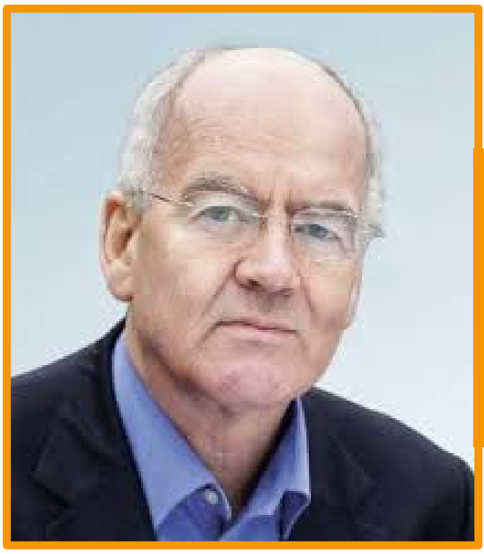
Triple Bottom Line



John Elkington

Founder of the **global sustainability movement** & Executive Chairman and Co-Founder at **Volans Ventures**

Definition

- Also called the **3Ps** (people, planet and profits)
- A "**win-win-win**" strategy benefiting the firm, its consumers and its environment
- **Accounting concept** including three different pillars related to performance, that is, the social, environmental and financial dimensions
- **Differ** from **traditional frameworks** because it contains ecological and social measures
- Do not have a **common** unit **measure**. You can use dollars and index, for example.

Origin

1994:

Development of the **Triple Bottom Line** (TBL) framework by John **Elkington**

Article called '**Toward the Sustainable Corporation**: Win-Win-Win Business Strategies for Sustainable Development'

The **original** goal was **measuring sustainability** and then, companies' performance on those pillars

Goals

Support **sustainability goals**

Assess the **ramification** of your **decisions** on a long-term perspective

Useful to different kinds of structures such as **firms**, **non-profit organizations**, and **governmental instances**

Understand and **maximize** your **change** to survive in a more competitive environment

How to implement it?

1 Determine your scope

- Realize a **SWOT** regarding your environment and sector
- Identify your **corporate mission**
- What are the **goals** of your organization on the **short**, **medium** and **long-term**?
- Identify **measures** which are important in the **Triple Bottom Line spectrum**

2 Collect Data

- Collect information on:
  - **Economic measures** (flow of money, P&L), e.g., income, expenditures, taxes, employment, business diversity factors
  - **Environmental measures** (natural resources and its sustainability), e.g., air and water quality, energy consumption, solid and toxic waste
  - **Social measures** (social responsibility of the firm), e.g., education, equity, health, well-being, standard of living
- Identify **specific data** on each metric
- Collect data on **each metric** depending on your **scope**: national, local, organizational levels
- Data on each **dimension** will depend on your **project** and **needs**

3 Determine your unit measure

- Depend on the **nature** of your **organization**
- Depend on **data collected**
- Challenge is to find a **common measure** to the **economic** performance, which is easy, and **social** and **environmental** performance

4 Calculate the Triple bottom line (TBL)

- Measure the **full cost** of **doing business**
- Observe at which dimension you **perform well** and at which you **under-perform**

5 Assess your project performance

- See how you can **improve** some of the **dimensions** with your project
- Do the steps again with your **project forecast**
- Observe the **positive** and **negative changes** on your identified criteria (step 1)
- Make a **planning** to **implement** your project

Strengths & Weaknesses

Complete traditional frameworks

Adapt the framework to your goals

Flexibility of the method

Can be applied to specific projects (e.g., local level) or larger goals (e.g., national level)

Long-term view

Well-established

Look beyond profits

Focus as much attention on social and environmental issues as financial issues

Assess your performance on sustainability

Survive in the future

S

W

Measuring TBL framework

No universal standards

Subjective

Hard to create a comprehensive and meaningful index

Explain your own definition of sustainability within your organization

The ease level of including sustainability within your business can depend on your sector and corporate structure

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Triple bottom Line

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The LCA methodology

It is not an eco-innovation method but a methodology to calculate the environmental impact of a product

Definition

- **Human activities** have **consequences**, and the **physical** flows of matter and **energy** are quantitatively computed related to those effects.

- We can find **two methods**: the non-simplified and simplified **LCA** approached. The simplified method allows **companies** to focus on their **own needs** and, usually, it is related to specific sectors such as '**Product Review**' (developed by ADEME, 2008), '**Foodprint**' (for products from the agricultural industry, in 2012), '**BEE**' (for packaging, developed in 2013 by CITEO), and '**Spin-it**' (for the textile industry, in 2015).

- It is based on two pillars:
  - **Life cycle approach**: raw materials extraction, energy consumption, distribution, collect, usage, supply chain transportation; all those stages produce **environmental impacts**
  - **Multi-criteria approach**: LCA uses different criteria in each of **incoming** (iron, water, oil and gas resources) and **outcoming** (waste, carbon emissions, discharged liquids) **flows**

- It allows the **calculus** of **environmental impacts** of a **product** throughout its **life cycle.**

Origin

1969: Coca Cola has realized researches to **assess** the **environmental impact** of **packaging** possibilities to choose the less **polluting** one

1973: First **oil shock**: it has awakened people and fifteen reports were written + creation of the **Directorate General** for the **Environment** by the European Commission

Reaction: the '**Society of Environmental Toxicology and Chemistry**' (SETAC) worked on the scientific aspects of the **LCA method**

Origin

1992: Appearance of new **methods** such as **CML-IA** (United States), **EDIP** (Danish), and **TRACI** (the US Environmental Agency), and softwares such as **SimaPro** and **EIME**

1997 (October 2006 for the French version) : the **ISO 14040** norm has been created by the **International Organization** for **Standardization**

2005: Creation of the **European platform** on **LCA**

2006: Development of the **ISO 14044** norm completing the **ISO 14040** norm

Goals

Stakeholders can have a **global view** on the **environmental performance** of organizations or the environmental **impacts** of specific products

Products' and **processes**' improvements

Results serve to several use: **Communication**, **eco-conception**, and **orientation** of public policies

Facilitate **decision-making**

It **prevents** from **transferring** the **negative environmental impact** from one stage of the **life cycle** to **another**

Possibility to **compare** two products having the same **usefulness**, two different **goods** having the **same role**, or one product and one digital service

This method can be used in the framework of several eco-innovation pillars:

- **Products and services**: It can compare the actual environmental impact of different products or help identify the most polluting stages of a product life cycle. Then, it promotes innovation by looking for alternative solutions for the identified factor without damaging another variable.
- **Technological**: It assesses the pollution of the object studied as well as waste and resources utilization. Indeed, it can concern technological processes such as in the building industry.
- **Systemic**: We can assess, for example a product from the circular economy and another from the linear life cycle and see the environmental performance of each one.

It would allow a company to improve its processes and review its products' production steps.

How to implement it?

1

Guidance

- **Justify** the **reasons** why you use LCA method
- **People** or **business** units having access to results
- Use of **results**
- Clarify the **main goals**
- Establish the **scope**
- If it is used to make **comparisons**
- Products' **process description** and its **limitations**
- Hypothesis
- Limitations
- **Assessment** methodology
- Requirement of data **quality**
- Management of **missing** data
- Report format
- Functional unit
- **System frontiers** : processes you have to incorporate in the system
- Possible to **come back** to it at each **step** of **LCA assessment**

2

LCA Inventory

- **Collect data** : It takes a consequent amount of **time**
- Determine the **inventory scope**: Allows the **quantification** of **ingoing** and **outgoing flows** related to the object studied
- Come back to the first step in case of new **constraints** or **requirements** appearance

3

Impacts' assessment

- **Choose** impacts' categories
- **Distribute flows** to each category according to its **features** by realizing a **characterization** (calculus method)
- Transform **flows** into **environmental impacts** such as greenhouse effects, acidification, eutrophication or toxicity, to quote some of them
- **Justify** the choice of **impacts' indicators**

4

Impacts' interpretation

- Make **recommendations** either on the **improvement** of your **LCA methodology** or on the possible environmental impact improvements regarding the target
- **Look** more cautiously on the **impact**
- Verify the **data availability** necessary to **interpret** results
- Control the results reliability by realizing a **sensitivity study** that is playing with **one parameter** to verify its **influence** on results
- Realize a consistency **check** between **hypothesis**, **methods** and **data** with the study of **objectives** and **scope**

5

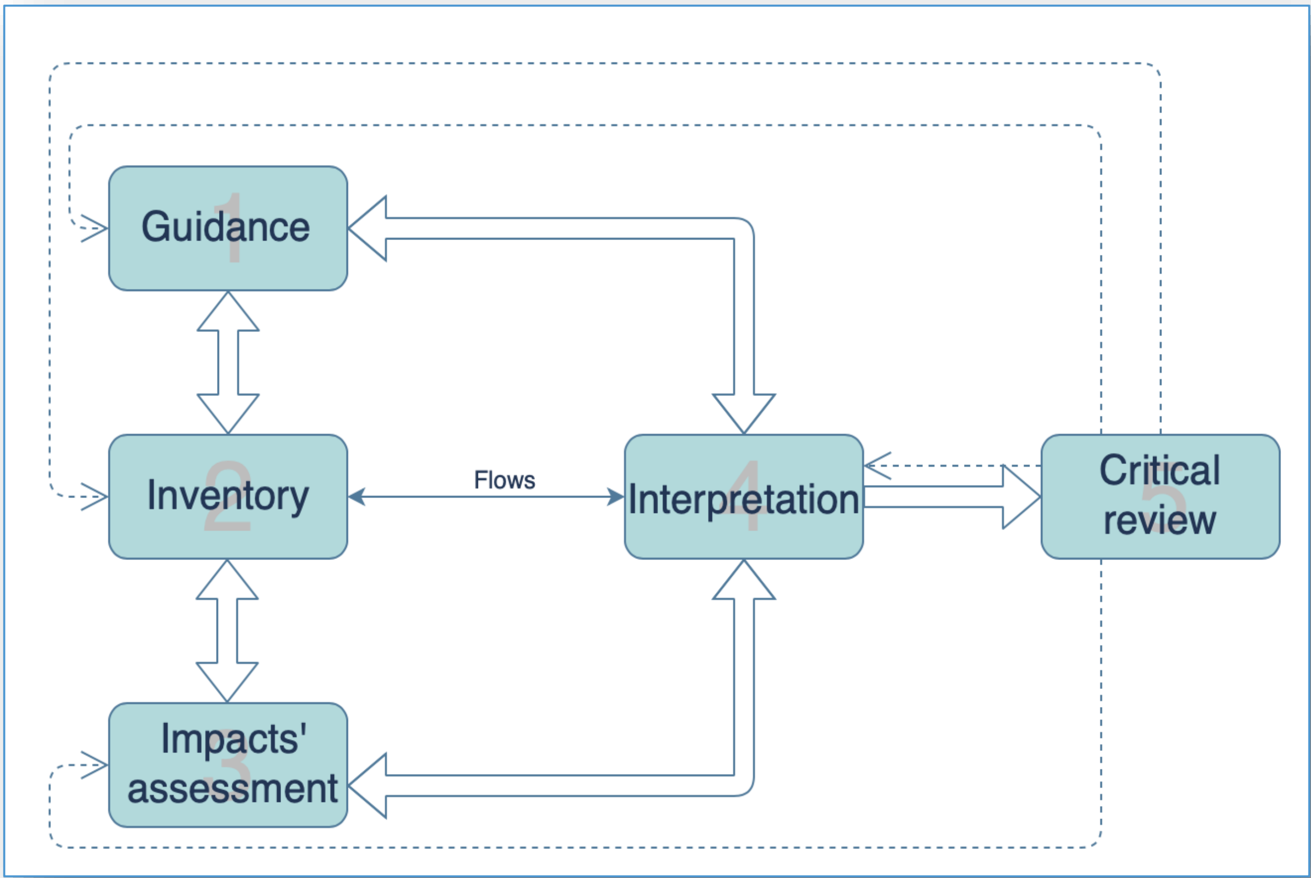
Critical review

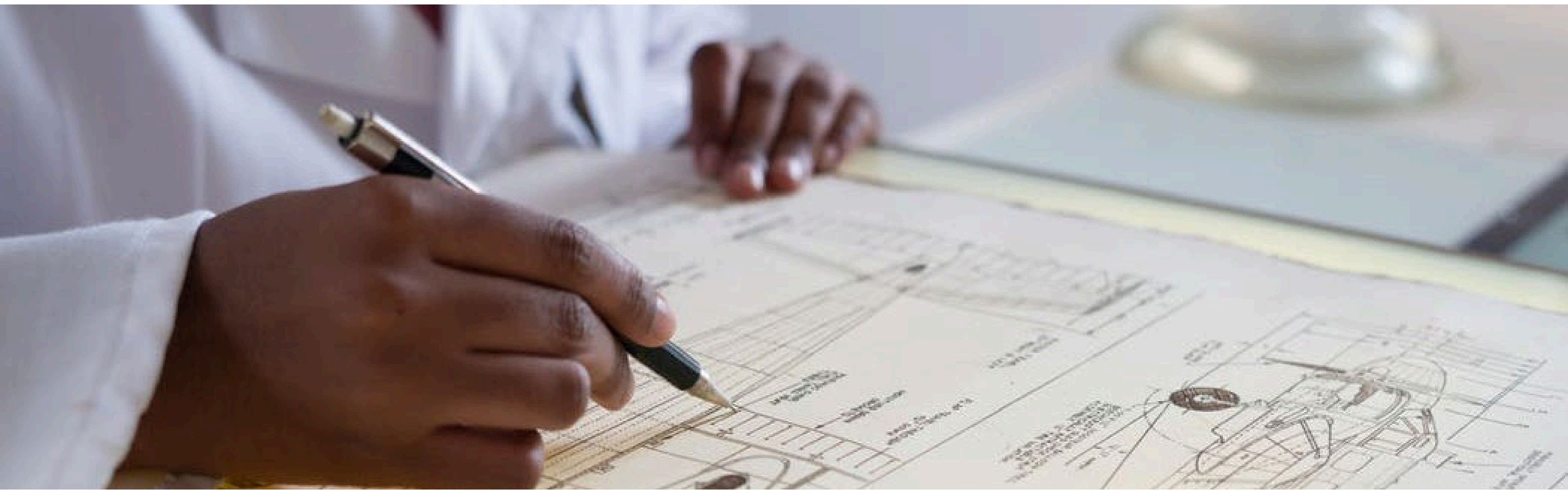
- Verify that the study has been well-conducted by respecting the **methodology**, **data**, **interpretation** and **communication** requirements according to the LCA principles and **ISO 14044** rules
- Check:
    - **Methods pertinence** regarding the 14044 ISO norm
    - **Methods validation** according to scientific and technical points of view
    - **Pertinence** of **data** regarding the study aims
    - **Interpretations** that reflect the **limitations** and the study **objectives**
    - The report **transparency** and **consistency**
- Possible to realize **critical reviews** at each step of the LCA
- Do not forget to **justify** all your steps and show that your modifications will have a real **improvement** on the product environmental performance

6 Use of the Life-Cycle Cost Analysis (LCCA) method (optional)

- It evaluates the **economic impacts** of an **investment** during his entire life
- It **compares** the different **project's costs**
- It only evaluates the **economic impacts** and not the environmental ones
- It allows to find a **balance** between the **economic** and **environmental** impacts

Visual representation of the LCA process





Strengths & Weaknesses

Strengths

Take into account ingoing and outgoing flows

Iterative process

Quantitative approach

Standardized tool

Take into account all the life cycle

Check thanks to the critical review

Multi-criteria approach

Software availability

Take on board the possible impacts' transfer from one unit in the value chain to another

Exhaustive method

Weaknesses

Subjective

Possibility of different results between two LCA software

Misuses of companies LCA results (greenwashing)

No prioritization between ecological qualities of products studied

Need transparency to not false results

Time consuming

Complex method

Not easy to use

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LCA

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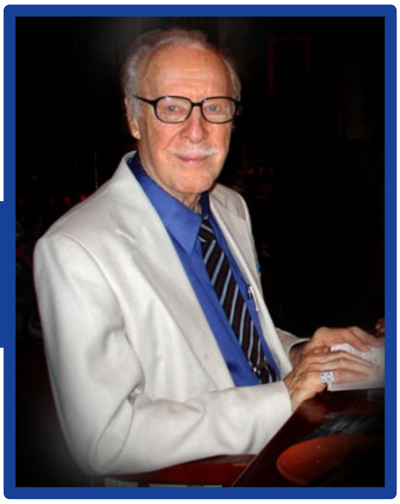
Environmental impact assessment

"National Environmental Policy Act" Lynton Caldwell , 1969

Lynton Caldwell

American political scientist



Definition

- **Environment Impact Assessment** (EIA) is a study to identify, **predict** and **evaluate** the effect of an **activity/project** on the environment considering inter-related both beneficial and adverse **cultural**, **socio-economic**, and **human health impacts**.

- This is a **decision-making** tool which **compares** various **alternatives** for a project and seeks to identify the one which represents the best combination of economic and environmental **costs** and **benefits** for the **projects**.

Origin

1970's: Development of EIA with the implementation of the National Environmental Policy Act (NEPA) 1969 in the US	**1980's**: Adoption and implementation of the **EIA** approach by many **developed** and **developing countries** such as in **Europe** with "European Council EIA Directive 85/337/EEC of 27 June 1985"	**1989**: The **World Bank** adopted **EIA** for major development projects

Goals

- Examine and consider both **beneficial** and **adverse consequences**, **impact** of the project during project design to find ways and means to **reduce adverse impacts**
- Identify significant **positive** and **negative impacts** on **cultural**, **socio-economic**, and **human health**
- Provide information for **decision-making** on the environmental consequence of a project
- Promote environmental and **sustainable development** by identifying and **mitigating impacts**
- Ensure that **resources** are used **appropriately** and **efficiently**
- **Compare** between alternative **proposals**
- **Improve** environmental **design**

How to implement it?

1

Screening

- Determine if the **project** requires an **EIA** and the level of assessment required
- **Two** important **questions** must be asked:
    - 'What will be the effects of this development on the environment?'
    - 'Are those effects significant?'
        - If the answer to the second question is 'yes', an **EIA** may be required

2

Scoping

- Identify the **key issues** and impacts that should be further **investigated**
- Identify alternative solutions that avoid, mitigate or compensate adverse impacts on biodiversity
- Define the **boundaries** and **time limit** of the study

3

Impact analysis

- Identify and predict the **environmental** and **social impacts** of the project
- Evaluate the **significance**

4

Mitigation and impact management

- Make recommendations to avoid, **reduce** or **compensate** the potential adverse environmental consequences of **development activities**

5 Reporting

- Present the result of **EIA** in a form of a **report**
- Include an environmental management plan (**EMP**), and a **non-technical summary** for the general audience.

6 Review of EIA

- Assess the adequacy and effectiveness of the **EIA report**
- Provide the information necessary for decision-making based on the terms of reference (scoping) and public (including authority) participation

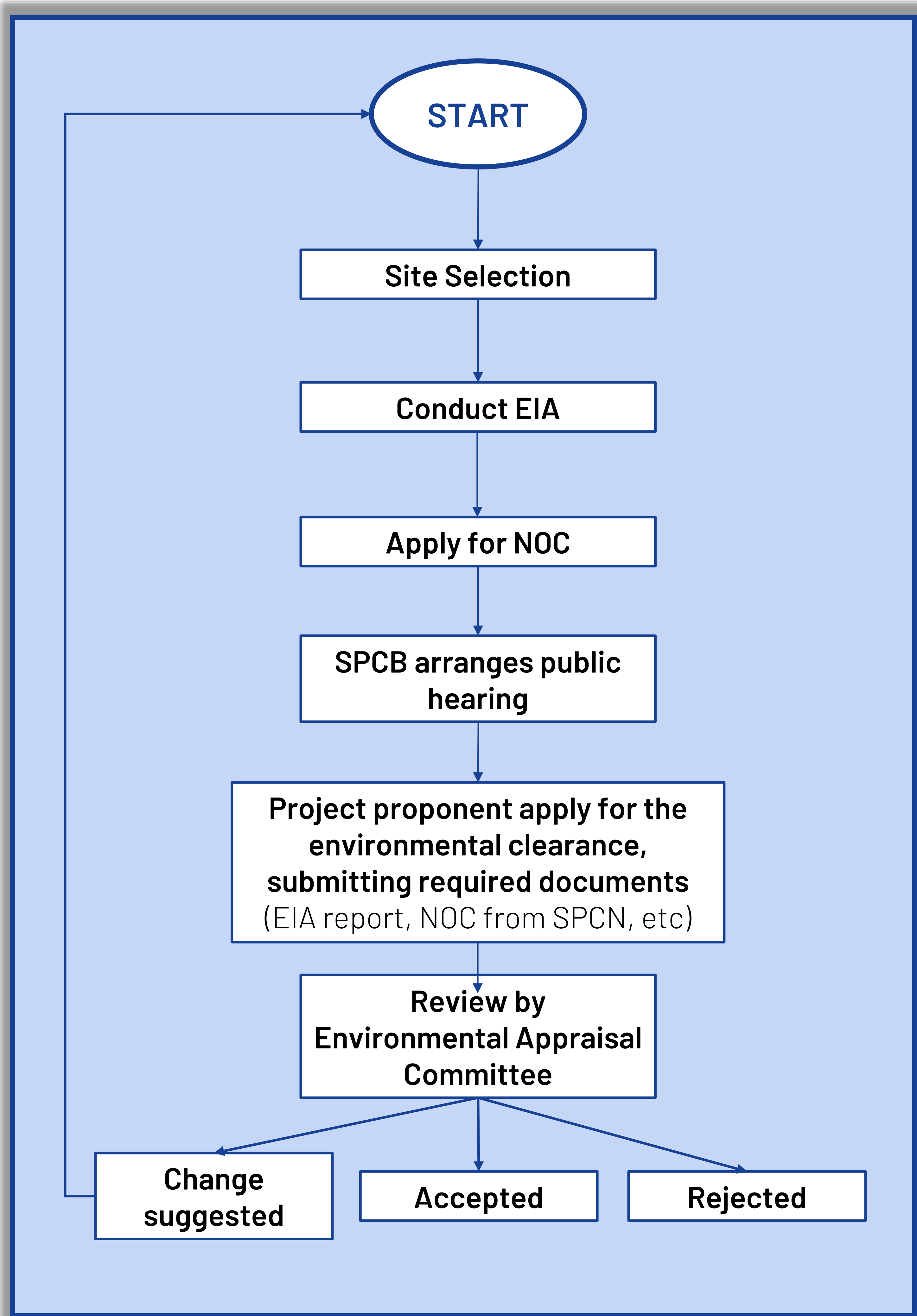
7 Decision-Making

- Decide whether the **project** is **rejected**, **approved** or needs **further change**
- Set the **terms** and **conditions** under which it can proceed

8 Review of EIA

- **Check** to ensure that the impacts of the project do not exceed the **legal standards**
- Monitor whether the predicted impacts and proposed **mitigation measures** occur as defined in the **EMP** to take any action necessary to improve problems, to undertake **audit** and **evaluation** for the **future EIA applications**
- **Data** generated by **monitoring** and other aspects of follow up should be **compared** with the **original** predictions and mitigation measures in the EIS to determine

    1. The **accuracy** of the **original predictions**
    2. The **degree** of the **deviation** from the predictions
    3. The possible **reasons** for any **deviation**
    4. Whether mitigation **measures** have achieved their **objective** of reducing or **eliminating impacts**


START
Site Selection
Conduct EIA
Apply for NOC
SPCB arranges public hearing
Project proponent apply for the environmental clearance, submitting required documents (EIA report, NOC from SPCN, etc)
Review by Environmental Appraisal Committee
Change suggested
Accepted
Rejected

Strengths & Weaknesses

S

Mitigation of negative impacts

Reduce time cost in the long term

Savings in capital and operating costs

Ensure compliance with environmental standards

Better environmental planning and design

Integrate the three aspects of sustainability: environmental, economic and social

Boost efficiency of a project

Reduce conflict around the project

Benefits of integrating EIA have been observed in all stages of a project, it concerns the entire life cycle

Facilitate an inclusive approach with the project stakeholders

Improve environmental and social efficiency by reducing negative impact

Improve transparency and public trust, acceptability

W

Rely on technical inputs

Extra costs and uncertainty on the project

Written for and by experts

Costly time delays

Require preparation and follow up

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EIA

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Alternative function fulfillment (AFF) strategy

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Alternative function fulfilment: incorporating environmental considerations into increased design space

F. van der Zwan *, T. Bhamra

International Ecotechnology Research Centre, School of Industrial and Manufacturing Science, Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK

Received 7 January 2002; accepted 27 October 2002

Abstract

The focal point of this paper is the relatively unknown concept of alternative function fulfilment (AFF), which is a design strategy that can be used to generate new ways of fulfilling a certain function and is referred to in the context of ecodesign. It can be considered an attractive environmental innovation strategy, provided that the increased design space is used to create more sustainable products and services.

This paper explores the AFF concept and discusses the implications of adopting this concept. It thus focuses on how design and business processes may need to change to allow the radical shift towards AFF, in order to facilitate the envisaged significant environmental improvements.

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Keywords: Alternative function fulfilment; Ecodesign; Eco-innovation; Design methodology

1. Introduction

Since the Brundtland commission first coined sustainable development in 1987, society has become aware that it has to find solutions "that meet the needs of the present without jeopardising the needs of future generations" [1]. Companies are challenged to contribute to sustainability by improving the environmental performance of their current way of doing business. This means reducing the amount of natural resources, energy consumption and toxic emissions related to the manufacturing, use and disposal of their products and services. Scientists across the world have proposed various targets for improvement to get global resource and energy consumption in line with the Earth's carrying capacity. These targets range from a factor of 4 [2] to as much as a factor of 20 [3], i.e. doing the same while only using 25–5% of the resources that are currently used, respectively. Although the exact factor of improvement might be debatable, it is evident from these figures that we are faced with a challenge. If we are to take up this challenge, these targets for improvements will need to be operationalised. That is when the discipline of cleaner production and more specifically the field of ecodesign emerged. Ecodesign can be defined as 'design which addresses all environmental impacts of a product throughout the complete life cycle of the product, without unduly compromising other criteria like function, quality, cost and appearance' [4]. The aforementioned challenge has been visualised by using the hierarchy of the Rathenau Institute [5], which takes an ecodesign viewpoint. The hierarchy illustrates that environmental improvements can be made in four stages, with each stage increasing both potential environmental benefit and the degree of innovation that is required in the design process [6]. This hierarchy is shown in Fig. 1.

The four stages can be explained as follows [5]:

""Alternative function fulfillment: incorporating environmental considerations into increased design space", F. van der Zwan & T. Bhamra, **2003**

F. van der Zwan

PhD researcher at the **International Ecotechnology** Research Centre at Cranfield University in the **United Kingdom**

T. Bhamra

PhD researcher at the **International Ecotechnology** Research Centre at Cranfield University in the **United Kingdom**

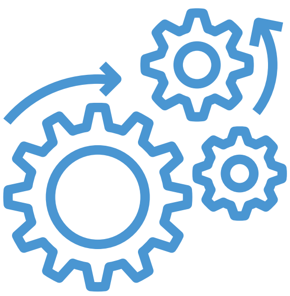
Definition

- "An innovation strategy, which is aimed at **reducing environmental impact** by embracing the **increased design space** when focusing on the **need** that a product system fulfills rather than relying on existing product use routines that are anchored in society'."
- The **need** that is **fulfilled** by the **product** or **service** is questioned and this involves probing how the current need can be fulfilled in a different way with **reduced environmental impact.**
- Focus on the **function** rather than the product.
- The desired outcome of the AFF strategy is an **alternative solution** with less **environmental impact** than the former traditional solution.

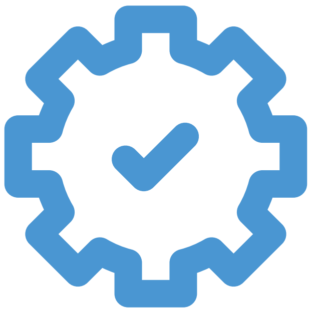
Definition

1. Identify system
2. Identify results
3. Environmental profile
4. Other system characteristics
5. Generate AFF concepts
6. Benchmark and select

Goals



Change **design** and **business processes** to bring about solutions with radically **reduced environmental impact**



AFF aims to **increase efficiency** of '**function fulfillment systems**' focus on environmental aspects

How to implement it?

1 Identify the system of which the existing product is part

- A **product** is generally part of a system and requires **additional infrastructure** to **function**

- Ask these questions:
  - Which other **products**, **services** and/or **infrastructure** does the product under consideration require to provide its **full functionality**?
  - How is the **product** used? Are there elements in its **use** environment that are **crucial** to its **performance**?
  - Once a **product system** has been defined, is it possible to **enlarge** it? This is to **prevent** a definition of **product system** that is too narrow and to **ensure** that the whole **product system** is captured

2 Identify the result the system delivers

- **Identify** the result the system delivers, or the **needs** it **fulfills**

- **Adjust** the **system** from the previous step if it is either too wide (which could paralyze this process) or still be too narrow (it might actually be a much wider system that delivers a certain result)

- Ask these questions :
  - What **needs** does the product system **satisfy**? (From specific to more generic needs)
  - Does the **product system** fulfill any **hidden needs**?

3

Make an environmental profile of the current system

- **Generate** an **environmental profile** of the system throughout its **entire life cycle**. It might reveal the **environmental inefficiencies** of the current system.
- It is essential to **plot** the **materials input**, **energy use**, and **toxic emissions** of the system throughout the stage of its **life cycle**

4

Identify the other characteristics of the system

- Use the **profile** made in step 3 to **identify** the **environmental bottlenecks** and to highlight the **environmental characteristics**, like high energy consumption during the **use phase** or an **end-of- life** problem due to the materials used
- Map out the **rewards** and **incentives** in the system
- Map the **external** forces, like **regulations** (present and future)

5

Generate AFF concepts

- Start the design process with the (environmental) **bottlenecks** and **inefficiencies** of the system identified earlier
- Aligning the **incentives** within the system can be another way of **optimizing** the **system**, both from an **economic** and **environmental** point of view

6

Benchmark alternative solutions with the original system and select

- **Evaluate** and **benchmark** the alternative **solutions** by using metrics applied in previous steps
- The **solutions** have to be **scored** on more than their improved environmental qualities alone. Especially since it is likely that the generated solutions require a considerable amount of change and effort from all parties involved to further develop into marketable propositions.
- Therefore, looking at the **amount** of **change needed** and the **profitability** of the generated concepts will be vital before **selecting** the **solution**(s) to take further into the development process

Strengths & Weaknesses

S

Systemic view of the product environment

Easy to apply

Function rather than product

Generate new solutions

W

Lack of research on AFF concepts

Too simplistic

Lack of tools for identifying systems

References :

AAF

- Van der Zwan, F. and Bhamra, T., (2003) 'Alternative function fulfilment: incorporating environmental considerations into increased design space' Journal of Cleaner Production, 11(8), pp.897-903.

Product-Service Systems

Definition

- It is a method which allows to **create** or **improve goods** and **services** in order to answer better customers' needs and increase the value for the company and the clients.
- In this process, the whole system is reviewed.
- It is a **customer-focused** strategy.
- We can find **three PPS types**:
  - **Product Oriented PSS** (POPSS): The goods are the property of one or several customer(s) and the role of the company is to provide services to ensure the functionality, durability and performance of the intended good.
  - **Use Oriented PSS** (UOPSS): The good is the property of the company and it sells the functionality of this product thanks to a service contract.
  - **Results Oriented PSS** (ROPSS): The company sells results to consumers without telling the way of reaching those outcomes.

Goals

- Accompany firms' shift to **create** more **integrated goods** and **services**
- **Add value** to products and services delivered
- **Increase** the product eco-efficiency and **decrease** the resources use
- Answer to **customers' needs** in the most **suitable** way
- Create more **sustainable** customers' **relationship**
- Serve to **radical** innovation
- Help to **survive** in **changing environments**
- Find **new markets** and **customers**
- Increase **flexibility**

How to implement it?

1

Understand your current system to examine new opportunities

- **Define** your scope, (e.g., specific market)
- **Collect data** to make a **state of play** of the current system
- Define the **amount** of **resources** you need and you can access for this project
- Define the **functional unit**
- Define your **current system**
- Understand the **customers' needs** that are already fulfilled and the remaining ones to cover in the future
- Define the **stakeholders** of **your system** and their related interests
- You can use the **system map** and the **sustainability SWOT** to realize this step

2

Produce ideas and choose the most suitable ones

- Develop concrete **ideas** to **improve** the **existing system**
- Resolve the **identified** issues
- Use the **opportunities**
- Satisfy your **customers' needs**
- Make your new **solutions** as **sustainable** as possible
- You can use the **sustainable guidelines** level one and the **sustainability and feasibility diagram**

3

Detail the selected ideas

- **Notice** the **necessary material** components of your product in a general way (even the infrastructure) and the **necessary services** to build your offer
- The goal is to **increase** the **value** of your **services** and **decrease** the **necessity** of the **material** part
- Identify the **actors** needed to **create** your **offer** and the cooperation wanted with each one
- **Draw** the **product's** and the **service's life cycle**
- **Allocate** the **tasks** to each actor to **increase efficiency** and **minimize costs**
- You can use the **sustainability guidelines** level 2 to realize this step

4

Assess and test your new system

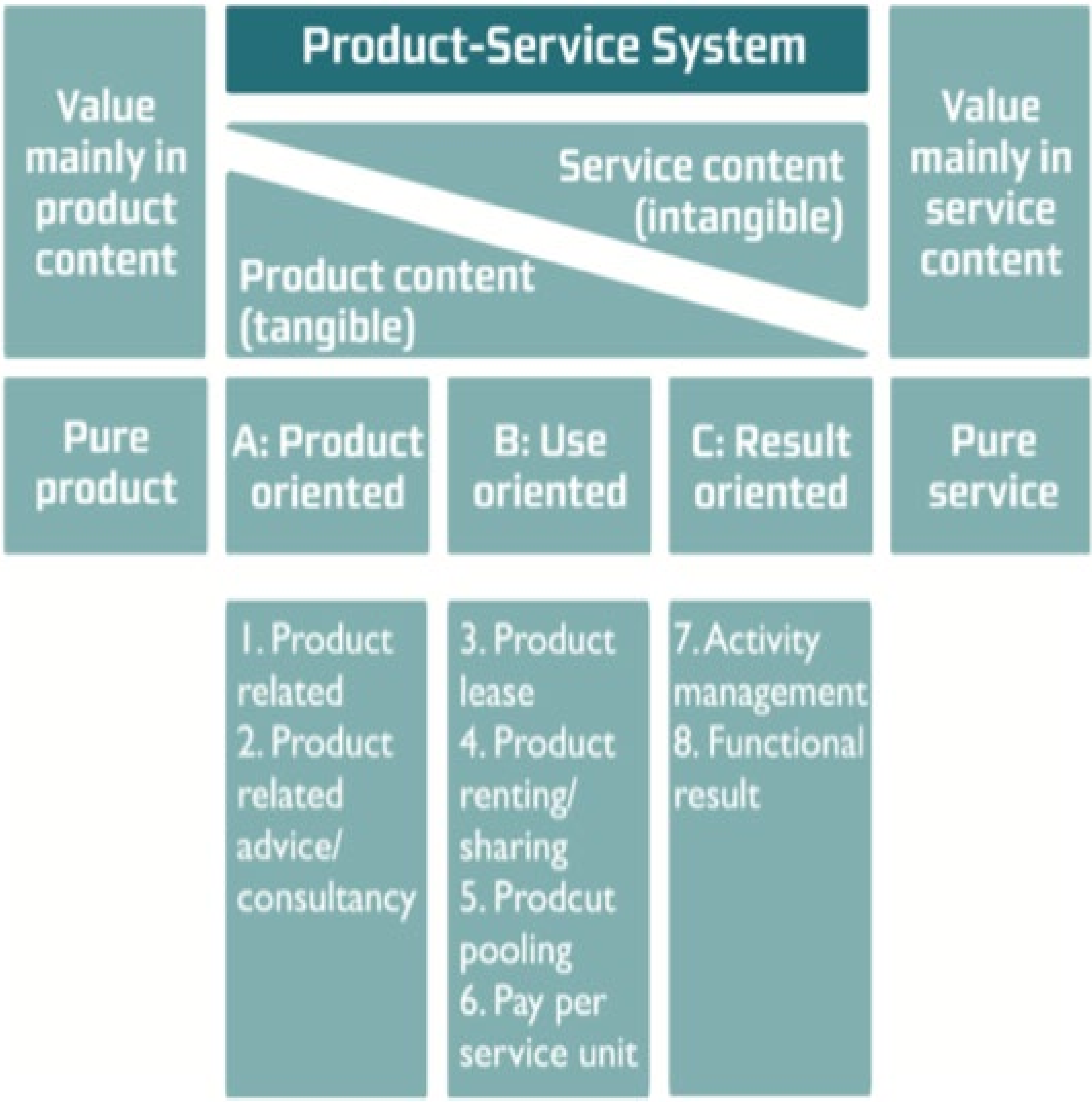
- **Compare** your **new system** with the **previous** one according to each dimension (environment, socio-cultural and economic) and their related criteria
- **Identify** the **improved aspects** and the deteriorated points (if any)
- Make **modification** for the remaining **weak points**
- Allow to see if you are on the **right path**
- With this step, you can also **compare different solutions** to choose the best one

5

Implement

- **Design** and **buy** the **components** needed
- **Arrange** the **service functioning**
- Create a **user interface**
- Review your communication to **promote** your **new offer**
- Make a **business plan**

PSS


Product-Service System
Value mainly in product content
Service content (intangible)
Product content (tangible)
Value mainly in service content
Pure product
A: Product oriented
B: Use oriented
C: Result oriented
Pure service
1. Product related
2. Product related advice/ consultancy
3. Product lease
4. Product renting/ sharing
5. Prodcut pooling
6. Pay per service unit
7. Activity management
8. Functional result

Strengths & Weaknesses

S

Create new partnerships

Systemic innovation

Service-oriented business

Align stakeholders' interests

Focus on satisfaction

Take into account the environmental, social and economic sides

Numerous tools are available

Can be a way to survive or entry in new sectors

Based on win-win solutions

W

Imply cultural shift for the user

Deep change in corporate culture

Difficult to quantify the savings between the old and the new system in economic and environmental aspects

The payback period is longer than for a simple product

Modify the company "business as usual"

Conflict with the current functioning and procedures

Possibility of rebound effects (unwanted side effects)

Exist different definitions of PSS

References :

PSS

- Gerlach, R. (n.d) The Sustainability SWOT Analysis - A tool for Strategic Sustainability Management & Innovation, Threebility [Online]. Available at: https://www.threebility.com/post/the-sustainability-swot-analysis (Accessed: 8 December 2020)

- Tischner, U. and Vezzoli, C. (n.d) Module C: Product-Service Systems; Tools and Cases, United Nations Environment Programme and Delft University of Technology [Online]. Available at: http://www.d4s-sbs.org/MC.pdf (Accessed: 8 December 2020)

- United Nations Environment Programme and Delft University of Technology. (2009) Design for Sustainability: A Step-by-Step Approach [Online]. Available at: www.d4s-sbs.org/d4s_sbs_manual_site.pdf (Accessed: 8 December 2020)

Open Green

Gingko 21 is a consulting firm specialized in **eco-design** and **eco-innovation** created in **2005**

Auki is a consulting firm specialized on **sustainable innovation** created in **2004**

Definition

- It is an **eco-conception method** developed by insights from the **field** which structures the approach to develop **innovative ideas** in the objective of **managing** overall **costs**, creating **value** for customers and **reducing** the **environmental impact** of a product or service.

- It is useful to start **implementing** an **eco-conception** process without questioning the development process of the company thanks to a **360° analysis.**

Origin

Developed by **Gingko 21** and **Auki** which guide companies to develop **eco-innovation** approaches and resolve **complex problems**

See the "**Eco-innovation Guide**" published by **Eyrolles**

Goals

Integrate a **learning process**

Conduct an **innovative process** integrating environmental aspects

Innovate for and **with** customers

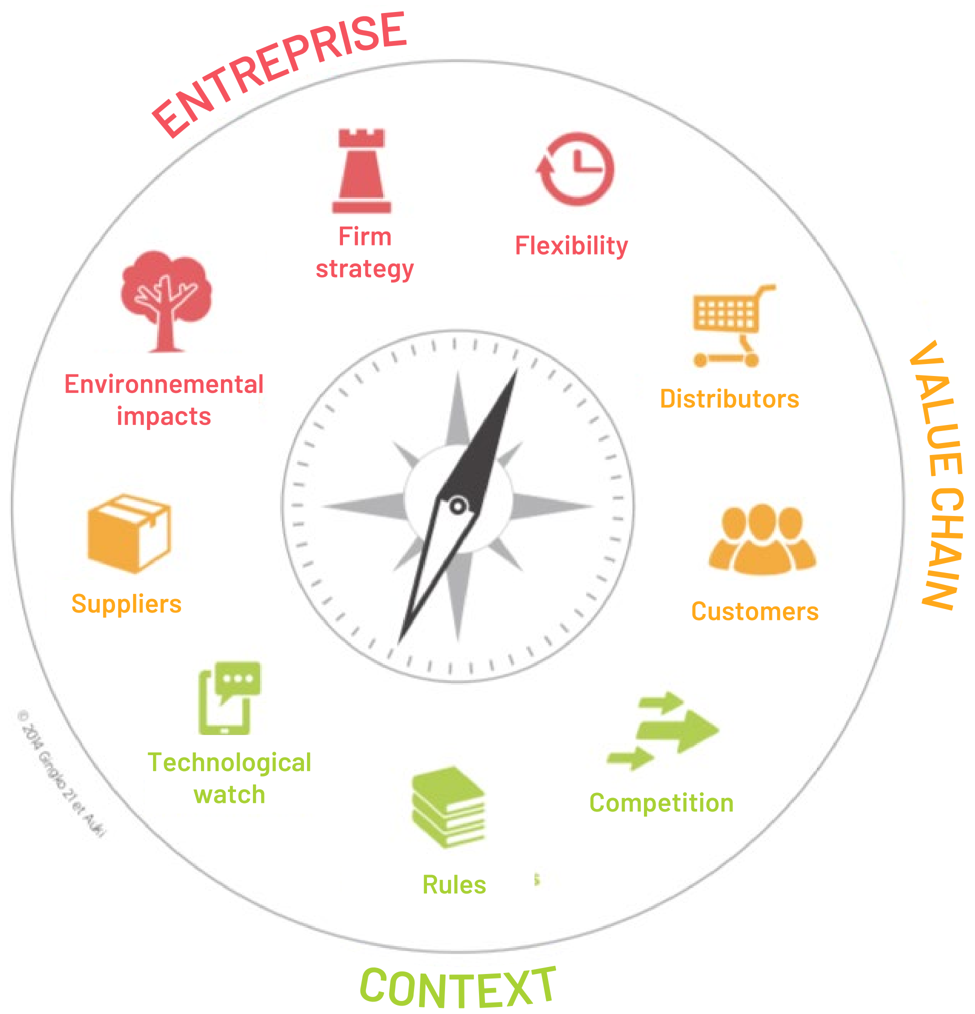
Respect **deadlines** and **budgets**

Create environmental **value** but also **added-value** for customers as well as **reducing costs**

How to implement it?

1 Identify opportunities

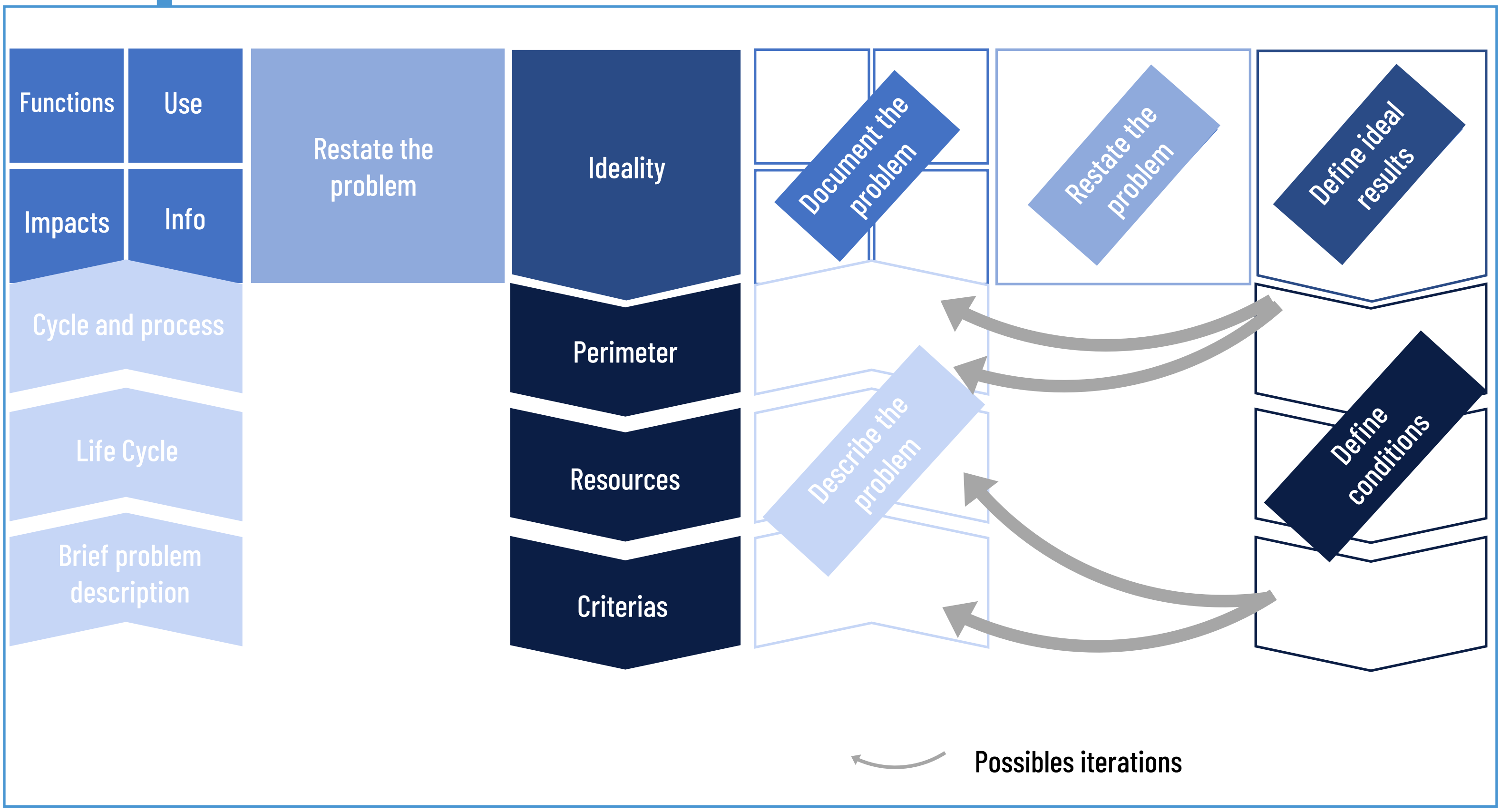
- **Analyze** your environment and context
- Identify the **reasons** why you want to **integrate eco-conception** approaches
- Choose the **product**(s) or **service**(s) in which you want to **focus** on
- Recognize the **factors** which **support** your **choice**
- Find **arguments** to convince **internal stakeholders**
- Use the **wheel** below to structure this step by **answering** each **question** present in this schema



2

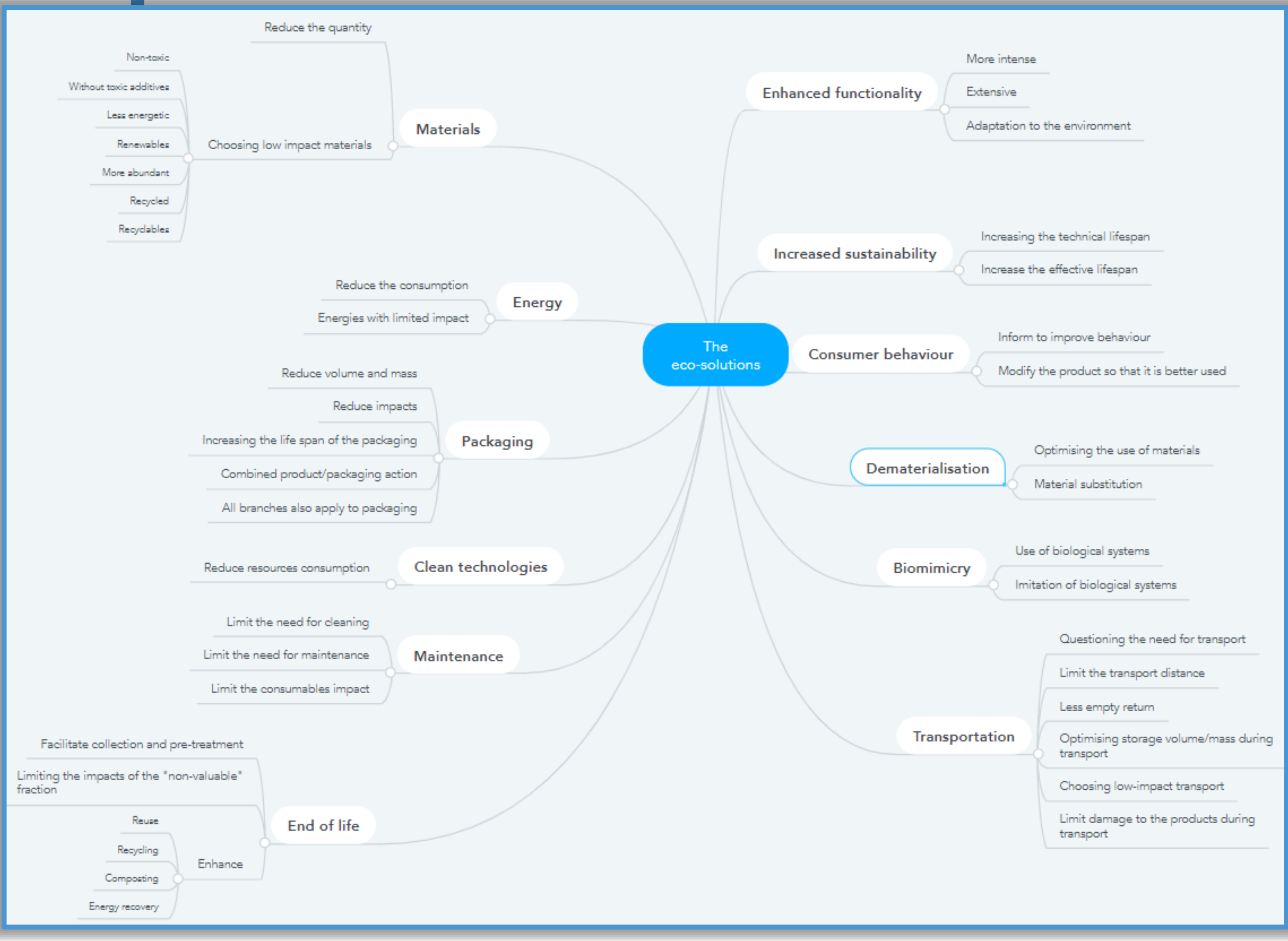
Analyze

- Sum up the **ins** and **outs** of the situation
- **Register** all the **aspects** of the product or service
- **Do not rush** on the first solution which is generally not the good one
- With this **tool**, you can **zoom** on all the **necessary components** of an environmentally friendly approach: the **life cycle**, the **environmental** and the **social impacts** will complete the **functional analysis**
- The most suitable result are to find objectives shared by everyone
- You can also use the **MIME matrix** (see in the toolbox)



Imagine solutions

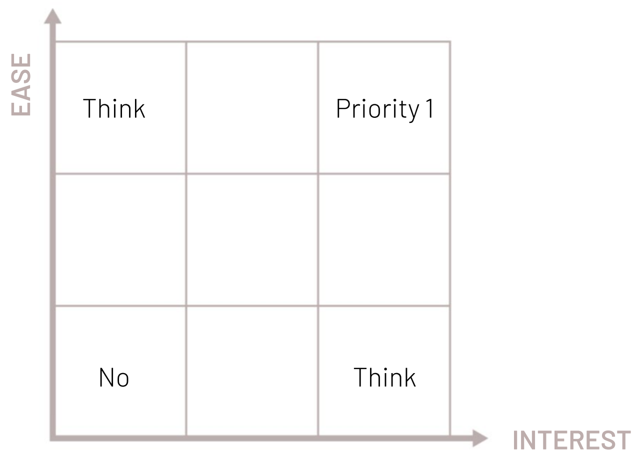
- **Creative** process
- Objectives of this step: **focus** on **researching eco-innovation opportunities**, supported by robust arguments
- Take into account all the **elements** from the **context** which can have an impact on your research
- **Identify** the different **solutions** and align them with the **corporate strategy**
- Be **exhaustive** regarding solutions
- A strong support is needed to train teams and accelerate the pace
- You can use **TRIZ** tools and eco-solutions **OpenGreen**
- The most important principles are:
    - **Overcome doubts**
    - **Lighten** the **issue** thanks to contextual elements, clear objectives and eco-innovation axis
    - **Form** a **team** with different profiles with around 8 to 10 people



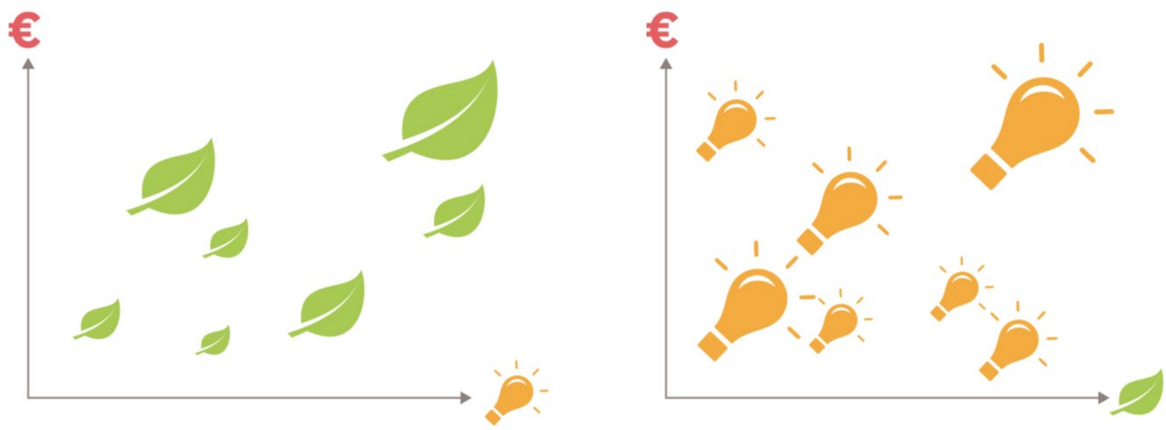
4

Choose

- The complex part is to **filter solutions** by eliminating some of them
- **Maximize** your **knowledge** by putting all the **information** regarding solutions on "**cards**"
- Each team member will share **his arguments** and results around a meeting to have a **collective choice**
- **Evaluate** them according to a **rational process** by picking factors with related weights
- Choose the **remaining ideas**
- This method proposes to choose solutions according to 3 factors: **the environmental impact**, the **cost** and the **value creation** for customers
- Looks like **cost-benefits** analysis
- See below the different tools:



Evaluation and prioritization – 9 boxes matrix



Evaluation and selection of ideas under 3 dimensions

In the last graph, the leaves represent the environmental impact, and the bulbs represent the value creation of customers. Their size is proportional on the benefits released from each idea.

5

Implement

- **Apply** those **solutions** in the industrial process
- **Test** the new processes
- **Compare** with the previous one
- **Launch** the new product on the **market**

6

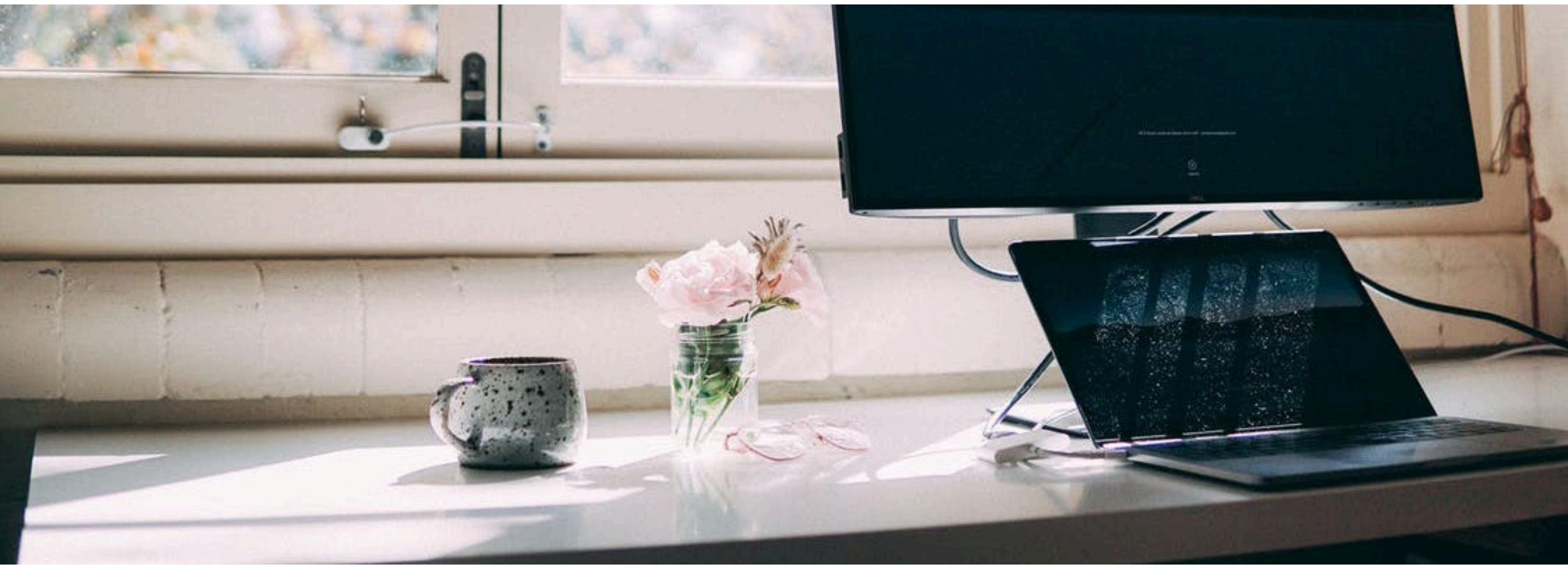
Communicate

- Add on your **communication visuals** the new spectrum of the products' environmental impacts and the **added-value** for **customers**

7

Capitalize

- **Register** the acquired **knowledge** thanks to the project
- Be sure that they are **available** for the **intended people** in the company
- **Learning process**



Strengths & Weaknesses

Do not need previous competences

Method from the field

Work in a transversal way

Easy to use and implement

Bring knowledge in the company

S

W

Not a scientific method

It has to be structured to not be muddled and time-consuming

Need support to implement this creative process

The team configuration is extremely important

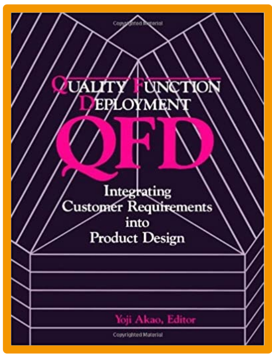
References :

OpenGreen

- Touze, S. (2019) Benchmark des centres de ressource en ligne sur la performance environnementale des produits (biens et services), ADEME [Online]. Available at: https://www.ademe.fr/sites/default/files/assets/documents/benchmark-cdr-peps-centre-de-ressource-2019-rapport.pdf (Accessed: 7 December 2020)

- Teulon, H. (2015) Le Guide de l'Éco-Innovation, Eyrolles [Online]. Available at: https://atmo-hdf.fr/joomlatools-files/docman-files/Depliants_plaquettes/livret-ecoinnovation-hteulon-ademe-web-min.pdf (Accessed: 8 December 2020)

QFDE



"Quality Function Deployment (QFD): Integrating Customer Requirements into Product Design"
by Yoji Akao

Searcher at **National Institute** of Advanced **Industrial Science** and **Technology** in Tsukuba **Japan**

Keijiro Masui

Associate Professor in the Department of **Management** and **Engineering** at Linkoping University

Tomohiko Sakao

Associate Professor in the Department of **Environmental** and **Energy** at **Chemistry** Kogakuin University

Atsushi Inaba

Definition

- Quality Function Deployment (**QFD**) is a method to **collect** vaguely expressed **quality requirements** from the market and to deploy them into actual **design** work (Akao, Y. Quality Function Deployment, Productivity Press, Cambridge, MA, 1990).
- **QFDE** has been developed by adding **environmental aspects** (Environmental requirements and Environmental engineering specifications) into QFD to cope with the **environmental** and **traditional** product quality requirements **simultaneously**.
- QFDE is a "methodology to evaluate the **effects** of **design improvement** concerning the parts on environmental quality requirements" (Quality Function Deployment for Environment in Product Eco-design Wu Yongming, Luo Baixiang, Li Muzhi).
- **Customers** and the **environment** are viewed as the most important aspects in the whole design process.

Origin

It was developed by **Mizuno** and **Akao** in **1965**

Quality Function Deployment (QFD): Integrating **Customer Requirements** into **Product Design** de Yoji Akao

QFD theory started in **1972** at **Mitsubishi's** Kobe Shipyard

QFDE (quality function deployment for environment) was published in: **2009** International Conference on Energy and Environment Technology in a report named: "**Quality Function Deployment** for **Environment** in **Product Eco-design**" "

QFDE (1st report) is a **methodology** in **early stages** of Design for effect by: Masui, Sakuo and Inaba

Goals

- Possibility to apply the QFDE method in all **industries sectors**
- **Identify** the **priorities** of **environmental criteria** which represent the improvement efforts for creating environmentally friendly products
- QFDE proposes a **methodology** to **drive** towards the **engineering** problem **free** and **zero defect** of products
- Permit transforming **customers' needs** into design requirements
- Develop **sustainable solutions** with the respect of environment and customers needs
- Use it in the **early stages** of **product design**

How to implement it?

The two first phases permit to identify the components that should be focused on product design.

1 Identify the target of design improvement

- Identify **customers' needs** in terms of product and environment thanks to a **quantitative** approach
- Deploy a table with **VOC** (voice of consumer) to **Engineering Metrics** (EM) for **product design**
- VOC items in the table include the **environmental VOC** items such as "**less material usage**" as well as requirement items from customers
- VOC items are weighed based on market surveys to show the "**Customer Weights**" with a specific scale:
    - "9" = very important
    - "3" = important
    - "1" = relatively important
- EM items include new items such as "**amount of energy consumption**"
- At crossing points between **VOC items** and **EM items** are shown numbers indicating the **magnitude** of **both factors** called "Relational Strength" which use the same scale as **VOC**
- The total of the sum multiplied by "**Customer Weights**" and "**Relational Strength**" is the "**Raw Score**" for each EM item. "Relative Weight" for each item is obtained by the Raw Score / Sum of the Raw Score.

2 Deploy engineering metrics items to components of products

- **Evaluation method** of design improvement
- Relative importance of components is **finding** by the same process, **scale developed** in phase I
- Deploy **EM** to **Part Characteristics** (PC)
- Allow the user to **identify** environmentally **significant components** (components, parts and devices) of the product

The two last phases permit for design engineers to examine the possibility of design improvements for each component and find out the improvement effects of their design changes.

3 Estimate the effect of design changes on engineering metrics (EM)

- There are **two approaches** when design engineers will decide where they should first focus on:
  - One approach **originates** from a **target VOC**
  - The second approach is **examining** the most **important components** identified in Phase II
- Give priority to an **environmental aspect**, and the **design improvement** plan
- The improvement rate to each EM item mr, is obtained from the following equation:

$$mr_j = \frac{\sum_{k=1}^{K} b_{j,k} c_{j,k}}{\sum_{k=1}^{K} b_{j,k}} \qquad (j = 1,\ldots,J) \qquad (1)$$

With :

- C,k = 1 (improvement possible)
- C,,l = 0 (improvement impossible)

where K is the index number of a component and J is the index number of an EM item. $b_{j,k}$ is the relational strength between EM item j and component k in phase II. $C_{j,k}$ is the improvement rate of EM item j to component k and originally allowed to take the real number from 0.0 to 1.0. In this paper, to make it simple, $C_{j,k}$ can take the binary numbers:

4 Translate the effect of design changes on EM into environmental quality requirements (environmental VOCs)

- Goal: **select** the most **effective design** changes' plan
- The **improvement rate** for each environmental VOC is obtained from the following equation:

$$vr_i = \frac{\sum_{j=1}^{J} mr_j a_{i,j}}{\sum_{j=1}^{J} a_{i,j}} \qquad (i = 1,\ldots,I) \qquad (3)$$

- Where :
  - J = the index number of an EM item
  - I = the index number of a VOC item
  - a,i,j = the relational strength between VOC item i and EM item j in phase I
- The improvement effect for the environmental VOC considering **customer weight** is obtained by multiplying **vr** by the customer weight **i**
- Allow the user to **choose** the most **environmentally friendly design** from all proposed (improvement) designs

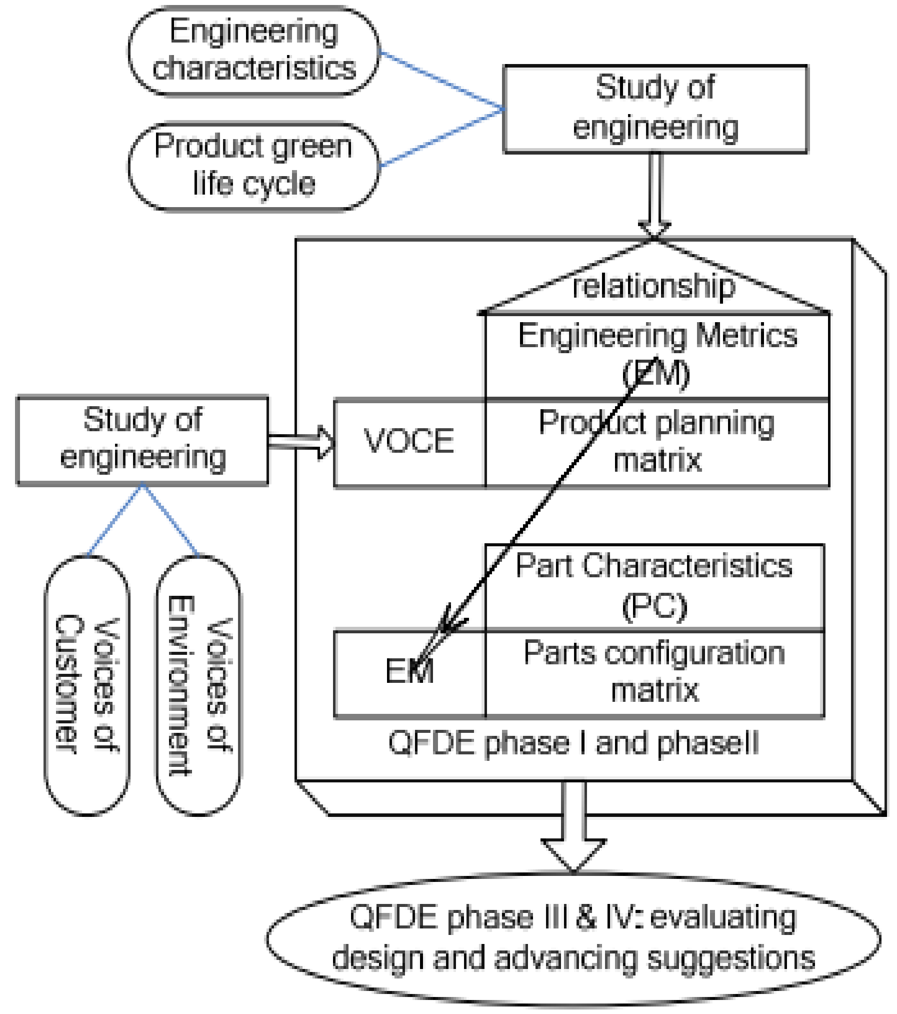
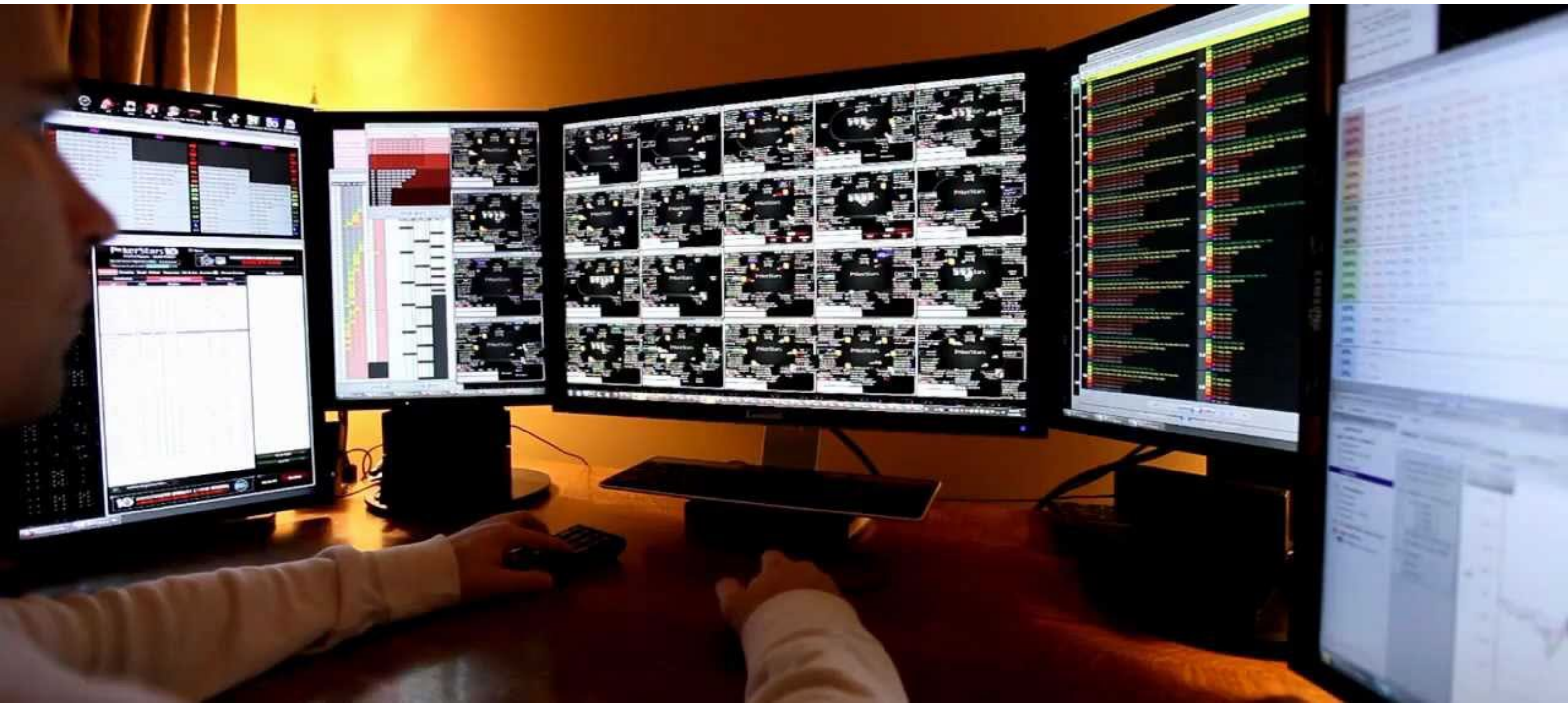


Figure 1. The process and 4 phases of applying QFDE



Strengths & Weaknesses

Simple and logical

Identify customers' needs

Satisfy the market

Be more competitive on the market

Take decisions more easily for developing new eco-products

Improve economic efficiency

Improve design efficiency

Save costs

Improve the product quality and environmental performance

Build strong knowledge base for product development projects

Understand technical specifications correctly and briefly

Time consuming and labor intensive

Big size of the matrix with many correlations

Less adaptable to changing demand

Limited Focus

Vagueness of the categories used

Need to analyze a large amount of data

Difficult to precisely define the strength of relations between customers and technical attributes

Based mainly on qualitative data

Dynamic customers' needs

References :

QFDE

- Mami, K., Sakao, T. and Inaba, A. (2001) Quality Function Deployment for Environment: QFDE (1st Report) - A Methodology in Early Stage of DfE [Online]. Available at: https://www.computer.org/csdl/pds/api/csdl/proceedings/download-article/12OmNzuljsq/pdf (Accessed: 8 December 2020)

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MGE2

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FACULTAD DE MINAS

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http://dyna.medellin.unal.edu.co/

MGE2: A framework for cradle-to-cradle design

María-Estela Peralta-Álvarez [a], Francisco Aguayo-González [b], Juan-Ramón Lama-Ruiz [c] & María Jesús Ávila-Gutiérrez [d]

[a]. Engineering Design Department, University of Seville, Seville, Spain. mperalta1@us.es
[b], Engineering Design Department, University of Seville, Seville, Spain. faguayo@us.es
[c] Engineering Design Department, University of Seville, Seville, Spain. jrlama@us.es
[d] Engineering Design Department, University of Seville, Seville, Spain. mavila@us.es

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Abstract
Design and ecology are critical issues in the industrial sector. Products are subject to constant review and optimization for survival in the market, and limited by their impact on the planet. Decisions about a new product affect its life cycle, consumers, and especially the environment. In order to achieve quality solutions, eco-effectiveness must be considered, therefore, in the design of a process, its product development and associated system. An orderly methodology is essential to help towards creating products that meet both user needs and current environmental requirements, under paradigms that create environmental value. To date, the industry has developed techniques in an attempt to address these expectations under Cradle-to-Cradle (C2C), which is loosely structured around the conceptual frameworks and design techniques. The present work describes a new framework that encompasses all stages of design, and enables interaction under a set of principles developed for C2C. Under this innovative new paradigm emerges the Genomic Model of Eco-innovation and Eco-design, proposed as a methodology for designing products that meet individual and collective needs, and which enables the design of eco-friendly products, by integrating them into the framework of the ISO standards of Life Cycle Assessment (LCA), eco-design, eco-labeling, and C2C certification.

Keywords: Eco-design, Sustainability, Industrial Ecology, Life Cycle Assessment, Eco-effectiveness, Eco-innovation

MGE2: Un marco de referencia para el diseño de la cuna a la cuna

Resumen
El diseño y la ecología son temas cruciales en el sector industrial. Los productos están sometidos a revisiones constantes para sobrevivir en el mercado y a optimizaciones que los mantienen bajo los límites de impacto sobre el planeta. Las decisiones acerca de un nuevo producto afectan su ciclo de vida, los consumidores, y sobre todo el medio ambiente. Con el fin de lograr soluciones de calidad, Eco - eficacia debe considerarse, por lo tanto, en el diseño de un proceso, su desarrollo de productos y el sistema asociado. Una metodología ordenada es esencial para ayudar a la creación de productos que satisfagan tanto las necesidades de los usuarios y los requisitos medioambientales actuales, bajo los paradigmas que crean valor ambiental. Hasta la fecha, la industria ha desarrollado técnicas en un intento de abordar estas expectativas bajo la cuna a la cuna (C2C), que está vagamente estructurada alrededor de los marcos conceptuales y técnicas de diseño. El presente trabajo describe un nuevo marco que abarca todas las etapas de diseño, y permite la interacción bajo un conjunto de principios desarrollados por C2C. En virtud de este nuevo e innovador paradigma surge el Modelo de Genómica de Eco-innovación y el diseño ecológico, propuesto como una metodología para el diseño de productos que satisfagan las necesidades individuales y colectivas, y que permite el diseño de productos respetuosos del medio ambiente, mediante su integración en el marco de las normas ISO de Análisis de Ciclo de vida (ACV), el ecodiseño, ecoetiquetado y la certificación C2C.

"MGE2: A framework for cradle-to-cradle design". M.E Peralta-Alavrez & al **(2014)**

Professor of **Engineering Design** at Universidad de **Sevilla**

Francisco Aguayo González

Professor of **Engineering Design** at Universidad de **Sevilla**

María Estela Peralta Álvarez

Professor of **Engineering Design** at Universidad de **Sevilla**

María Jesús Ávila Gutiérrez

Definition

- Process for the **design** and **development** of products that converts **C2C** (cradle-to-cradle) into a practical and applicable technique
- Model of design and development of **industrial products**
- Inspiration from **Cradle-to-Cradle**
- Support the **ISO 14000** standards requirements
- Can be supported by Concurrent Engineering and **PLM** (Product Life Management) environments, whilst considering a continuous review based on **Life-Cycle Assessment**
- **The model has a bio-inspired architecture and use biological terms**
- Integrate the **C2C paradigm**, the objective is the incorporation into the **products** of a series of **characteristics** that designate their **sustainability** during **manufacture** and **use**, and at the **end** of their useful **life**, where they repeatedly restart the process as technical nutrients, thereby rendering them autopoietic, and self-healing
- The design requirements that **MGE2** incorporates into products are defined in order to ensure **eco-compatibility**, by enabling **integration** of the **nutrients** into successive **redesigns** (new generations of products), while taking into account the evolution of the associated ecosystem product (market, Technosphere, Naturesphere, etc).

Goals

Design products that meet **individual** and **collective needs** and which are **eco-friendly**

Integrate the **C2C** paradigm in **product design**

Integrate products into the **framework** of the **ISO standards** of the Life Cycle Assessment (LCA), eco-design, eco-labeling, and C2C certification

How to implement it?

The process is divided into two sections:

- **Genotype**, the stage of **gestation** of the product (design and development)

- **Phenotype**, which defines the **associated system** of the product (manufacturing, use, withdrawal and end of life, market, policy, legislation, and competence)

The two processes (genotype and phenotype) need a strategy (sustainable) that determines their evolution, and require constant analysis and interaction management, achieved with a Life-Cycle Analysis.

The **MGE2** has a five-hold structure

- **Product Strategy**
- **Genotype**
- **Food Chain**
- **Phenotype**
- **Life Cycle Analysis**

1 Product Strategy

- Define the **objectives** under **C2C principles**, which design or redesign for a new product and manage its life cycle
- It is the establishment of the product strategy of a **systemic**, **autopoietic**, **eco-innovative**, **eco-friendly**, and **metabolizable** character

2 Genotype

- Based on product strategy, select and apply various techniques and design tools associated with **C2C** in order to establish the "**genes**" that **define** the **materials** (nutrients), **metabolic routes**, and the **types** of **energy** (possibly renewable) which will sustain the products from cradle-to-cradle

3 Food Chain

- It is the phase of **growth** and **development**; the product is ready to be manufactured and that it will later become part of its associated system

- Conduct a study of possible interactions by considering two key elements: **Naturesphere**, which constitutes the **environment** where the industry extracted the natural resources and where the biological nutrients are returned; and **Technosphere**, as a means of attaining the flow of **technical nutrients**, which must be taken into account for the material flow analysis (MFA) and substance flow analysis (SFA)

- Other **actors** should work to render the rest of their **life cycles eco-effective**, with decisions on logistics or management of the end of life

4 Phenotype

- Development of the analysis of the real and **potential interactions** of the product with the **environment** as an expression of its genes (genotype + environmental interactions = phenotype)

- Determine the expected **outcome** of the product on the market (environment)

- Takes into account **market analysis**, **legislation**, **user analysis**, material **resources** available, **traditions**, forward and reverse **logistics**, **stakeholder analysis**, **processes** of the **end** of useful **life**, etc.

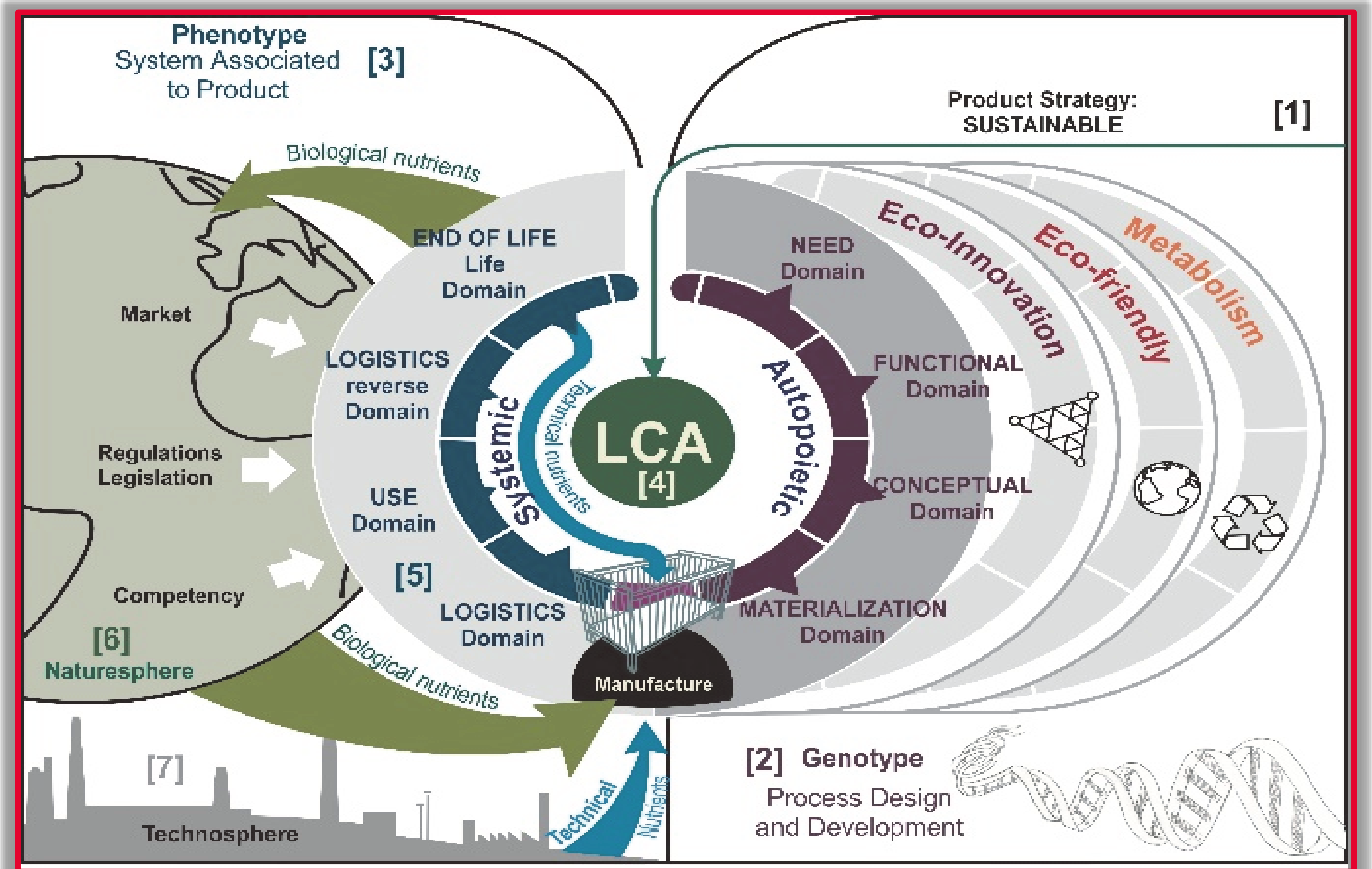
- Analyze the required **performance** of the product under the **C2C sustainability criteria**, based on data obtained from the system into which the product will be integrated and associated

5 Life Cycle Analysis

- **Determine** the environmental **impact** that is associated with the **phenotype** of a product or with its new design (genotype), so that the impact can be considered within the product

- **LCA** can be applied at **various stages** (on the phenotype - product to be redesigned - or on the genomic - design of a new product)

MGE2



Phenotype
System Associated to Product
[3]
Product Strategy:
SUSTAINABLE
[1]
Biological nutrients
END OF LIFE
Life
Domain
Market
LOGISTICS
reverse
Domain
Regulations
Legislation
USE
Domain
Competency
[5]
[6]
Naturesphere
LOGISTICS
Domain
Systemic
Technical nutrients
LCA
[4]
Autopoietic
NEED
Domain
Eco-Innovation
Eco-friendly
Metabolism
FUNCTIONAL
Domain
CONCEPTUAL
Domain
MATERIALIZATION
Domain
Manufacture
Biological nutrients
[7]
Technosphere
Technical
Nutrients
[2] Genotype
Process Design
and Development

Strengths & Weaknesses

Support regulatory requirements

Continuous improvement

Design and development of sustainable products

S

W

Does not cover services

Difficult to implement

Use of biological terms which make comprehension and application difficult

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MGE2

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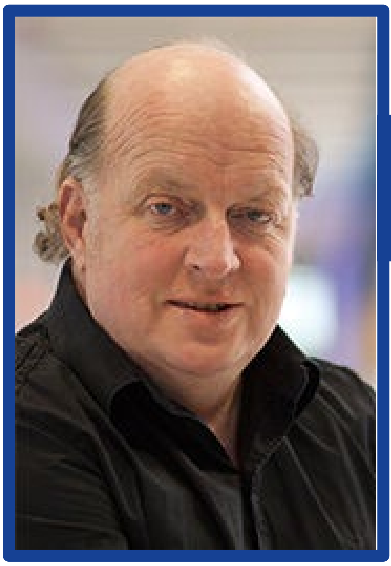
ECO DESIGN STRATEGY WHEEL

Eco-design: A promising approach to sustainable production and consumption
JC Brezet, van Hemel, UNEP, 1997
ISBN-10 - 928071631X



Johannes Cornelis Brezet

Emeritus Professor at TU Delft in **Industrial Design Engineering**
PhD in energy innovation

Carolien van Hemel

Director at **Utrecht Sustainability Institute**
PhD on Design for Environment

Definition

- Also called **Lifecycle development strategy wheel** (LiDS)
- An **eco-conception method** which represents a way of **evaluating** how well **a product** design reflects the application of **eight eco-design strategies**
- Useful to **stimulate innovation** on some **features** of **a product** by establishing strategies
- Help to select **new orientations** and can represent **a support to communicate** about it
- Could be used as **a map** to show the **different steps** a company needs to pass to product a **"better/cleaner/greener" product**
- Often works with the **MET matrix**

Origin

1990's: Growing importance of eco-conception through the eyes of stakeholders	Contribution of **Hamel and Brezet** to offer a conceptual **framework** in their publication called **'eco-design**: A promising approach to sustainable production and consumption**' (1997)**	It has been a part of the **United Nations Environment Program** (UNEP)	It is an **eco-design method** and widely used by **consultants**

Initial use: comparing two different products on their **environmental performance**	**Nowadays,** it serves to **assess** a new product by taking the previous one as a reference. The results show **the progression** of a product in terms of **ecological parameters**	**Possible to split** the **main categories** into subcomponents. Therefore, you can **change** the **analysis profoundness** according to your **needs**

Goals

- **Design** or re-design **products** to make it more **environmentally friendly**
- **Serve** to Product and Service innovation and Environmental Technology **projects**
- **Compare** different products
- **Evaluate** the environmental **improvements** of a product thanks to the actions undertaken
- **Visualize** quickly the **environmental performance** of an object on **several dimensions**
- **Point out sustainability** level of importance of the **product life cycle**
- **Select** the different **types** of possible changes
- **Capture** the main **sustainability features** of the product life cycle
- Let place to **brainstorming** and **creative** activities

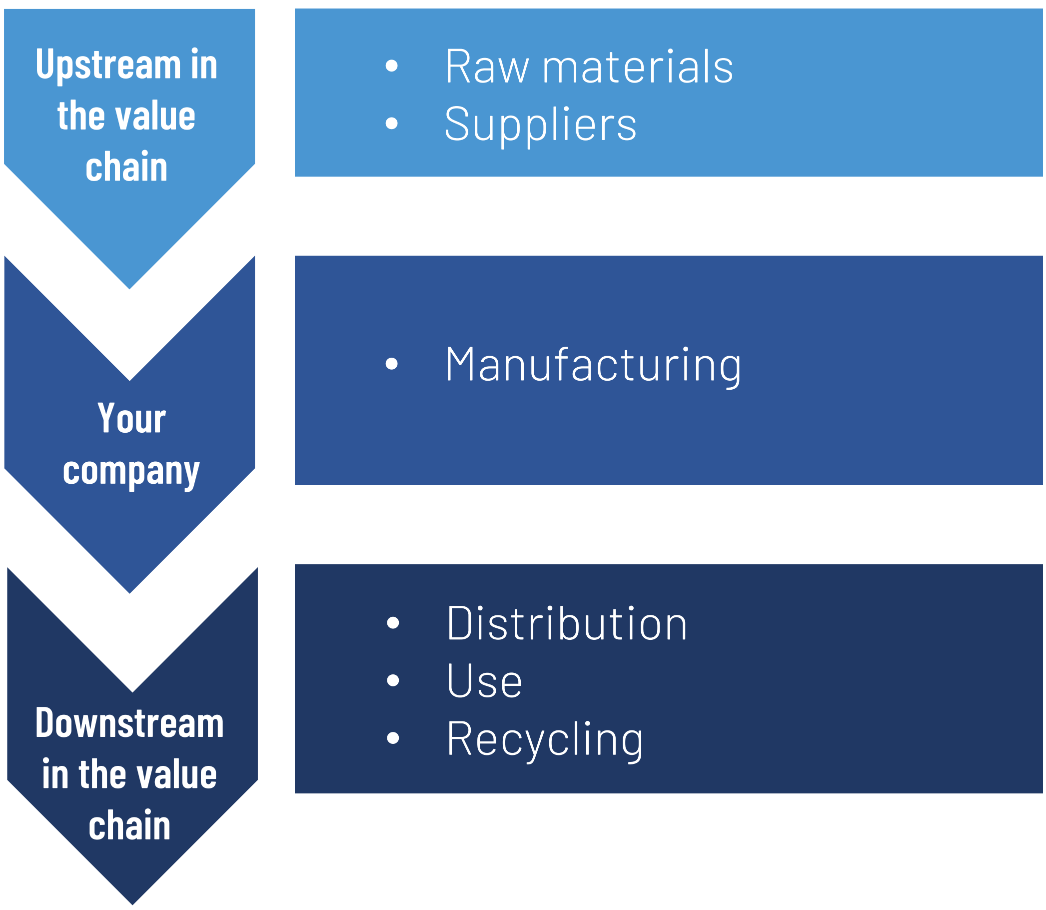
How to implement it?

1

Draw the key stages of the life cycle process

- **Clarify scope** of the project with its **limitations**
- **Define** the targeted product
- **Identify** the key stages of the **product life cycle**
- **Use** a life cycle process tree to **realize** this step
- **Example:** Note the upstream and downstream steps of your value chain. It helps to visualize the state of play of the product life cycle.

Example of a representation of a product life cycle process



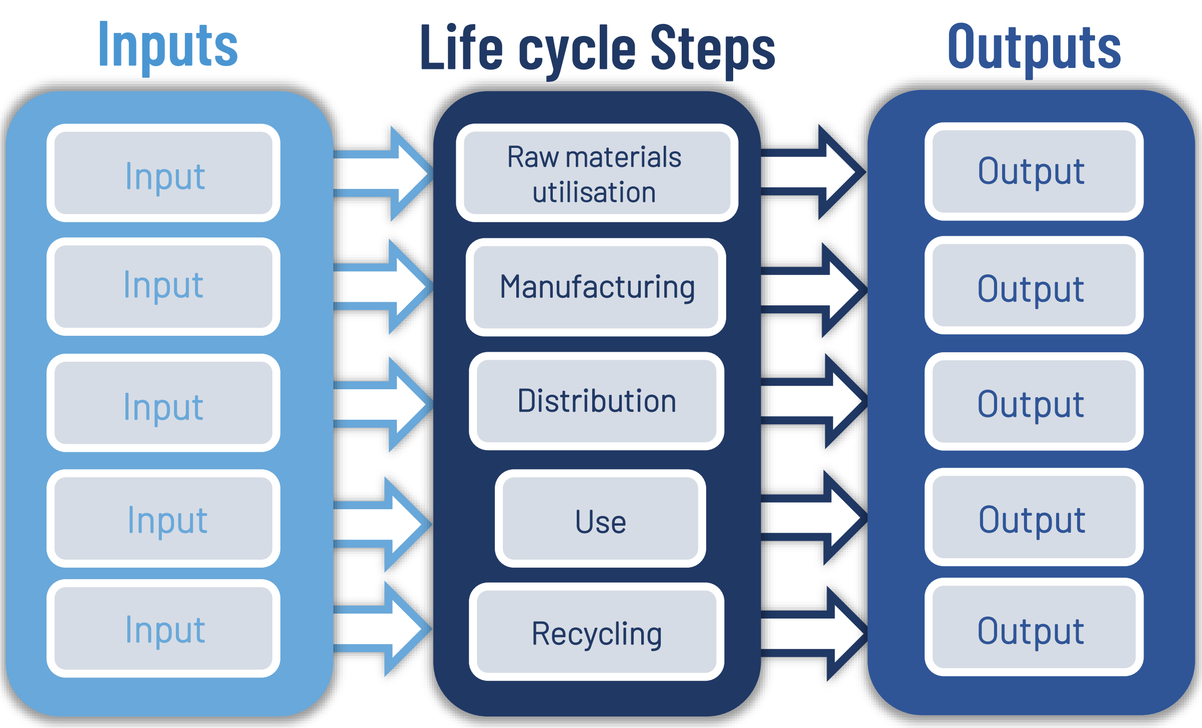
2 Describe the user scenario and functional unit

- **Describe** the user scenario which comprises the **production function**, **consumer use**, **location** and **time-related** elements of the product
- **Define** the **functional unit**: it will serve as reference to assess the environmental performance of the targeted product thanks quantification
- Do not forget the **frequency** and **lifespan** of the intended product
- **Identify** the **location** where the product will be used

3 Identify impact criteria

- **Identify** the environmental **impacts** of each step of the **product life cycle**
- Identify missing **information**
- Possibility to draw a **matrix** with, in column, the different steps of the life cycle and, in rows, the diverse **environmental criteria** such as the product **inputs** and **outputs**

Example of a diagram to identify impact criteria



4

Complete the impact diagram

- Pick **qualitative** or **quantitative** measures
- **Write** down only the **relevant** aspects
- **Sort** the impacts
- Possibility to **divide** the diagram in function of categories such as energy use containing energy consumption at all steps, and material impact based on constituent data which are not use at their maximum capacity

5

Prioritize the impacts

- **Identify** the cells containing the **poorest** and the **best** environmental **performance**
- **Prioritize** the impacts

6

Draw the Eco-design strategy wheel

- Draw the **eco-design strategy wheel**
- **Identify** the most **suitable** design **strategies** for improving your product
- Affect your **resources** on specific pillars
- **Observe** that each dimension is related to one step in the **life cycle process** of the product

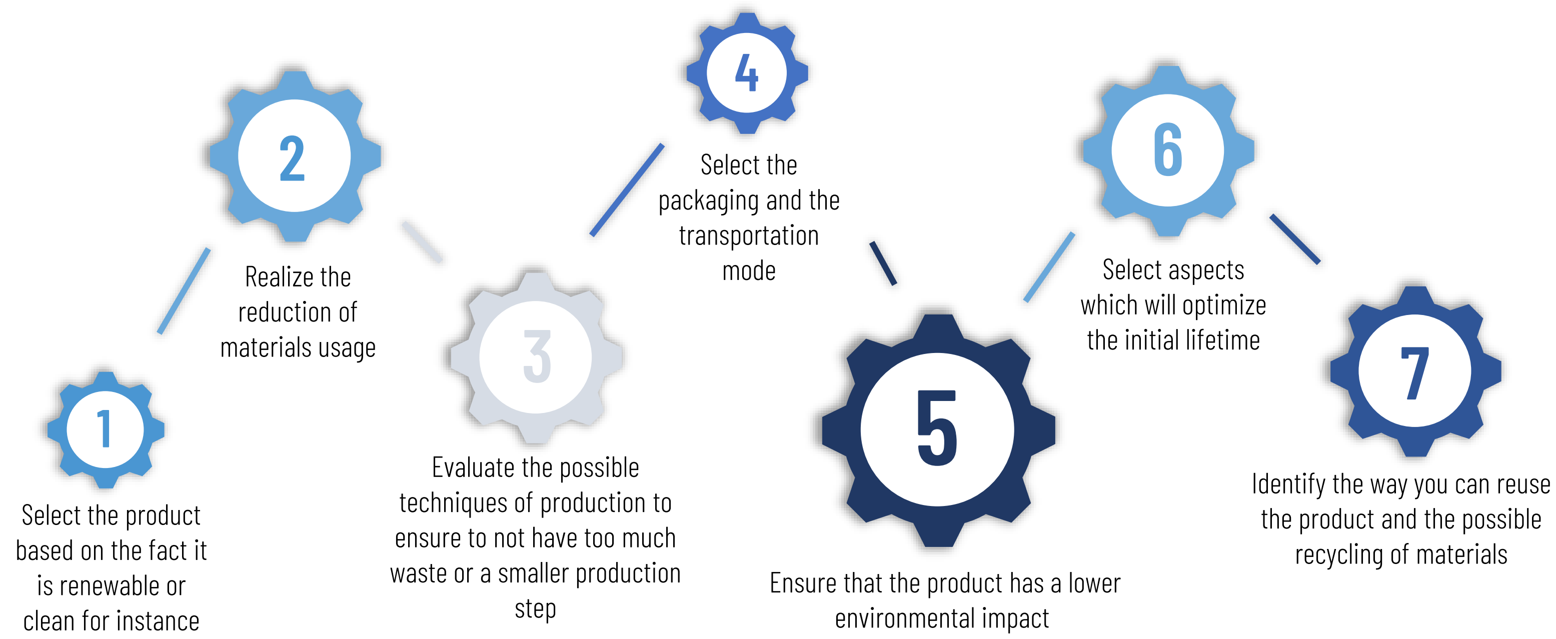
7 Create and select strategies

- **Find** innovative **ideas** thanks to **creative** activities
- Put criteria in place to **choose** between different **ideas**
- **Assign weight** to each criteria
- **Realize** a feasibility **assessment** to take your **final decision**
- Possibility to realize **simulations** on the **eco-design Strategy wheel** and create a new diagram to compare possibilities

8 Implement and monitor

- **Test** the actions chosen
- **Compare** the **improvements** made thanks to the changes and **quantify** it
- **Assess** its **performance** on the long-run and continue improving other parameters
- Collect **feedbacks** from **consumers** and **employees**

As you have noticed, we can find seven different steps within the diagram below:



Strengths & Weaknesses

S

Simple to implement and use

Clear graphical representation

Do not need specific knowledge

Ideal for a multidisciplinary working group

See the products improvement in terms of ecological parameters

Focus on innovation

Rapid visualization

Boost team projects

Can be used as a starting point

Connected to other methods

Follow-up from conception to end-of-life

W

Complicate to generate radical eco-innovations

Not possible to determine the real environmental impact of a product. Method based on an arbitrarily defined system of evaluation

Own system of evaluation

Too simplistic

Pre-defined guidelines can restrict usage to product-level considerations

No processes to evaluate and select the most promising ideas

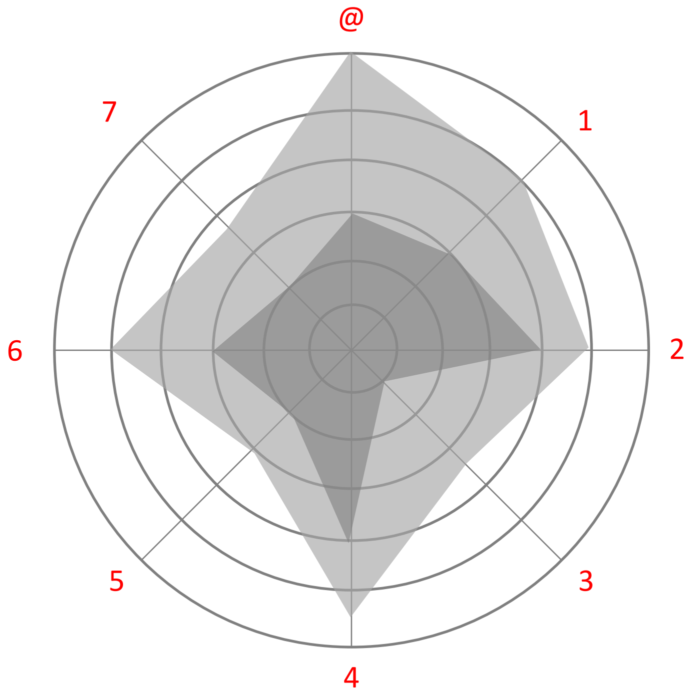
The EcoDesign Strategy wheel (Brezet and Van Hemel, 1997)

New concept developement :
- Dematerialization
- Share used of the product
- Intergrations of functions
- Functional optimisation of product (Components)

Product System Level

7. Optimisation of end-life system
- Reuse of product
- Remanufacturing/refurbishing
- Recycling of materials
- Safer incineration

8. Optimisation of initial lifetime
- Reliability and durability
- Easier maintenance and repair
- Modular product structure
- Classic design
- Strong product-user relation



Product Component Level

1. Selection of low-impact materials
- Cleaner materials
- Renewable materials
- Lower energy content materials
- Recycled materials
- Recyclable materials

2. Reduction of materials usage
- Reduction in weight
- Reduction in (transport) volume

5. Reduction of impact during use
- Lower energy consumption
- Cleaner energy source
- Fewer consumables needed
- Cleaner consumables
- No waste of energy/consumables

Product Structure Level

4. Optimisation of distribution system
- Less/Cleaner/reusable packaging
- Energy-efficient transport mode
- Energy-efficient logistics

3. Optimisation of production techniques
- Alternative production techniques
- Fewer production steps
- Lower/cleaner energy consumption
- Less production waste
- Fewer/cleaner production consumables

Priorities for the new product

Existing product

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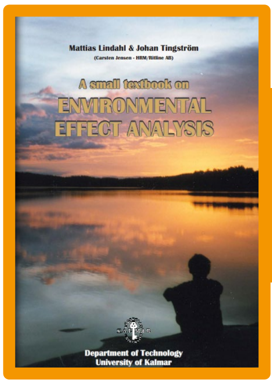
EEA



"A little textbook on ENVIRONMENTAL EFFECT ANALYSIS" M. Lindahl & J. Tingström

Mattias Lindhal

Specialized in **eco-design**
Department of **Management** and **Engineering** (IEI) at Linkoping University in **Sweden**

Johan Tingström

University of Kalmar, in **Sweden**
Department of **Technology**

Definition

- An environmental effect analysis (EEA) determines the **product's environmental impact** by taking into account **economic** and **technical characteristics** involved in creating the product.
- It is a **qualitative** method.
- It represents a systematic study of the environmental effects of a product system, from **extraction** of **raw material** to the **final disposal.**
- It is based on **environmental requirements.**
- It can be a part of an **environmental management** system according to **ISO 14 001.**

Origin

1999:

The name was changed from Environmental **FMEA** to Environmental Effect Analysis – **EEA**

EEA development started in the **mid-nineties**, because of a great need for an **easier** and **faster** method for **environmental impact** evaluations than the ones at hand

Had to be compatible with the **ISO 14 001** (1996) standardized **Environmental Management System** (EMS)

Goals

Identify and **evaluate** significant **environmental impacts** of a product to find **alternative** materials and processes

Use it during the **early stages** of product design

Find "**hot spots**" that is, the environmental effects particularly important to work with to **decrease** the environmental **influence** of the **product**

Prevent or limit in a simple and **cost-effective** way the product's entire life-cycle with EEA tools

Facilitate companies' work with an **environmentally friendly** product development

1 Collect relevant information

- **Data** are needed regarding the product, its life-cycle and its **environmental impact**
- This collect can be divided into three part: **authority demands**, **market demands** and **internal demands** (e.g. controlling documents, internal environmental aims)

When an EEA is performed, a **special form** is used (see the table below).

Example of an EEA form

Environmental Effect Analysis - EEA [The SIO-Method]

Part Name	Part Number	Drawing Number	Function	Date	Issue

Project	Supplier	Info	Follow-up Date	Page No.

EEA Leader	EEA Participants

Inventory				Valuation				Actions							
Life-cycle		*Environmental Characteristics*						*Proposals for Action*		*Valuation*				*Realization*	
No.	Life-cycle Phase	Activity	Environmental Effect / Aspect	S	I	O	EPN / F	Recommended Actions	Environmental Effect / Aspect	S	I	O	EPN / F	Remarks	Responsible

The form may vary somewhat, depending on the type of evaluation that will be made and on the specific user needs

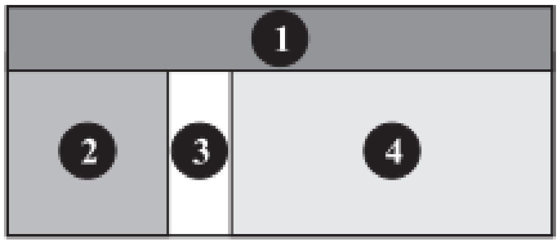


Figure 11. An EEA-form contains four parts; the form heading (1), the inventory part (2), the valuation part (3) and the actions part (4).

2

Fill the form heading (1)

- Facilitate the **future identification** of the performed environmental analysis
- Necessity to **introduce changes** on the **process** because of companies' special demands and needs

3

Fill the inventory part (2)

- Contain two main areas: the **Life cycle** and **Environmental characteristics**
- Necessity to **identify** the different **phases** of the **product**

Life-cycle

- **Number**: Associate one serial number for each activity
- **Life-cycle Phase**:
    - o **Identify** the different **life-cycle phases** of the product
    - o **Fill** information on which **life-cycle phase** the current **activity** belongs to
    - o Choose **life cycle phases** depending on the limitations made and the extent of the EEA
    - o **Detail** your work to have a better **analysis**
    - o Divide the phases of the life-cycle like: **Purchase**/**Acquisition** (I), **Production** (T), **Use** (A), **End-of-life treatment** (R)

Environmental Characteristics

- Identify the environmental **effects** of each **activity**
- **Activity**:
    - o Divide the **life-cycle** into **different activities** parts where something is performed or happens and where environmental impact is caused.
    - o **Identify** the activities related to **environment** for every step of the **product's life-cycle**
- **Environmental Effect**/**Aspect**: refer to **external** and/or **internal influences** on the environment, caused by a human activity

Inventory			
Life-cycle		*Environmental Characteristics*	
No.	Life-cycle Phase	Activity	Environmental Effect / Aspect

Figure 12. The inventory part of the EEA-form.

4 Fill the evaluation part (3)

- **Evaluate** and rank the different **environmental significance** based on various **parameters**
- Example of parameters: **control documents**, **public image** and **emission amounts**
- Result in a list of what are known as **hot spots**, that is, those activities with the most significant **environmental impact**

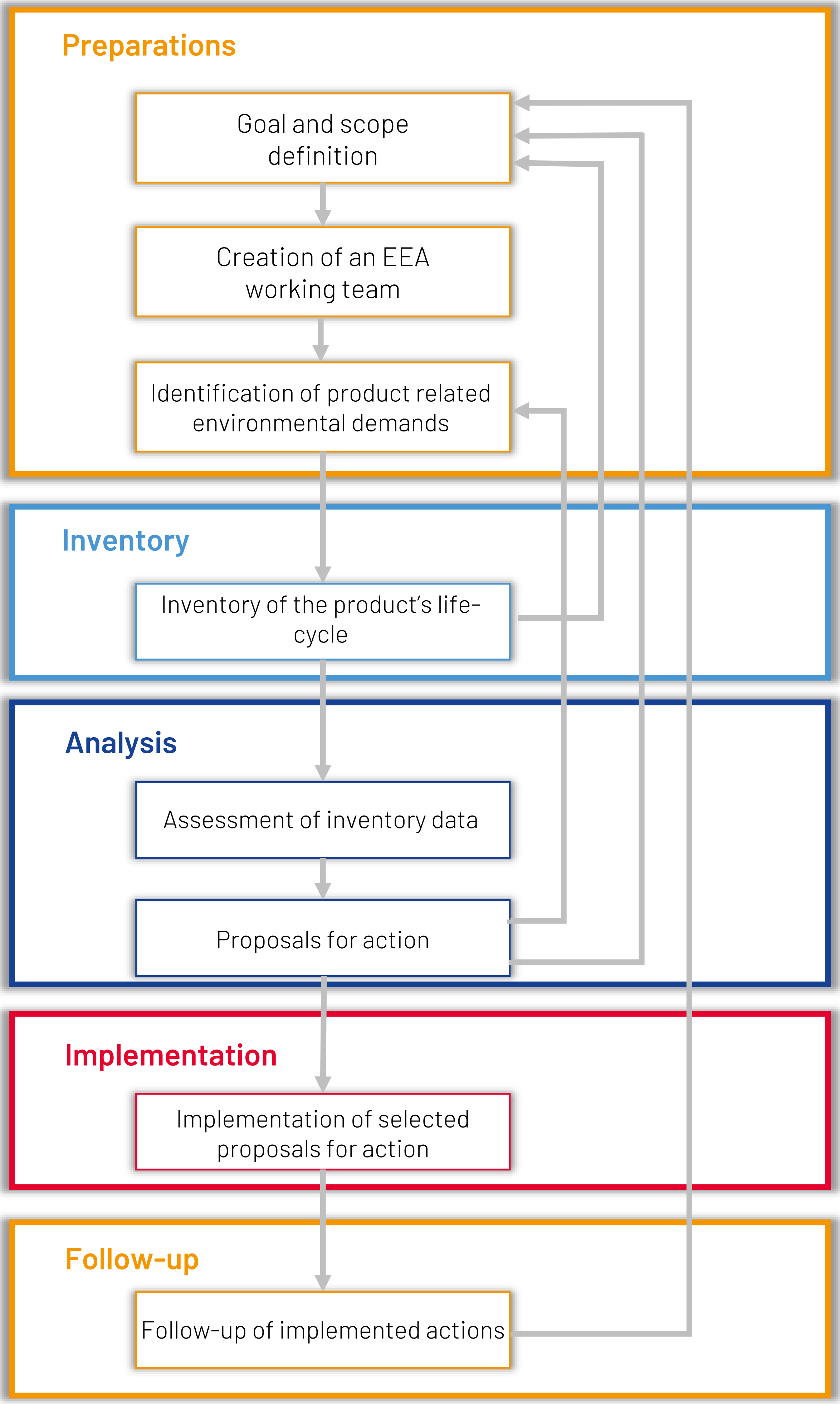
5 Fill the action part (4)

- **Identify** activities which can be measured thanks to the **evaluation part**
- List different **recommendations**
- Take **decisions**
- **Analyze** those **decisions** to be sure that environmental improvements are achieved
- **Short description** of the different columns in the actions part of the EEA-form:
  - **Proposals for Action Recommended Actions**: Based on the evaluation part, adequate actions are suggested to eliminate or reduce the environmental effect
  - **Evaluation**: to ensure that the recommended actions result in environmental improvements, they are evaluated once again
  - **Realization Remarks** : Remarks, references, comments and identification of the person or division within the company that oversees the actions and responsible for its accomplishment

Actions							
Proposals for Action		*Valuation*				*Realization*	
Recommended Actions	Environmental Effect / Aspect	S	I	O	EPN / F	Remarks	Responsible

Figure 13. The actions part of the EEA-form.

EEA Methodology



Strengths & Weaknesses

Simple

Cost and time effective

Flexible method

Transparent and understandable

Iterative process with feedbacks

Multifunction teamwork

Easy to learn, understand and use

Life cycle perspective

S

W

The planning of an EEA should coincide with the rest of the planning of the project

Need for coordination on different activities

Long preparation work

Necessity to reach a consensus within the group with respect to the information used

No quantitative data

The evaluation is subjective

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EEA

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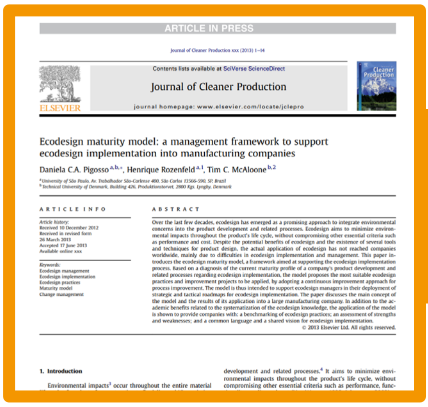
Eco M2



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Ecodesign maturity model: a management framework to support ecodesign implementation into manufacturing companies

Daniela C.A. Pigosso [a,b,*], Henrique Rozenfeld [a,1], Tim C. McAloone [b,2]

[a] University of São Paulo, Av. Trabalhador São-Carlense 400, São Carlos 13566-590, SP, Brazil
[b] Technical University of Denmark, Building 426, Produktionstorvet, 2800 Kgs. Lyngby, Denmark

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ABSTRACT

Over the last few decades, ecodesign has emerged as a promising approach to integrate environmental concerns into the product development and related processes. Ecodesign aims to minimize environmental impacts throughout the product's life cycle, without compromising other essential criteria such as performance and cost. Despite the potential benefits of ecodesign and the existence of several tools and techniques for product design, the actual application of ecodesign has not reached companies worldwide, mainly due to difficulties in ecodesign implementation and management. This paper introduces the ecodesign maturity model, a framework aimed at supporting the ecodesign implementation process. Based on a diagnosis of the current maturity profile of a company's product development and related processes regarding ecodesign implementation, the model proposes the most suitable ecodesign practices and improvement projects to be applied, by adopting a continuous improvement approach for process improvement. The model is thus intended to support ecodesign managers in their deployment of strategic and tactical roadmaps for ecodesign implementation. The paper discusses the main concept of the model and the results of its application into a large manufacturing company. In addition to the academic benefits related to the systematization of the ecodesign knowledge, the application of the model is shown to provide companies with: a benchmarking of ecodesign practices; an assessment of strengths and weaknesses; and a common language and a shared vision for ecodesign implementation.

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1. Introduction

Environmental impacts[3] occur throughout the entire material

development and related processes.[4] It aims to minimize environmental impacts throughout the product's life cycle, without compromising other essential criteria such as performance, func-

"Eco-design maturity model: a management framework to support eco-design implementation into manufacturing companies" Pigosso, Rozenfeld, McAloone (2013)

Senior **Professor** at University of **São Paulo**

Henrique Rozenfeld

Associate **Professor** at **Technical** University of **Denmark**

Daniela C.A. Pigosso

Professor at **Technical** University of **Denmark**

Tim C. McAloone

Definition

- The **eco-design maturity model** is a **management framework** with a **step-by-step** approach, aiming to **support companies** in carrying out **eco-design implementation**.

- A model focuses on **process improvement** (product development and related processes) from a **managerial perspective**, rather than on product improvement (improved environmental performance of a product/family of products) from a **technical perspective**.

- It focuses on the **systematic** and **sustained integration** of environmental considerations into the **processes** of a **product development** organization, with a view to deployment in all subsequent projects of the **organization**.

Origin

A model created by researchers to implement and manage eco-design inside companies	**Theoretical development:** Systematic literature review which comprised the theoretical analysis of 2321 scientific studies and the evaluation by a group of 14 eco-design experts	**Empirical development:** An action research study was carried out inside a large capital goods manufacturer	**Theory testing**: To test the hypothesis that the model could support companies in eco-design implementation and management, two case studies were carried out

Goals

Diagnosis of the current maturity **profile** of the company's product development regarding **eco-design** implementation

Support eco-design managers in their deployment of **strategic** and **tactical roadmaps** for eco-design **implementation**

Support the **eco-design** implementation **process**

Assessment of **strengths** and **weaknesses**

Benchmark eco-design **practices**

Common language and a **shared vision** for eco-design implementation

How to implement it?

1 Diagnosis of the current maturity profile in eco-design

- The **maturity assessment** is made based on the **capability** of the application of each **eco-design** management **practice**
- This diagnosis is performed in **three stages**:
  - **Product development processes** (PDP) **analysis**
    - Use to **understand** how the company is **organized**, **structured**, and **documented**
    - Held **interviews** with key **employees** (ideally 2-8) to gather **information** about how the **process** is applied in **practice** and to identify its main **strengths** and **weaknesses**
  - **Interviews for maturity assessment**
    - The goal of this stage is to **evaluate**, which eco-design management **practices** the **company** applies and with which **capability**
    - Execution of a set of **90 min** face-to-face **interviews** with the selected employees in 3 parts
      - **Introduction**: eco-design definition, brief explanation about the context of the model application at the company, clarification of the structure of the interview and discussion about the capability levels
      - **Semi-structured interview**: application of a structured questionnaire. The interviewee is asked about the capability level of each management practice and is asked to provide additional comments and evidence to justify the answer
      - **Final remarks**: the interviewees are asked about additional eco-design practices that the company applies but were not discussed (which can be used to improve the model itself) and to provide additional comments
  - **Consolidation of the results**
    - **Analyze** and **compare** the **capability levels** with the comments to ensure coherence and consistency
    - If necessary, the capability level can be **changed**, based on the **comments** and on the **evidence** of **documental analysis**
    - Based on the results, the company's current profile in **eco-design** is **outlined** using the **maturity radar**

2 Proposition of eco-design management practices and improvement projects

- Once a company's current **maturity profile** has been determined, the most suitable management practices to be adopted are proposed, based on a **gap analysis**
- There are **two approaches** for process improvement:
  - **Staged approach**
    - Suitable for companies with a **low maturity profile** in **eco-design**
    - **Provides** a **systematic** and **structured** way for **implementing process** improvements, based on the implementation of one stage (maturity level) at a time
    - Each stage indicates that the **process** already has the necessary **foundation** and **structure** that qualifies it for the next stage
    - Each **maturity level** contains a set of **management practices** to be applied, according to a certain **capability** that characterizes different **organizational behaviors**
  - **Continuous approach**
    - Recommended when the company **knows** which **eco-design management practices** require improvement and what are the dependencies between these practices
    - Provides **maximum flexibility**, since the organization can improve the application of specific practices related to a single evolution level, or can focus on several areas that are closely aligned with **business goals** and **strategies**

3 Portfolio management of improvement projects for eco-design implementation

- **Assessment** and **counterbalance** of strategic drivers for **eco-design adoption** (e.g., environmental compliance, cost reduction, increased environmental awareness, new business and innovation opportunities, etc.) with the proposed projects for **eco-design implementation**
- Establish a **roadmap** (i.e., a timeline) for the **implementation** of the improvement projects

4

Planning of the improvement projects for eco-design implementation

- **Detail** improvement projects
- **Describe** work packages and activities
- **Define** teams
- **Deploy** responsibilities
- **Identify** stakeholders
- **Set** implementation schedules
- **Allocate** resources
- **Calculate** risks
- **Elaborate** communication plans

5

Implementation of the improvement projects

- Take special care to **cultural change** and **people change management**, since people are the gatekeepers of change
- Include considerations about **resistance** to **change**, **leadership** role, **change planning**, **communication**, **motivation** and **encouragement** of people, staff **training**, among others

6

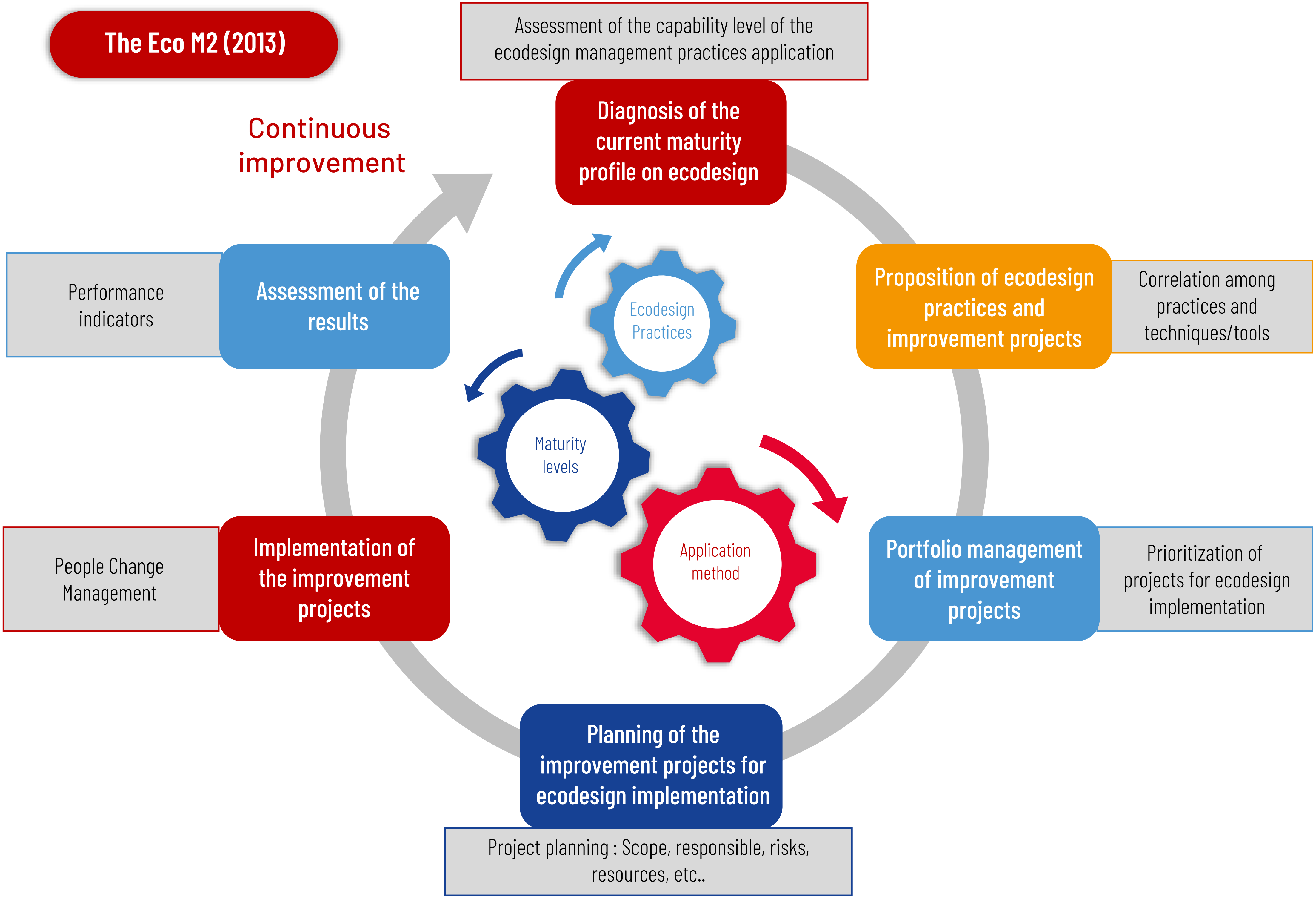
Assessment of the results

- Requires that **performance indicators** are **determined** and **monitored** throughout the implementation of the **eco-design management practices** in the product development and related processes
- The definition of performance **indicators** should take into consideration the **primary goal** of each improvement project and should be performed internally by the company, according to the **selected projects** and to the specific products developed

7

Continuous improvement

- After each **improvement cycle**, a new **diagnosis** should be performed in order to measure which practices were **effectively implemented** by the company and to **identify** further **improvement** opportunities, keeping the continuous improvement toward higher **maturity levels**


The Eco M2 (2013)
Assessment of the capability level of the ecodesign management practices application
Diagnosis of the current maturity profile on ecodesign
Continuous improvement
Performance indicators
Assessment of the results
Ecodesign Practices
Proposition of ecodesign practices and improvement projects
Correlation among practices and techniques/tools
Maturity levels
Application method
People Change Management
Implementation of the improvement projects
Portfolio management of improvement projects
Prioritization of projects for ecodesign implementation
Planning of the improvement projects for ecodesign implementation
Project planning : Scope, responsible, risks, resources, etc..

Strengths & Weaknesses

Systemic approach of eco-design

Assessment of eco-design practices

Continuous improvement

Complete model from assessment of actual situation to implementation and re-assessment of the new situation

S

W

Lack of research on the implementation for service companies

Lack of framework to monitor the performance of the improvement projects by using relevant key performance indicators

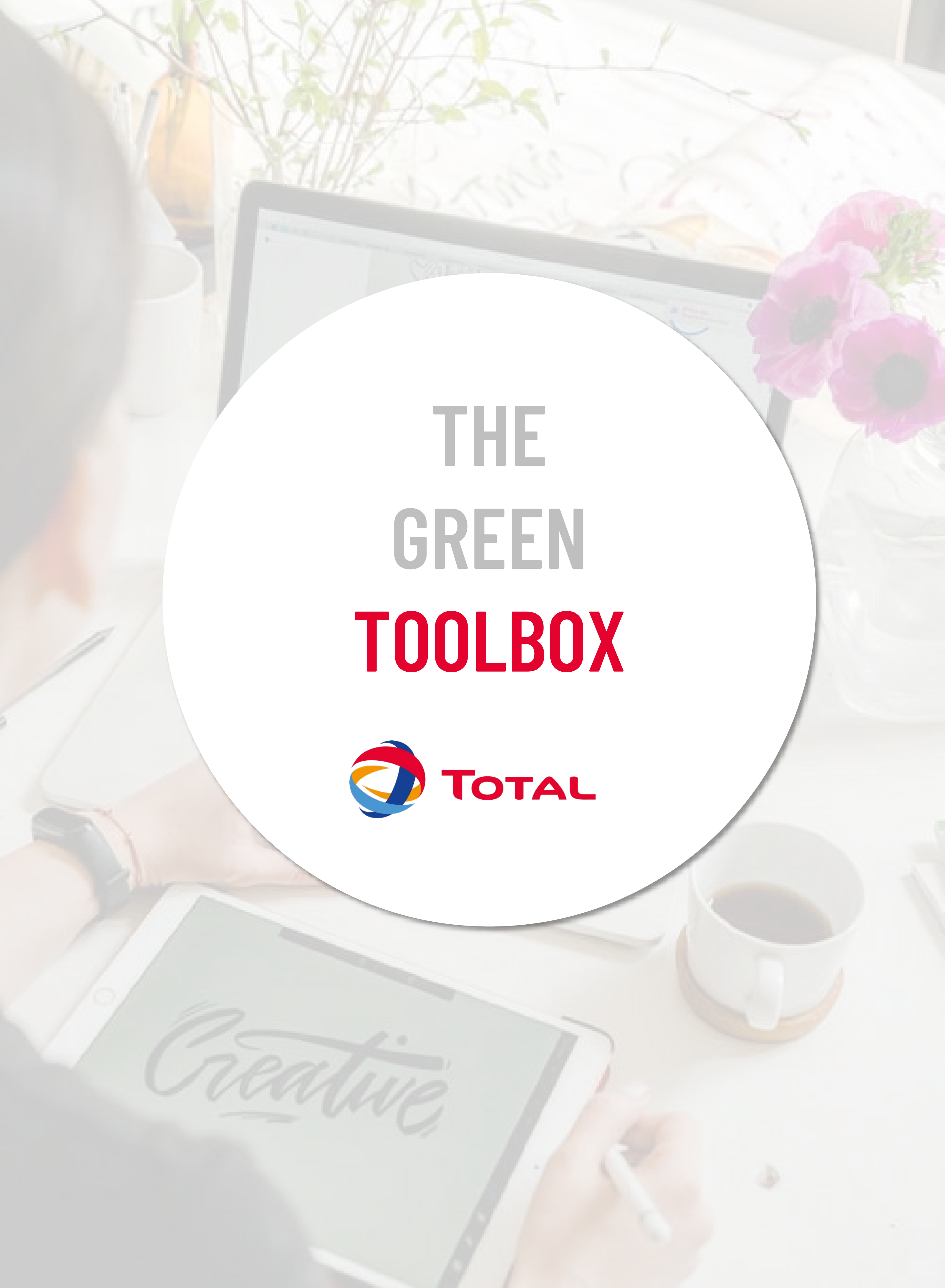
Lack the establishment of the financial efforts needed for the implementation of subsequent improvement cycles

References :

EcoM2

- Pigosso, D.C.A., et al. (2013) 'Ecodesign maturity model: a management framework to support ecodesign implementation into manufacturing companies', Journal of Cleaner Production, 59, pp.160-173.

THE GREEN TOOLBOX



The MET Matrix

Definition

MET (Materials, Energy, and Toxicity) Matrix is an **analysis tool** used to evaluate various **environmental impacts** of a product over its life cycle. The tool takes the form of a **3x3** matrix :

One dimension of the matrix is composed of a **qualitative input-output model** that examines environmental concerns related to the product's materials use, energy use, and toxicity.

The other dimension looks at the **life cycle** of the product through its production, use, and disposal phase.

Goals

- It can be used in the **idea generation stage** or in the concept development stage in every product development
- It serves as a tool to **analyze** the **product's impact** on the environment
- It helps to **uncover areas** where the product might be improved to become more sustainable or environmentally friendly

Advantages	Disadvantages
Qualitative & easy to assess	Arbitrarily System (No scales defined)
Easy to compare between the different products	Own system of Evaluation
Connected to other methods	
Global method	

STEP 1

Define what exactly belongs to the product system being studied and what does not

- Do not focus on the **physical product only**
- Consider also the **components** and **consumables** which are necessary for the product to **function** properly over its total lifetime
- **Example**: when you compare two or more products or concepts, it is essential to define system boundaries that make them truly comparable

STEP 2

Perform a **needs' analysis** by respecting the product system just defined

- How does the actual product **fulfill** the **needs** it is meant to fulfill?
- Can a **product system** be developed that **fulfills** the same **needs** in a radically more effective and efficient way?

STEP 3

Make a functional analysis, using the **MET matrix**

- **Identify**:
  - The **product's functionality**
  - Its **weak** and **strong aspects** (which parts or functions tend to cause the product to fail)
  - The **product's actual lifetime** and its **energy consumption**
- Take the **product** to **bits**
- **Measure** the **weights** of the various sub-assemblies and components
- List the **type** and amount of **materials** and **components** used
- **Identify** the **connections** between them

STEP 4

Fill in a **MET** matrix:

- **Materials**:
  - Note environmental problems concerning the input and output of materials
  - Include figures about the application of materials which are non-renewable or create emissions during production (such as copper, lead and zinc), incompatible materials and inefficient use of non-reuse of materials and components in all five stages of the product life cycle
- **Energy use**:
  - List energy consumption during all stages of the life cycle
  - Include this consumption for the product itself, transportation, operating, maintenance and recovery
  - List in the first cell of this column inputs of materials with extremely high energy content
  - Include exhaust gases produced as a result of energy use
- **Toxic emissions**:
  - Identify toxic emissions to land, water and the air in the five life cycle stages

MET matrix worksheet

	Inputs		Outputs
	(M) Use of materials	**(E) Use of Energy**	**(T) Toxic Emissions**
Raw materials & component production	All the necessary materials, parts and components	Energy consumption for the obtainment of raw materials Energy used to refine the materials Energy consumption for transport of the materials to the factory	Toxic waste generated by the extraction and refinement of materials prior to production
Factory production	Auxiliary materials purchased (screws, electrical items ...) Additional substances used in the production process	Energy consumption in the processes employed in the factory	Toxic waste produced in the factory Remainder of materials : Offcuts, rejects
Distribution & Supply Chain	Materials used for product packaging Elements of repackaging used for transport and distribution	Energy consumption during packaging and packing Transports from the factory to the final distributors	Waste from combustion produced during transport Waste packaging
Use Operation (normal functioning) & Service (Maintenance and repair)	Consumables Estimated spare parts	Energy consumed by the product throughout its estimated useful lifetime	Waste from consumables Waste from spare parts
End of life system (EOL) Waste management – recovery and Disposal	Consumption of raw materials and auxiliary materials for the end of life treatment	Energy used in the EoL system form materials or parts (Incineration, recycling ..) Energy for transport to EoL systems	Toxic waste generated by the product at EoL Waste from combustion Recycling & disposal of materials

References :

MET Matrix

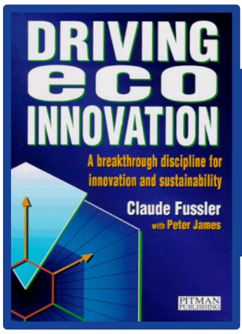
- Van Berkel, R., Willems, E. and Lafleur, M. (1997) 'Development of an industrial ecology toolbox for the introduction of industrial ecology in enterprises – I', Journal of Cleaner Production, 5(1-2), pp.11-25.

- Delft Design Guide. (n.d.) MET Matrix [Online]. Available at: http://wikid.io.tudelft.nl/WikID/index.php/MET_matrix (Accessed: 7 Decembre 2020)

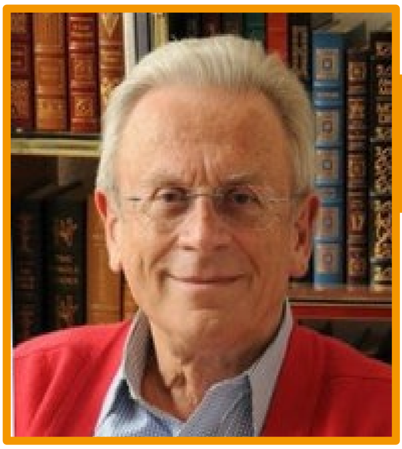
- Remmerswaal, H. (2002) 'Milieugerichte Productontwikkeling', Academic Service, Schoonhoven.

- Brezet, H. and van Hemel, C. (1997) 'EcoDesign: A promising approach to sustainable production and consumption', UNEP, France.

ECO-COMPASS



Driving Eco-innovation: A Breakthrough Discipline for Innovation and Sustainability



Claude Fussler

Founding Partner at Académie Durable
Chemical Engeneer from CPE Lyon

Peter James

Founder of Gatchi
Rural Engineer from Cranfield University

Definition

- The **Eco Compass** is a **comparative tool** to evaluate one **existing product** with **another**, or to compare a current product with new development options [Fussler and James, 1996].
- It has **six dimensions**, intended to encompass all significant environmental issues
  - Two of them are **largely environmental**: health and environmental potential risk, and resource conservation
  - Four of them are **business** as well as **environmental significance**: energy intensity, mass intensity, revalorization, and service extension

STEPS

Each of the axis **records a score from 0-5** for the new product

Input your original design or 'base case' with always a scores 2 in each dimension

Then score the new product from 0 to 5 **relatively to the original design**

Eco-compass **measures the life cycle impact** of a product or its conceptual design along six dimensions which cover all relevant environmental issues. These **six** "**poles**" are defined as follows:

Mass Intensity (the quantity of material used per unit service) is the amount of materials in the product viewed from a life-cycle perspective. It considers knock-on effects such as: amount of raw materials extracted, transport energy, and packaging required. Each material used in the product has a hidden material 'rucksack' of environmental effects such as erosion, earth displacement and waste of unconverted materials.

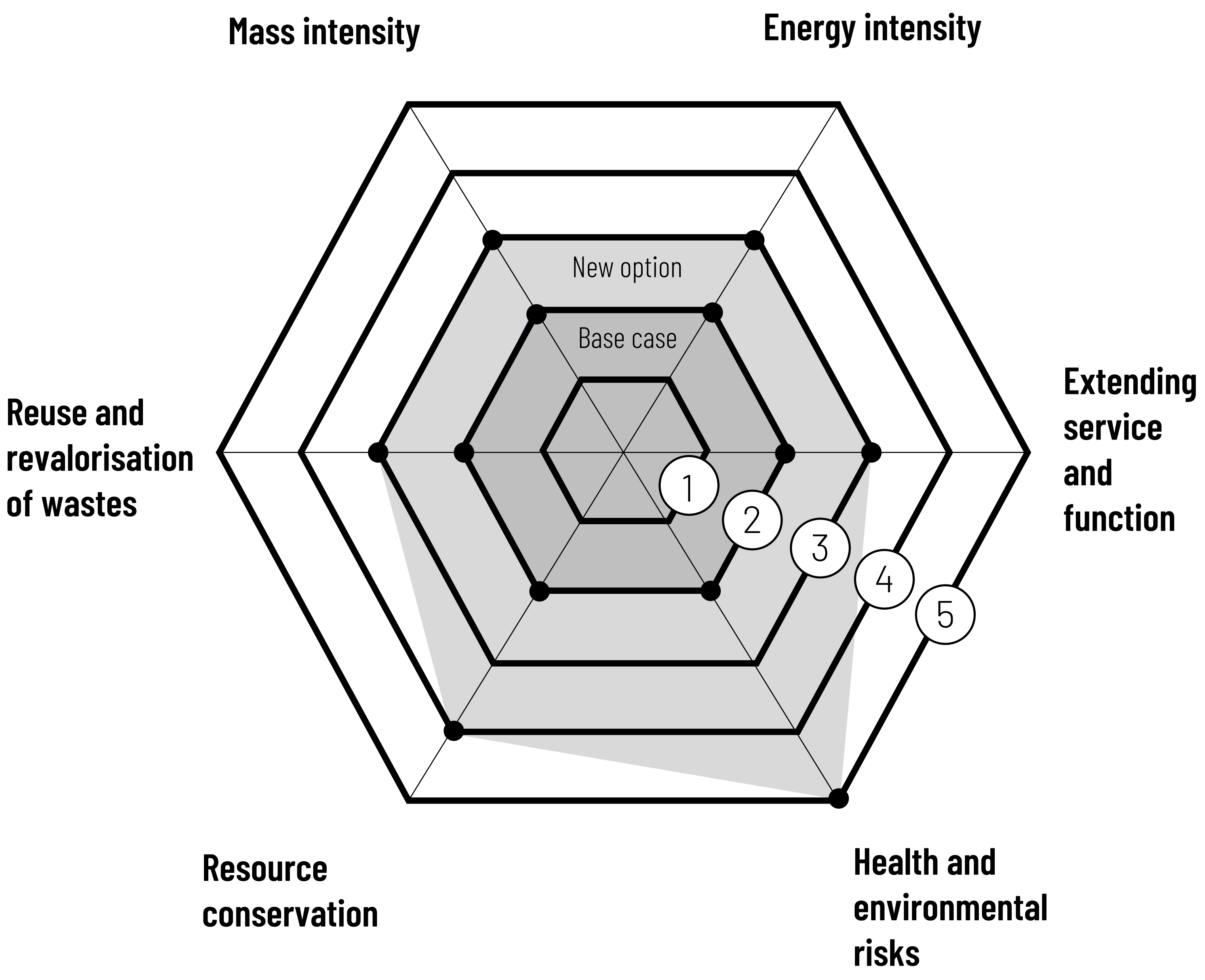
Energy Intensity (quantity energy used per unit service) is the energy consumption at all stages of the product's lifetime. The production and consumption of energy produce pollution and waste materials. When derived from fossil fuels, energy production depletes non-renewable resources as well as generating carbon dioxide emissions.

Extending Service and Function (increasing quantity of functional units in the product) considers ways of delivering more service to customers from a given amount of environmental inputs. This can be achieved by increasing product: durability, reparability, upgradeability, multi-functionality or shared use of the product.

Health and Environmental Risk (quantity of hazardous substances emitted to air soil and water): Toxicologists try first to identify the ways in which a product or process creates health and environmental risks. Secondly, they consider the importance of the risk identified. Identifying hazardous substances and setting reduction targets is an ongoing process. Eco-innovation helps to meet these targets.

Resource Conservation (quantity of scarce or depleting resources used) focuses on the nature and renewability of the energy and materials needed for a product or process. It considers the overall impact of specific resource needs.

Revalorization (quantity of waste not Eco-efficiently recycled) includes several different approaches to waste. The main aim is to close the loop on materials and products by recycling (converting wastes back into raw materials) reuse and remanufacturing (refurbishment of complete products or components).



References :

Eco compass

- Brzustewicz P. (2016) 'The application of Eco-compass method in sustainable product development' Acta Sci. Pol., Oeconomia, 15 (1), pp.5–14.

MIME matrix

Definition

- This matrix allows the **identification** of the **environmental impacts** from a **large-scale** to form a synthetic view of environmental stakes.
- Use the two principles of the **LCA** approach, that is a **multi-criteria** process and the **product's life cycle**

Goals

Focus on the **essential**

Mobilize a wider **creativity** on complex aspects of the project

Limit the **ideas generation** to stay focus on the objectives and not spread your time

Frame your environmental **priorities**

Identify the **complex stages**

Identify **blinded spots**

Origin

- Developed as part of the development of the **OpenGreen method**

Advantages	Disadvantages
Visual tool	It is preferable to realize an LCA analysis in preliminary steps
Synthetic	Need to be filled by several people to create useful and contradictory debates
Easy to understand the results by all	Not a tool developed in the scientific literature
Iterative process	Recent tool
Developed from insights from the field	
Useful for a wide range of products	

STEP 1

Realize an LCA (if possible)

- **Assess** the **environmental impacts** of your products through its life cycle
- Base your **MIME matrix** on those results
- If it is not possible to realize an LCA, you would adopt a **semi-quantitative** approach

STEP 2

Draw the MIME matrix in the analysis phase

- Write the **steps** of your **product life cycle** in columns
- Write down the **criteria** selected in rows
- **Fill each case** by following the rows' order in a qualitative way. The **most significant** impacts are the most **important**.
- Fill each case with **quantitative** data thanks to the **LCA assessment**

Matrice MIME (multi-impacts / multi-steps)	Raw materials	Manufacturing	Packaging	Transports	Use	End-of-life
Energy / greenhouse effect						
Water consumption						
Materials consumption						
Consumption of agricultural material						
Household waste						
Waste plastic						
Organic waste						

Low : + / Medium : ++ / High : +++

STEP 3

Interpret the results

- **Analyze** the results by having an **overall vision** of the product life cycle and its related environmental impacts
- Prioritize the **aspects** on which to **focus** on
- **Fix** realizable **goals**
- **Compare** your results with a **benchmarking** or the **LCA** of other products with the **same functionality**

STEP 4

Review this matrix all along the project

- **Remind** your objectives and priorities
- Possible to add a row at the matrix, especially for social stakes for each step of the product's life cycle to make a more complete analysis

References :

MIME Matrix

- Teulon, H. (2015) Le Guide de l'Éco-Innovation, Eyrolles [Online]. Available at: https://atmo-hdf.fr/joomlatools-files/docman-files/Depliants_plaquettes/livret-ecoinnovation-hteulon-ademe-web-min.pdf (Accessed: 8 December 2020)

- Costedoat, S. and Boyer, N. (n.d) 'Animer le lancement d'une démarche d'éco-conception pour améliorer la compétitivité d'une entreprise', Guide Orée, pp.1-51.

- Sen, N. and Boucher, J. (2018) Le cabinet médical vert: Comment éco-concevoir un cabinet durable ?, EA Shaping Environmental Actions [Online]. Available at: https://congress.sgaim.ch/fileadmin/user_upload/Adaptionen/Congress/Dokumente/HK_18/Praesentationen_HK_18/21_09_2018_Workshop_48_Boucher.pdf (Accessed: 8 December 2020)

SPICE model

Definition

- This is a **qualitative** tool which connects **stakeholders**, **material selection**, **eco-design** and **trade-offs** to allow strategic design management and material selection for eco-design as well as developing new conceptual models and material classification.
- The spice model concept was first defined in December **2014** in the Journal of Cleaner Production : 'Material selection for eco-innovation: **SPICE model**'.

Goals

- Improve **material knowledge** within the supply chain
- **Reduce** the environmental **impacts** of goods
- **Manage** three kinds of **risks** in material selection: the risks due to a lack of knowledge, the risks due to supplier's continual business, and the risks related to intellectual property rights

Advantages	Disadvantages
Easy to apply and use	Principally helpful for developing products
Clearly defined and elaborated	Materials' experts are required to choose the best solutions
Take or keep an edge over the market	Should be used for all products' range
Have a differentiating advantage compared to your competitors thanks to the use of eco-friendly materials	
Stakeholders engagement	
Value creation	
Improve materials knowledge	
Manage risk	
Ensure quality materials	

STEP 1 Classify the materials used for manufacturing the product

- Split the materials into the following five categories:
  - **Category S (Stimulation):** Designers perceive stimulating materials as desirable and inspirational. However, none of these materials have been already present in the market for a product often because they do not satisfy preconditions for material selection. Despite that, they stay attractive for designers and memorable for potential use in future applications.
  - **Category P (potential):** These materials are not yet been present to the market in a product, but they satisfy preconditions selection. The designers retain potential materials for use in future applications. However, barriers to use these materials are the need for an appropriate application and a suitable end-market.
  - **Category I (Incubating):** Incubating materials are trialed in a test product according to the outcomes, they can become part of the common portfolio.
  - **Category C (Common):** Common materials are consistently and repeatedly used in the product portfolio. They can change when substitution options overcome preconditions to material adoption. Furthermore, even if they are common to the portfolio, there still exists flexibility or interchangeability between them. It is possible to separate common materials into two types (1) organizationally common materials and (2) sector common materials.
  - **Category E (Embedded):** Embedded materials are tied to or immovable from the product portfolio. These materials can be integrated and fulfill its purpose thanks to the high and specific knowledge acquired on materials, safety standards, secure supply, in-house processing capabilities, sunk costs and material performance in use. Embedded materials are also of two types (1) organizationally embedded materials and (2) sector embedded materials.

SPICE model

Stimulating

S

Barriers : Technical

Strategy : Document for future applications

Eco-innovation : Material substitution

Potential

P

Barriers : Technical

Strategy : Identify suitable applications

Eco-innovation : Material substitution

Incubating

I

Barriers : Technical

Strategy : Trial in test products

Eco-innovation : Material substitution

Radical Eco-innovation

High risk

New supply chain

Common

C

Common to product and sector

Eco-innovation : eco-design strategies

Embedded

E

Embedded in product and sector

Eco-innovation : eco-design strategies

Incremental Eco-innovation

Risk averse

Existing supply chain

STEP 2

Identify the characteristics of each material and determine the key strategies and key tradeoffs

- Look at the table below to **identify** the **greatest opportunities** thanks to the key strategies and trade-off
- The model shows how **eco-design** efforts at each category level (1) **Stimulating** (2) **Potential** and (3) **Incubating** offer the greatest opportunities for material Eco innovation (disruptive or radical innovation)

Conceptual framework for eco-innovative material selection

Category	Key strategies	Key trade-offs	Source of materials
Stimulating	1. Material substitution 2. Toxicity reduction 3. Design for recycling	1. Material streamlining 2. Design for disassembly	Material selection is characterised by exploratory approach based on inspiration -dominated by new suppliers, material reasearch and assessing other sectors and products
Potential	1. Material substitution 2. Toxicity reduction 3. Light-wheighting 4. Design for durability 5. Design for recycling	1. Material streamlining 2. Design for disassembly	
Incubating	1. Material substitution 2. Design for Disassembly 3. Design for recycling 4. Light-wheighting 5. Reduced toxicity 6. Material streamlining	1. Material streamlining 2. Design for recycling 3. Design for diassembly	Material selection dominated by existing suppliers including : (1) Suppliers of components (2) Sub-assemblies (3) Material formulators
Common	1. Light-weighting 2. Material grade identification 3. Material streamlining 4. Design for recycling 5. Design for disassembly 6. Design for assembly	1. Design for diassembly 2. Design for recycling	
Embedded	1. Light-weighting 2. Material grade identification 3. Material streamlining 4. Design for recycling 5. Design for disassembly 6. Design for assembly 7. Reduced toxicity	1. Design for diassembly 2. Design for recycling	

STEP 3

Implement the desired changes to the materials according to a material expert after doing the SPICE analysis

- **Verify** that the changes realized do not **worsen** the environmental **impact** of the product
- **Compare** with the environmental impact of your **previous product** version
- Realize it to all of your goods

References :

Spice model

- Prendeville, S., O'Connor, F. and Palmer, L. (2014) 'Material selection for eco-innovation: SPICE model', Journal of Cleaner Production, 85, 31–40.

Eco-design Check-list

Origin

- From the book: '**Eco-design** : a promising approach to sustainable production and consumption', Hans Brezet, Carolien van Hemel (1997).

Definition

- Tool under the form of a **list** of **questions** that provides **support** for the **analysis** of the **environmental impact** of a product or service.'

Goals

- Provide **relevant questions** that need to be asked when establishing **environmental bottlenecks** during the product life cycle
- Avoid **missing** any environmental **impact** of the product
- Can be combined with the **MET matrix** and the **Eco-design Strategy Wheel** to complete the analysis
- Use it in the **concept generation** phase when a clear idea of a product has been developed
- Reassess existing products

Advantages	Disadvantages
Efficient tool	Need to be combined with the MET Matrix and the eco-design Strategy Wheel
Easy to implement	Time consuming, you answer all the questions in the eco-design Checklist
Good overview	There is not a direct result or answer or any other synthesis of the results
Cover each stage of the product's life cycle	
Clear and visual tool	
Good analysis and challenging tool	

STEP 1 Define the product idea, product concept or existing product that will be analyzed

STEP 2 Perform a needs' analysis to identify in what extent the product fulfills its main and auxiliary functions. You should answer this question before focusing on the environmental bottlenecks in the various stages of the product's life cycle.

STEP 3 Elaborate the questions that need to be answered to reach your objective

STEP 4 Systematically answer all the questions from the eco-design Checklist, per stage of the product's life cycle (production, distribution, utilization, recovery and disposal)

STEP 5 Provide options for improvement following the right hand side of the eco-design Checklist. Describe the options for improvement as clearly and precisely as possible.

- The Eco-design Checklist consists of two columns: the questions to be asked are given in the left-hand columns of the tables. Some improvement options are suggested in the right-hand columns. These improvement options are derived from the Eco-design Strategy Wheel.

STEP 6 Possibility to use the answers to the Eco-design Checklist to fill out a MET Matrix

The EcoDesign Checklist

Needs Aanalysis

How does the product system actually fulfill social needs?
- What are the product's main and auxiliary functions?
- Does the product fulfil these functions effectively and efficiently?
- What user needs does the product currently meet?
- Can the product functions be expanded or improved to fulfil user's needs better?
- Will this need change over a period of time?
- Can we anticipate this through (radical) product innovation?

EcoDesign Strategy @ New Concept Development
- Dematerialisation
- Shared use of the product
- Integration of functions
- Functional optimisation of product (components)

Life cycle stage 1: Production and supply of materials and components

What problems arise in the production and supply of materials and components?
- How much, and what types of plastic and rubber are used?
- How much, and what types of additives are used?
- How much, and what types of metals are used?
- How much, and what other types of materials (glass, ceramics, etc.) are used?
- How much, and which type of surface treatment is used?
- What is the environmental profile of the components?
- How much energy is required to transport the components and materials?

EcoDesign Strategy 1: Selection of low-impact materials
- Clean materials
- Renewable materials
- Low energy content materials
- Recycled materials
- Recyclable materials

EcoDesign Strategy 2: Reduction of material usage
- Reduction in weight
- Reduction in (transport) volume

Life cycle stage 2: In-house production

What problems can arise in the production process in your own company?
- How many, and what types of production processes are used? (including connections, surface treatments, printing and labeling)
- How much, and what types of auxiliary materials are needed?
- How high is the energy consumption?
- How much waste is generated?
- How many products don't meet the required quality norms?

EcoDesign Strategy 3: Optimisation of production techniques
- Alternative production techniques
- Fewer production steps
- Low/clean energy consumption
- Less production waste
- Few/clean production consumables

Life cycle stage 3: Distribution

What problems can arise in the distribution of the product to the customer?
- What kind of transport packaging, bulk packaging, and retail packaging are used (volume, weights, materials, reusability)?
- Which means of transport are used?
- Is transport efficiently organised?

EcoDesign Strategy 2: Reduction of material usage
- Reduction in weight
- Reduction in (transport) volume

EcoDesign Strategy 4: Optimisation of the distribution system
- Less/clean/reusable packaging
- Energy-efficient transport mode
- Energy-efficient logistics

Life cycle stage 4: Utilisation

What problems arise when using, operating, servicing and repairing the product?
- How much, and what type of energy is required, direct or indirect?
- How much, and what kind of consumables are needed?
- What is the technical lifetime?
- How much maintenance and repairs are needed?
- What and how much auxiliary materials and energy are required for operating, servicing and repair?
- Can the product be disassembled by a layman?
- Are those parts often requiring replacement detachable?
- What is the aesthetic lifetime of the product?

EcoDesign Strategy 5: Reduction of impact in the used stage
- Low energy consumption
- Clean energy source
- Few consumables
- Clean consumables
- No wastage of energy or consumables

EcoDesign Strategy 6: Optimisation of initial lifetime
- Reliability and durability
- Easy maintenance and repair
- Modular product structure
- Classic Design
- Strong product-user relation

Life cycle stage 5: Recovery and disposal

What problems arise in the recovery and disposal of the product?
- How is the product currently disposed of?
- Are components or materials being reused?
- What components could be reused?
- Can the components be reassembled without damage?
- What materials are recyclable?
- Are the materials identifiable
- Can they be detached quickly?
- Are any incompatible inks, surface treatments or stickers used?
- Are any hazardous components easily detachable?
- Do problems occur while incinerating non-reusable product parts?

EcoDesign Strategy 7: Optimisation of the end-of-life system
- Reuse of product (components)
- Remanufacturing/refurbishing
- Recycling of materials
- Safe incineration

fig. 2.4 The EcoDesign Checklist (Brezet, 1997)

References :

Eco design checklist tools

- Delft Design Guide. (n.d.) EcoDesign Checklist [Online]. Available at: http://www.dartmouth.edu/~cushman/courses/engs171/EcoDesign_Checklist_DelftUniversity.pdf (Accessed: 8 December 2020)

LEAN Toolbox

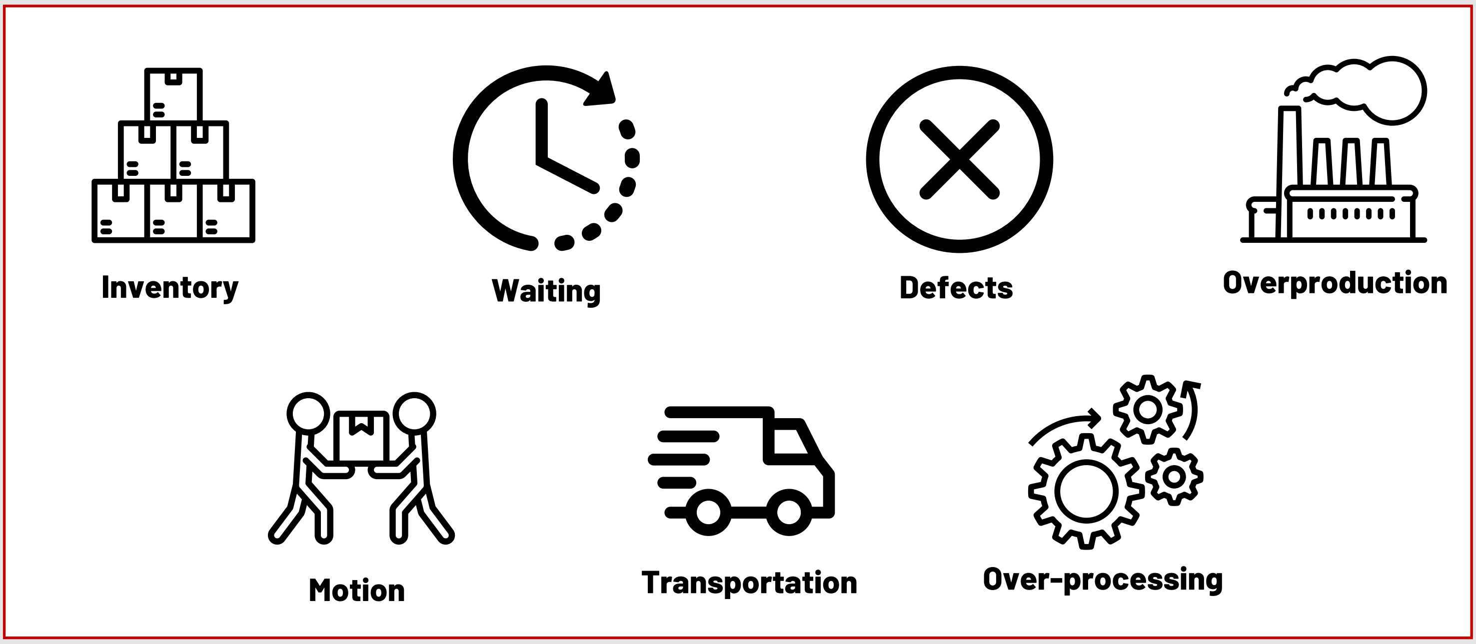
1 7 Wastes

Muda means 'Waste': aspects which have no value but increase the overall cost of the process

- **Movement**: Employees are doing non-essential movements
- **Stock**: Excess inventories or information
- **Waiting**: Lateness of information or reports
- **Defects**: Errors, confusion, forgetting

- **Overproduction**: Producing too much products compared to the demand
- **Transport**: Perform too long travels or take unnecessary path
- **Muda of process**: Unnecessary, complicated or unclear processes
- **New muda**: Underutilization of human potential by ignoring their ideas

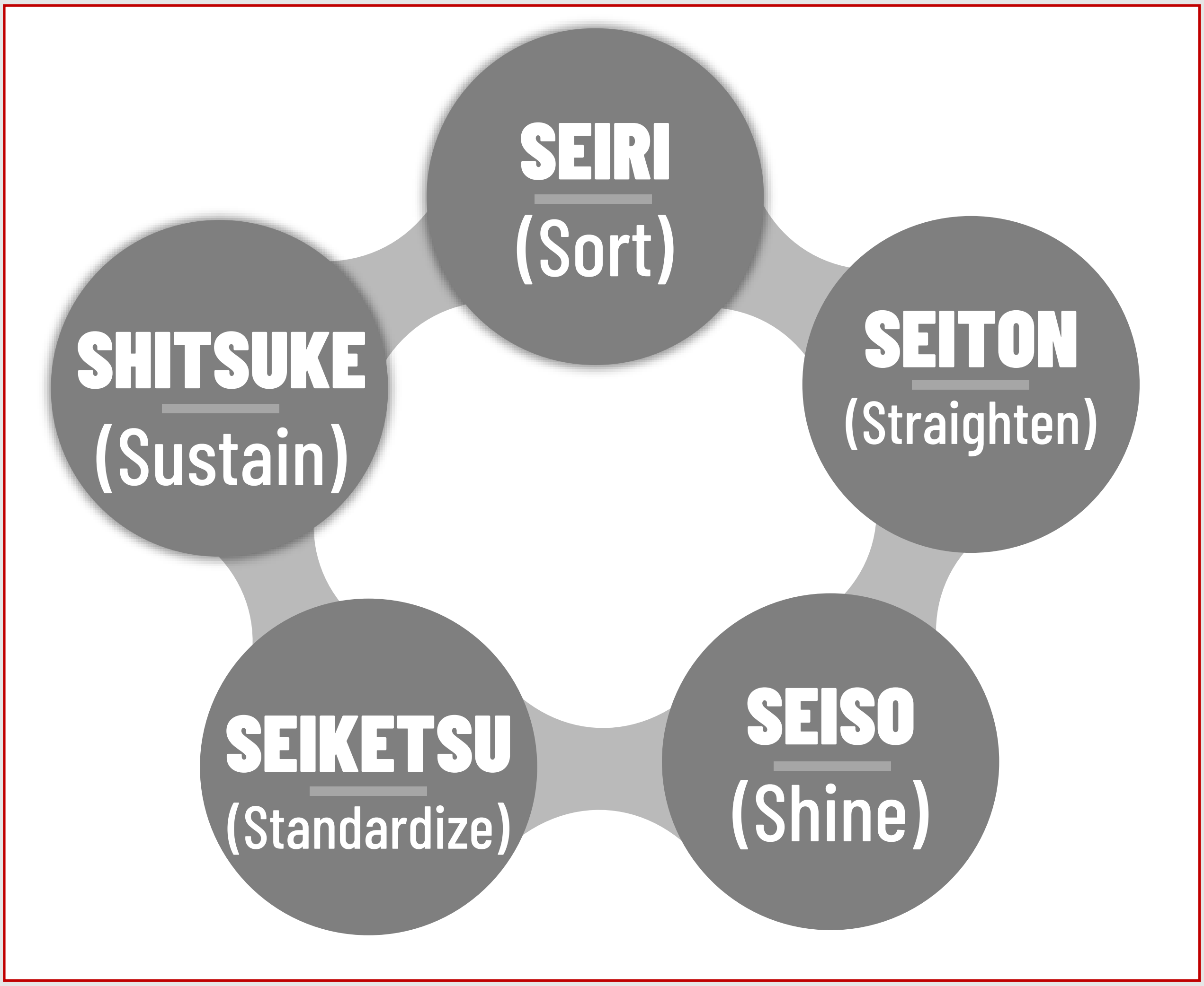
Identify waste and find solutions to eliminate those wasteful aspects



2 Pareto law (80/20 rule)

- In the majority of events, **80%** of the **consequences** are created by **20%** of the **causes**
- It is a distribution law
- E.g. 80% of turnover come from 20% of our business activity

Enable visual management: understand without efforts the workspace functioning

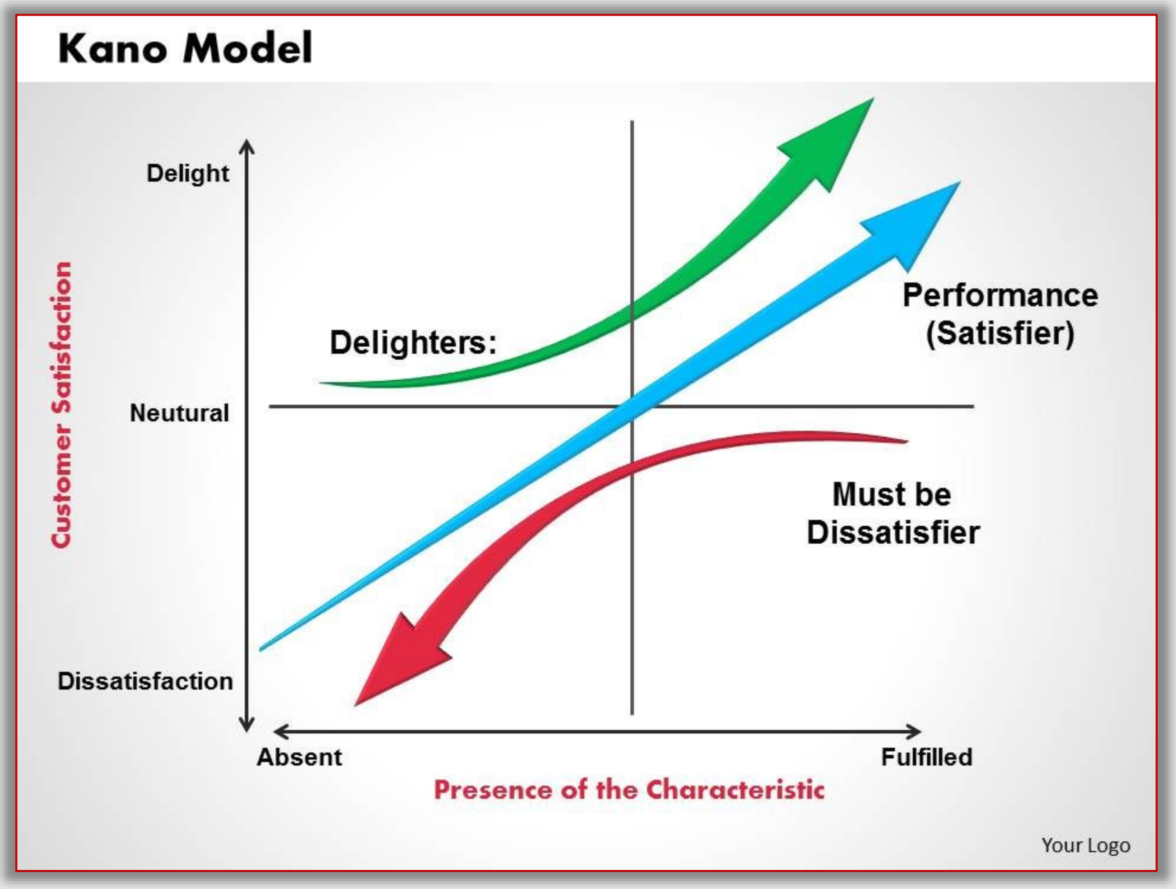


- **Seiri** (Sort): Identify and eliminate unnecessary objects
- **Seiton** (Straighten): Reorganize the workspace and rules to facilitate their identification
- **Seiso** (Shine): Identify and fix detrimental effects to tidy and assure safety in the workspace
- **Seiketsu** (Standardize): Put in place norms such as codes, norms, markings
- **Shitsuke** (Sustain): Implement best practices and improve them constantly

4 Kano Diagram tool

Must-be ⇩ if absence of expected features	Attractive ⇧ If additional features	One-dimensional ⇩or⇧ depending of attributes satisfaction
Those are the mandatory features that customers are expecting. They are taken for granted. If the product is good compared to comparative goods, customers are neutral. If the products do not have those features, customers are disappointed.	These features give fulfillment when accomplished totally but do not provoke disappointment when not met. Those are features which are not necessarily required by customers but are appreciated when they are present.	Features provoking happiness when satisfied and disappointment when not present. That are the characteristics in which competitors are fighting to take advantage.

- It exists a standardized questionnaire
- Consumers have to answer two questions for each attribute. One question is expressed in a positive manner (functional) and the other in a negative way (dysfunctional).

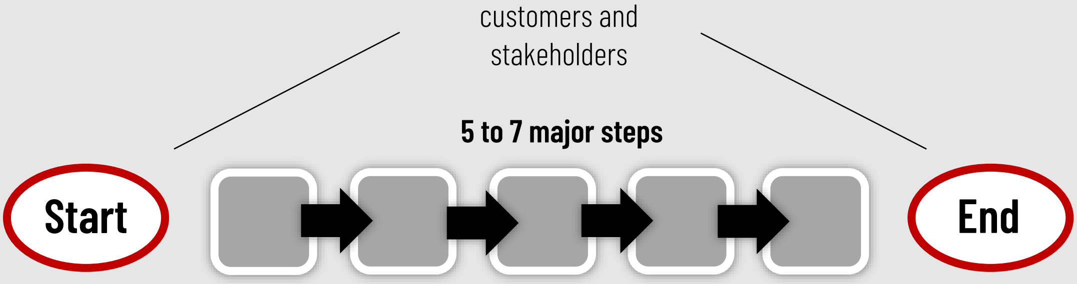


5 SIPOC

Define the business process

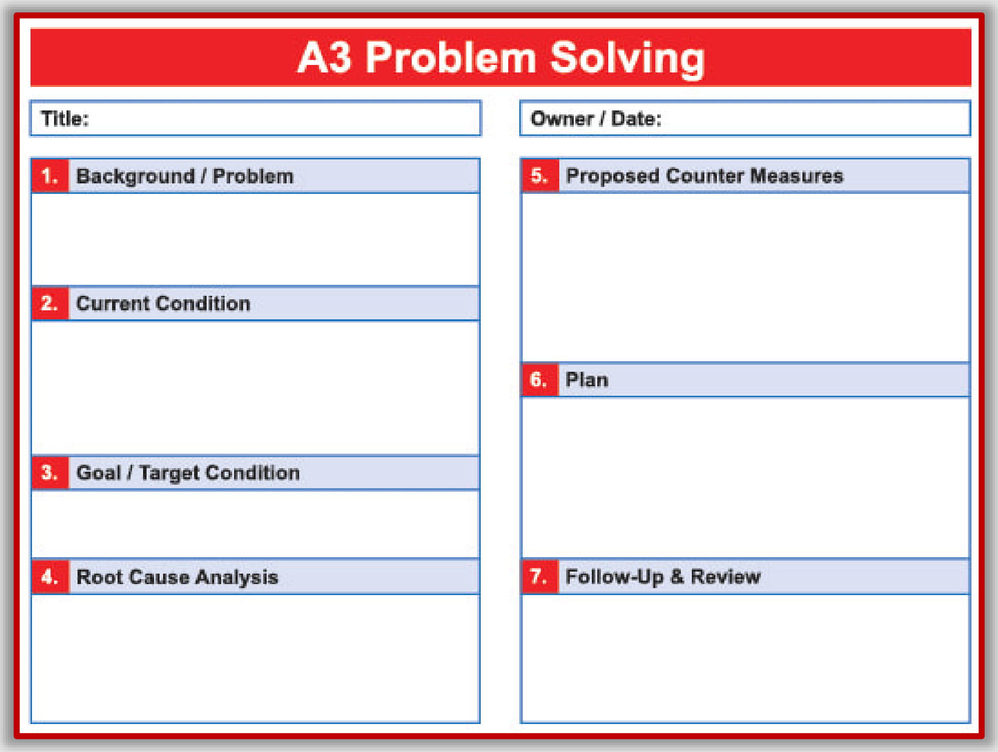
S – I – P – O – C

Suppliers	Inputs	Process	Outputs	Customers
The provider of inputs to your process	Materials, resources of data required to execute your process	A structured set of activities that transform a set of inputs into specified outputs, providing value to customers and stakeholders	The products or services that result from the process	The recipient of the process output



6 A3

- Created by Toyota
- Collect all information connected to a problem on a single A3 page



A3 Problem Solving

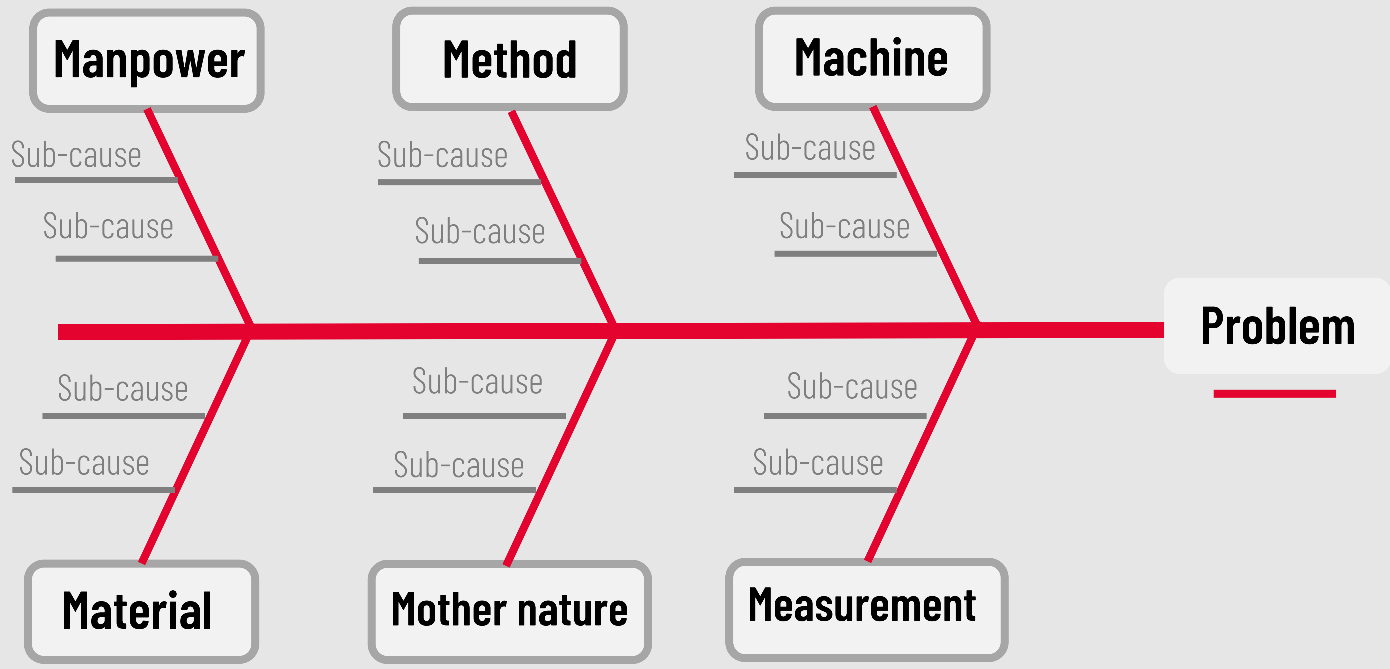
Title:

Owner / Date:

1. Background / Problem
2. Current Condition
3. Goal / Target Condition
4. Root Cause Analysis
5. Proposed Counter Measures
6. Plan
7. Follow-Up & Review

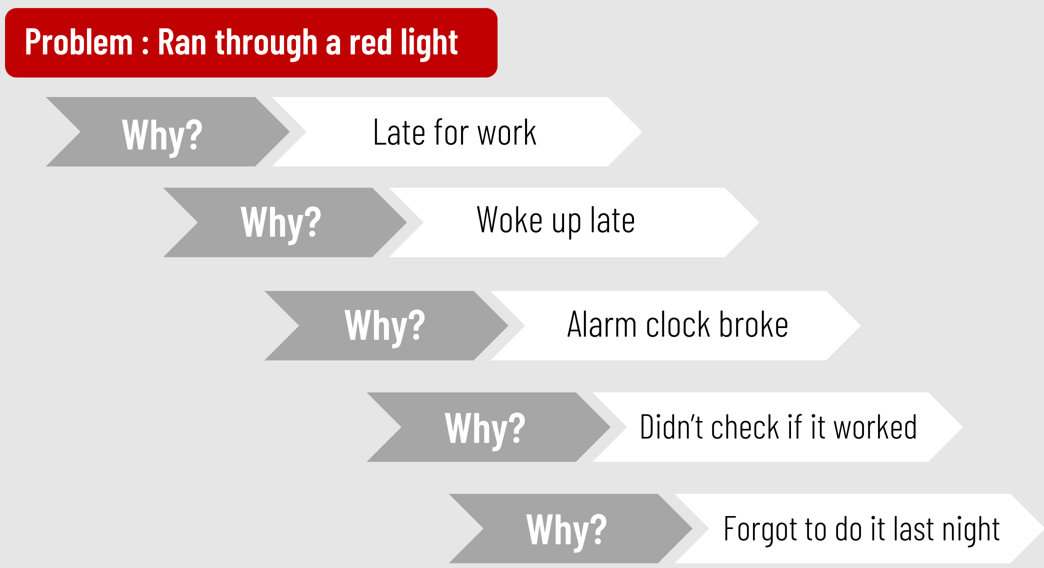
7 Ishikawa diagram

- Also called '**Fishbone diagram**' or 'cause and effect diagram'
- It is a visual method
- Identify **causes** according to their effects
- **6M**: measurement, material, machine, environment (mother nature), men and methods



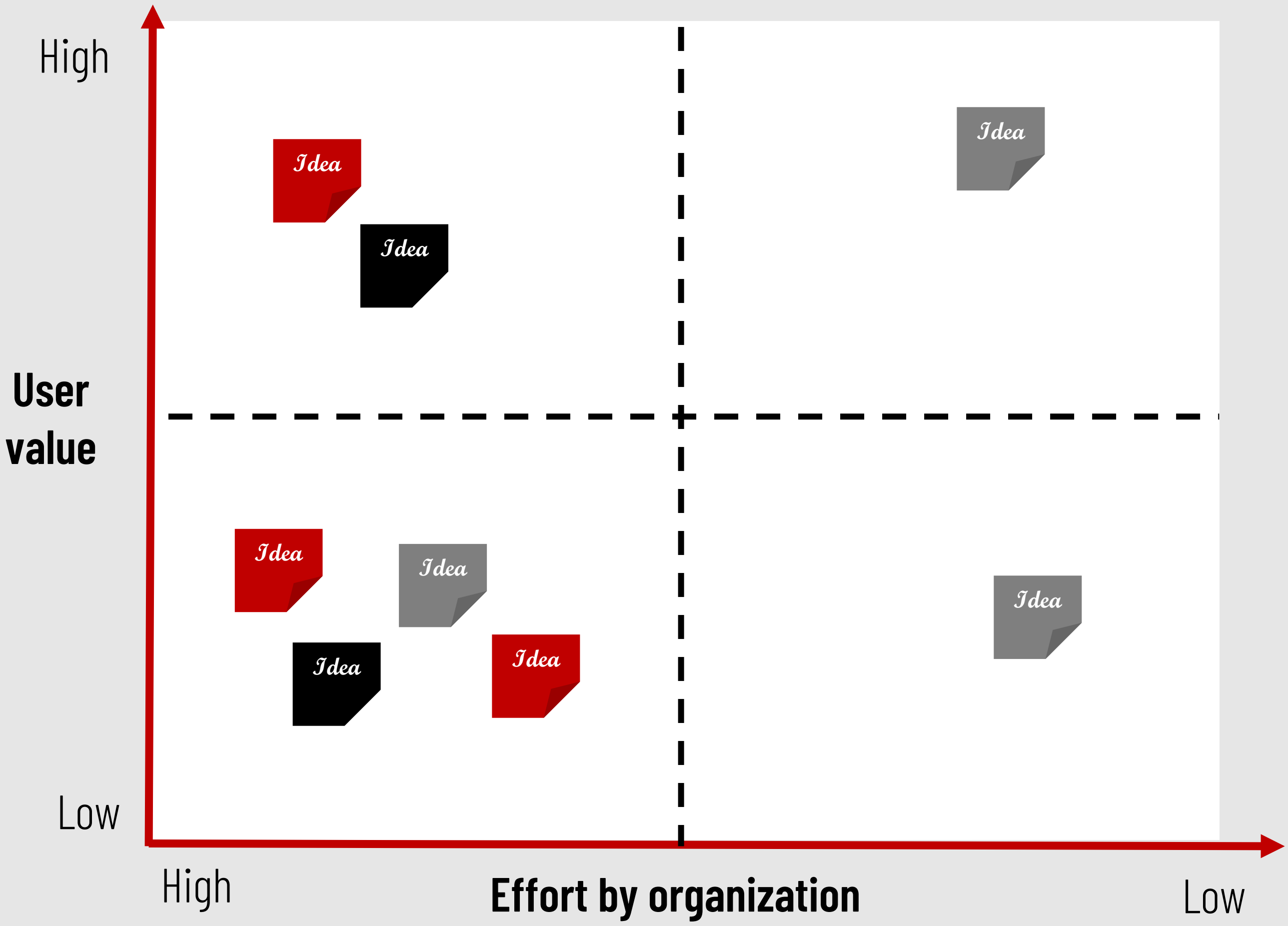
8 5 Why's

- Find the causes from the basis
- Ask 'Why' five times successively



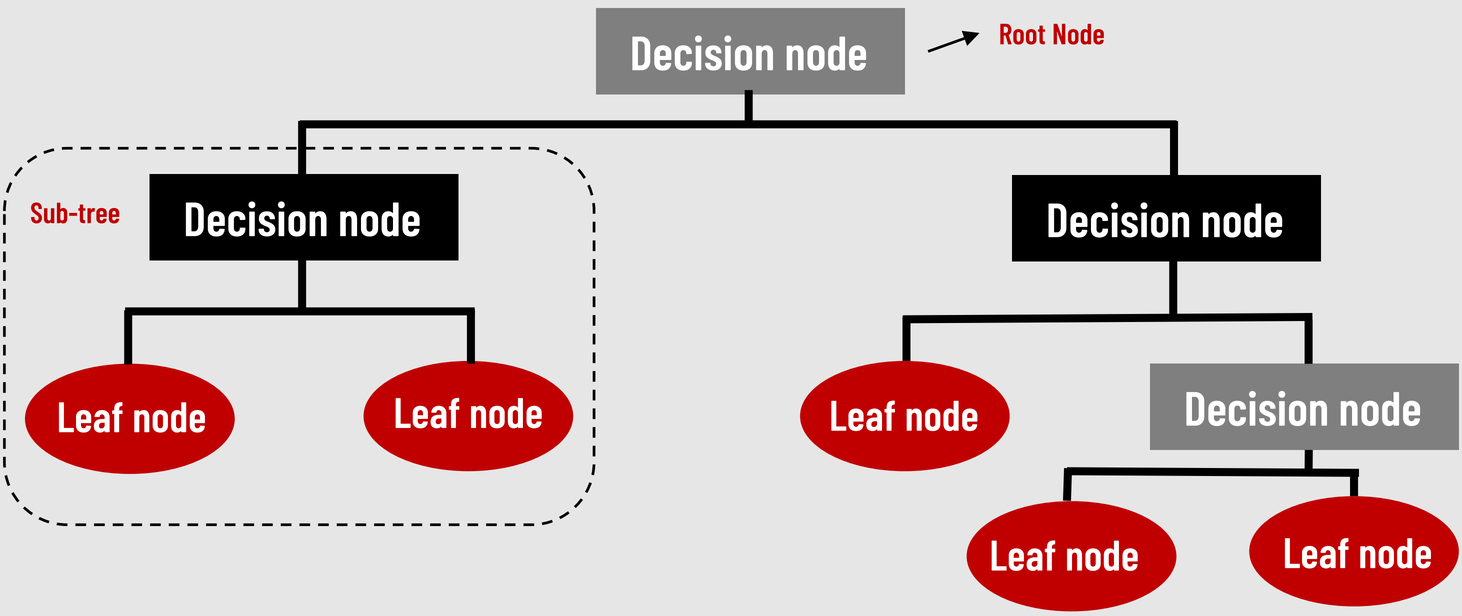
9 Feasibility /Efficiency matrix

- Sorting ideas from brainstorming
- Achieve the objective
- Prioritize actions



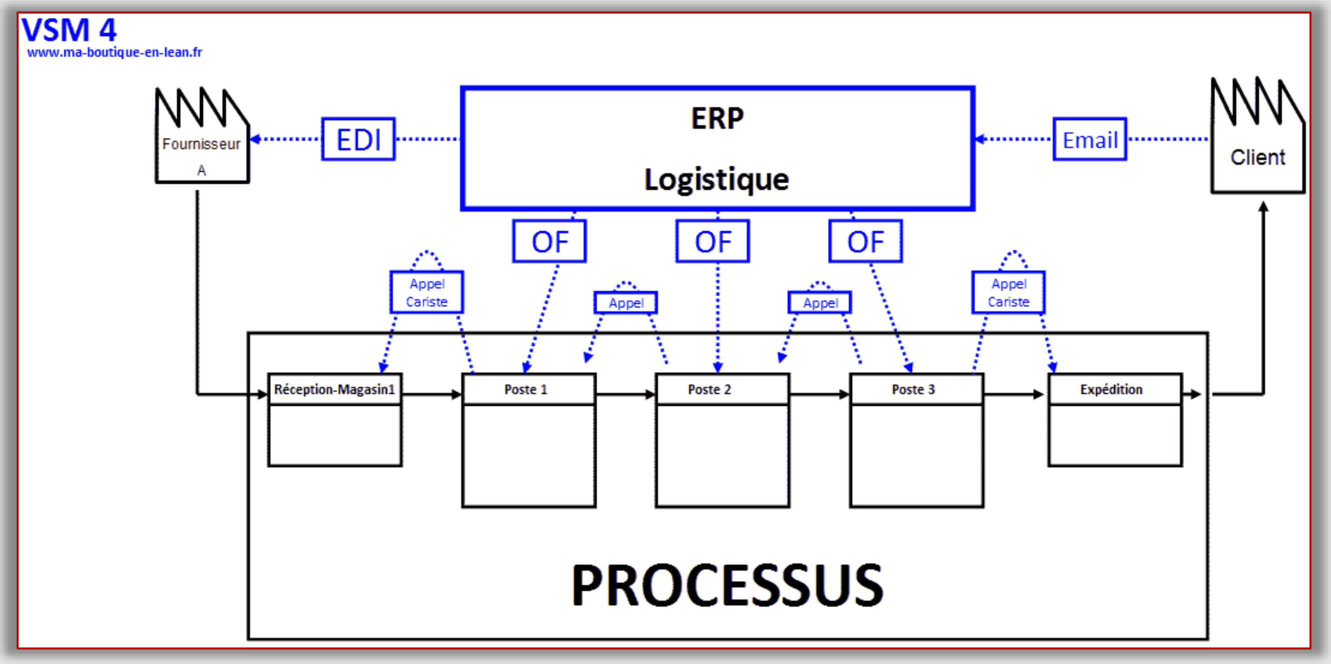
10 Decision Tree

- Facilitate decision-making
- Put the diverse decisions at the end of each branch



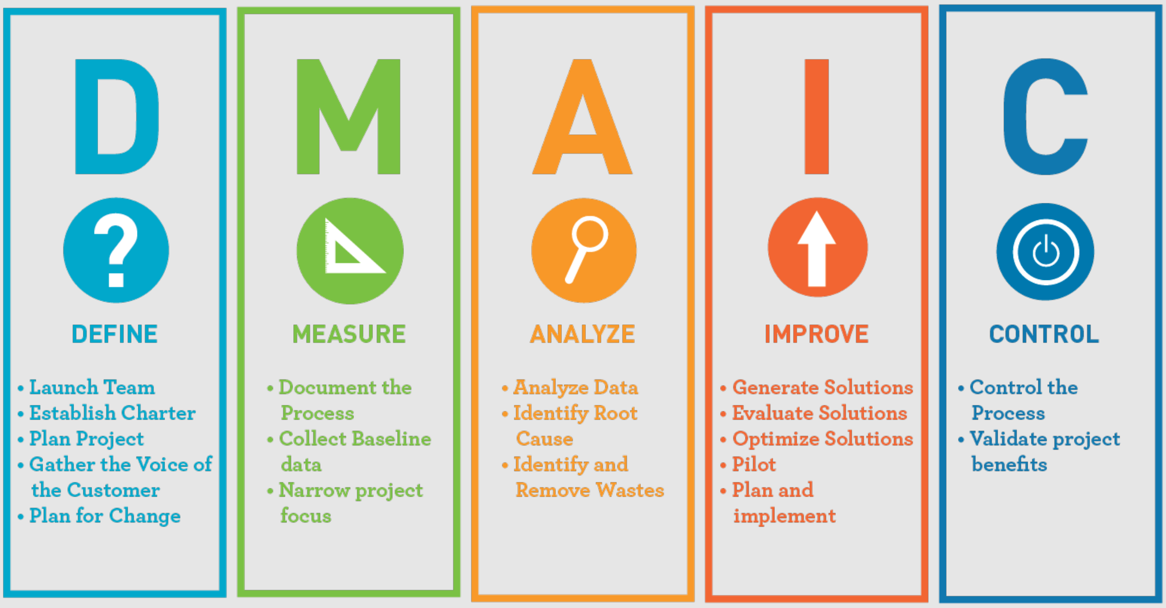
11 Value Stream Mapping

- It is a visual tool
- Study a process state of play
- Elaborate future process: your ideal process after the improvements' implementation
- Identify critical stages and specify quantitatively the time
- Suppress waste in the value stream
- Increase productivity by creating cleaner operations



12 DMAIC

- Resolve repeated issues from recurrent duties
- An organized method to solve business difficulties
- Improve process



TRIZ Toolbox

1 Thinking in time and scale (or Nine Windows):

- Catch the precedents and context of the issues
- Resolve technical and managerial problems
- Understand the possible evolution of the problem over time
- Locate solutions
- Used in three different ways in diverse steps of the problem understanding and solving

- Super-system (Macro) represents the external environment and constituents which are related to the problem
- System emphasizes on the current problem
- Subsystem (Micro) zooms on detailed parts of the problem

Example: Plan for safety improvement

	Past	Present	Future
Super-System	Corporation where safety is not a priority	Corporation where message that safety is a priority has not gotten through	Corporation where safety is a priority
System	Employees take occasional risks to get the job done	Ladder slipped and employee was injured in fall	Injury rate will be unacceptable
Subsystem	Management has criticized workers who stop production in the face of a danger	Workers remember the incidents, in spite of management's assertion that safety is paramount	Management has provided positive recognition for stopping production in the face of danger

2 Eight trends of technical evolution

- Predict new markets and products trends
- Understand what is your position
- Identify the most suitable development of your products
- Create and choose ideas for your product development

The eight trends

	Pattern
1	Technology follows a life cycle of birth, growth, maturity, and decline
2	Increasing Ideality
3	Uneven development of subsystems resulting in contradictions
4	Increasing dynamism and controllability
5	Increasing complexity, followed by simplicity through integration
6	Matching and mismatching of parts
7	Transition from macrosystems to micro using energy fields to achieve better performance or control
8	Deacreasing human involvement with increasing automation

3 Separation Principle

- Separation in time and space between both the components and the system
- Understand and resolve physical contradiction that is, opposite needs for the same system
- Find solutions to solve paradoxes
- Used for unresolvable contradictions

4 Uncovering and solving contradictions

- Understand your problem through technical contradictions and physical contradictions
- Use the contradiction matrix
- In the matrix, the features will be placed on the vertical and horizontal axis to see the interaction between them
- See the possible solutions to resolve technical contradictions

The 39 features of the contradiction matrix

Number	Features
1	Weight of moving object
2	Weight of stationary object
3	Length of moving object
4	Length of stationary object
5	Area of moving object
6	Area of stationary object
7	Volume of moving object
8	Volume of stationary object
9	Speed
10	Force
11	Stress or pressure
12	Shape
13	Stability of the object's composition
14	Strength
15	Duration of action by a moving object
16	Duration of action by a stationary object
17	Temperature
18	Illumination intensity
19	Use of energy by moving object
20	Use of energy by stationary object

Number	Features
21	Power
22	Loss of Energy
23	Loss of substance
24	Loss of Information
25	Loss of Time
26	Quantity of substance/the matter
27	Reliability
28	Measurement accuracy
29	Manufacturing precision
30	External harm affects the object
31	Object-generated harmful factors
32	Ease of manufacture
33	Ease of operation
34	Ease of repair
35	Adaptability or versatility
36	Device of complexity
37	Difficulty of detecting and measuring
38	Extent of automation
39	Productivity

5 Using the 40 inventive principles

- Define physical and technical contradictions
- Represent conceptual solutions to those contradictions

The 40 principles

Number	Principle
1	Segmentation
2	Taking out
3	Local Quality
4	Asymmetry
5	Merging
6	Universality
7	Nesting
8	Anti-Weight
9	Preliminary Anti-Action
10	Preliminary Action
11	Beforehand Cushioning
12	Equipotentiality
13	The Other way Round
14	Spheriodality / Curvature
15	Dynamics
16	Partial or Excessive Action
17	Another Dimension
18	Mechanical Vibrations
19	Periodic Actions
20	Continuity of Useful Action

Number	Principle
21	Skipping
22	Blessing in Disguise
23	Feedback
24	Intermediary
25	Self-Service
26	Copying
27	Cheap Short Lived Objects
28	Mechanics Substitution
29	Pneumatics and Hydraulics
30	Flexible and Thin Shells
31	Porosity
32	Color Changes
33	Homogeneity
34	Discarding and Recovering
35	Parameter Change
36	Phase Transition
37	Thermal Expansion
38	Strong Oxidants
39	Inert Atmosphere
40	Composite Structures

6 The 76 Standard solutions

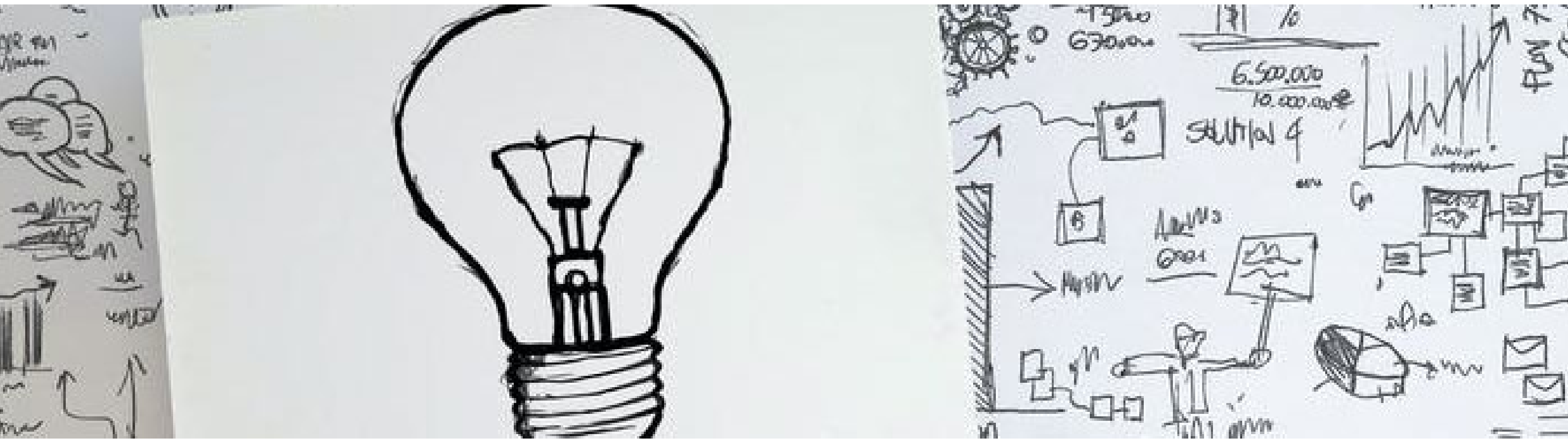
- Solve problems without needing the identification of contradictions
- Apply to set right the unwanted interaction between two parts of a system
- Have a look to the literature

7 Analysis of system resources

- Systematic search
- Analyze resources within and outside the system
- Find good, cost effective and sustainable solutions
- Source of innovation
- Results: solutions should be close to the ideal final result (IFR) and use smartly resources

8 Ideality (see the TRIZ Definition)

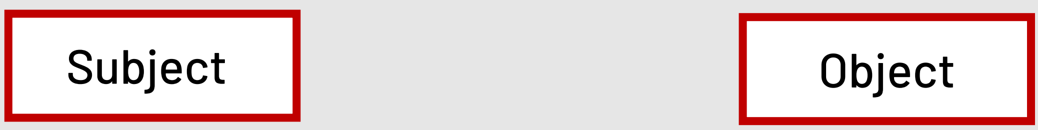
- Achieve the higher possible capacity
- Guide the achievement of innovative solutions



9 Functional analysis

- List the components and their negative, ineffective and excessive interactions
- Interactions are seen as Subject-action-Object which have been physicals
- Identify the problems occurring from the interactions
- Use the Trimming Rules which will eliminate problems and increase its ideality
- Finally, map the solution by picking one of the remaining problems. Your map is built with the range of possibilities.
- Choose the most suitable solution according to your constraints

Graphical representations of an S-a-O triad



Triz problem	Description	S-a-O grapical
Functional	Functional problems are those that occur when a useful function is required, but is is not delivered by the system yet and a subject that can perform it has still to be identified	
Performance	Performance problems arise if a desired function is delivered by a subject, but it is insufficiently or excessively performed	
Harmful-effect	Harmful-effect problems occur when a harmful function is performed by the subject	

10 Smart little people

- Overcome psychological inertia that is, psychological habits which stop creativity, out-of-the-box ideas and then changes
- Imagine that your system contains a group of smart little people. They can solve any problem and adapt to any situation
- Encourage innovative ideas to arise

11 Size-time-cost Operator

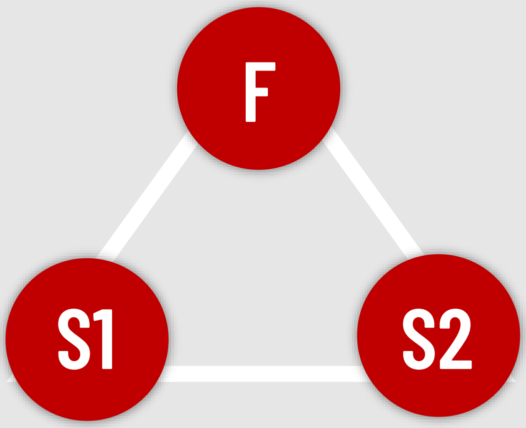
- Overcome psychological inertia
- Frame a complex situation

- The operator lists six ways of improvement to solve the situation
- A user is expected to think of her/his actions when each of the three parameters (size, time and cost) sequentially reaches two limits: zero and infinity

12 Substance-Field Analysis

- Close to function analysis
- Map the whole system by making the representation of the issue easier

- Use diverse substances and fields
- Analyze several resources
- Identify the problems



F types of energy or field which helps the creation of an output by an input

S1 output created by a substance

S2 input which creates the intended output

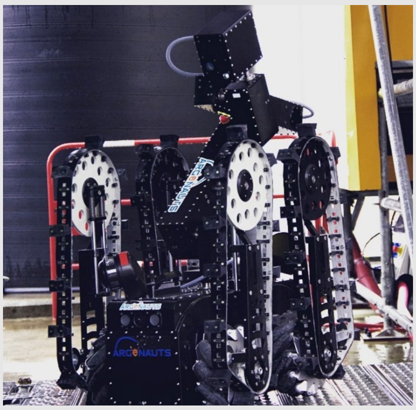
13 ARIZ (Algorithm for Inventive Problem Solving)

- Suitable for complex problems
- Use different TRIZ tools, especially: Ideality, Contradictions, Resources, S-field, 40 principles
- Follow the multi-step process which forces you to ask several questions to reformulate problems
- Firstly, assume that you do not know the intended problem
- Neutral solution




TOTAL






Product-Service Systems Toolbox

System Map

- Understand your current system by visualizing it
- Identify the potential issues, threats and opportunities
- See the financial flows
- Understand the relationship between actors
- Goal: visualize the new opportunities to create a more sustainable product or service

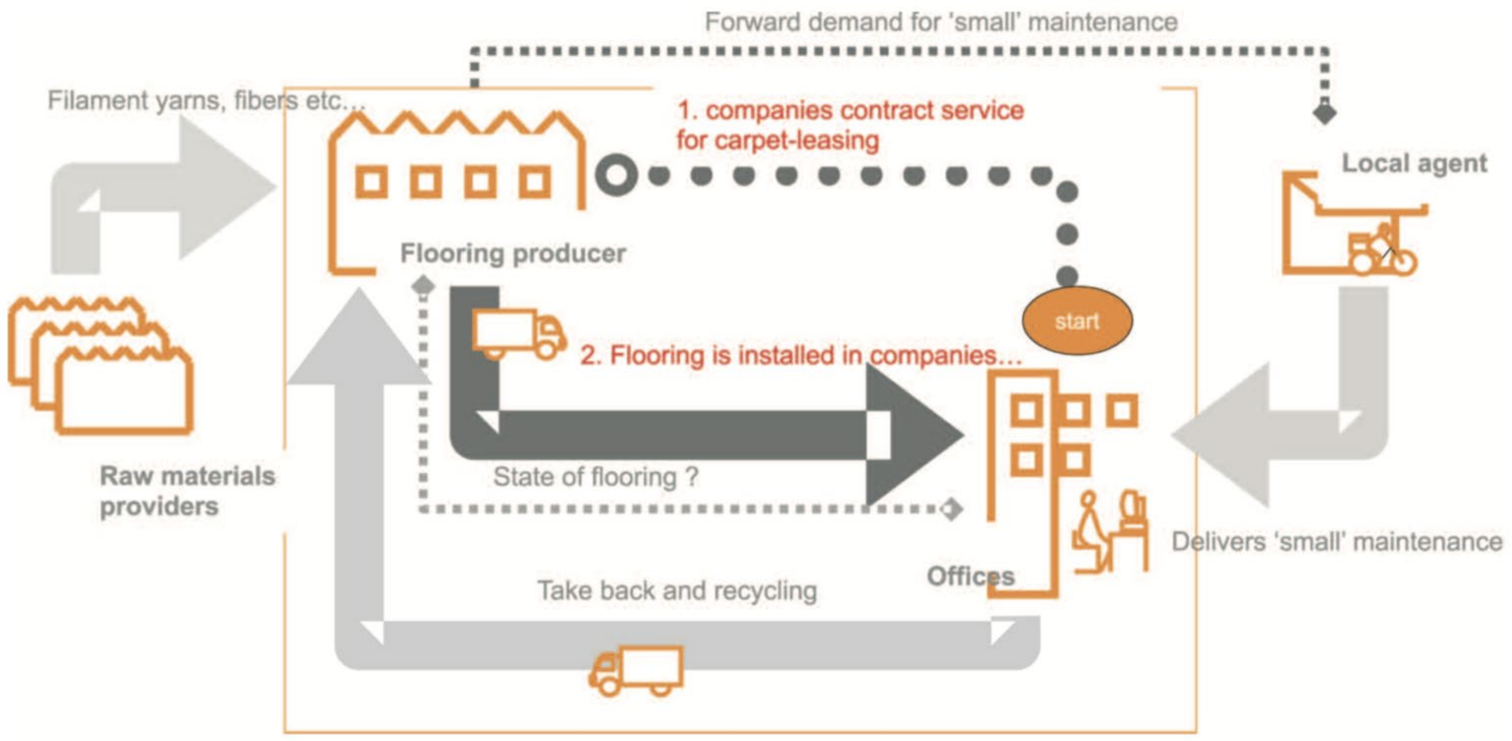


FIGURE 1 ___ SYSTEM MAP OF A CARPET LEASING SYSTEM FOR OFFICES. SOURCE: ECONCEPT

Sustainable SWOT

- Facilitate decision-making
- Identify the environmental and social challenges and opportunities
- Prioritize your actions

Environmental & social challenges & big trends → **Strenghts, Opportunities, Weaknesses & Threats** → **Prioritization & Action**

Challenges

- *How do you and others see changing ? For example :*

- *Natural resource scarcity*
- *Water availability*
- *Waste & hazards*
- *Global warming*
- *Climate variability and extremes*

Strengths

- *How can our strenghts adress environmental challenges?*
- *Start with traditional list of your companies' strengths, extend the list to the partners in you value chain*
- *Consider core & transferable strengths (i.e. R&D, Eng)*

Weaknesses

- *Who has similar weaknesses or faces similar risks ?*
- *Start with risks resulting from environmental challenges impacting markets (e.g. operations, regulation, commodity prices)*
- *Include partners in list*

Prioritize

- *Which insights will influence senior company stakeholders most ?*
- *Prioritise according to company vision and strategy*
- *Identify strong messengers*
- *Emphasise findings that would resonate with CEO and senior management*

Trends

- *What are the sustainability relevant big trends? For example :*

- *Innovation & technology advances*
- *Demographic & social shifts*
- *Global economic dynamics*
- *Political & regulatory requirements*

Opportunities

- *Look at threats that currently are not addressed, and how you can address these threats*
- *Consider the business value that can be created with new products, services, and business practices*

Threats

- *Where are environmental challenges threatening future business value ?*
- *Consider both direct threats as well as threats to partners in the value chain*
- *Look upstream and downstream and identify opportunities for joint action*

Act

- *What can be a short/mid/long term strategy?*
- *Categorize generated insights according to where and when you can act*
- *If needed, consider gathering more insights before planning action*

Sustainability guidelines (Level 1)

- We can find the environmental, socio-cultural and economic dimensions
- The environmental dimension has for aim the increasing of the product eco-efficiency
- The socio-cultural dimension allows to increase the social and cultural aspect of your good
- The economic dimension is looking for long-term and financially sustainable solutions
- Each one has six criteria
- Not all criteria have the same importance, depending on your project
- Weigh criteria to make priorities
- When you have picked the criteria with the higher weigh, decline the criteria into several questions
- Answer to the most important questions to fulfill the important objectives and then, find new solutions
- At the end, select the most promising idea

A - Environmental dimension

A.1 System life optimization
(Life extension or use intensification of system/product/component)

A.2 Transportation reduction
(Transporting reduction of persons, products, components during all life cycle phases)

A.3 Resources reduction
(Energy and materials reduction during all life cycle phases)

A.4 Waste minimization/valorization
(Reduction of landfilling in favor of recycling, energy recovery or composting)

A.5 Conservation/Bio compatibility
(Energy and materials reduction during all life cycle phases)

A.6 Toxicity
(Avoidance of toxic dangerous resources in any of the life cycle phases)

B - Socio-cultural dimension

B.1 Possibility of customers to consume socially more responsible
(Sufficiency)

B.2 Health and safety
(Of employees, customers, stakeholders)

B.3 Living conditions/ quality of life
(Customers/users perspective)

B.4 Employment / Working conditions
(Employee perspective)

B.5 Equity and justice/ Relation to stakeholders
(Society global perspective)

B.6 Respect cultural diversity
(Society local perspective)

C- Economic dimension

C.1 Market position and Competitiveness

C.2 Profitability / Added value for companies

C.3 Added value customers

C.4 Long term business Development/ Risk
Market risk/ implementation issues/ Return on investments

C.5 Partnership/ Co-operation

C.6 Macro economic effect

Example of questions for the first criteria in the environmental dimension (Guidelines level 1)

A.1 System life optimization
(Life extension or use intensification of system/product/component)

Can you offer services for shared use of products/infrastructures?

Can you add to the product/infrastructure offer, services for their **maintenance, reparability substitution?**

Can you add to product/infrastructure offer, services for their **technological up-gradeability?**

Can you add to product/infrastructure offer, services for their **aesthetic/cultural up-gradeability?**

Can you add to product/infrastructure offer, services for their **adaptation to new contexts (sight of use) ?**

Sustainability guidelines (Level 2)

- It follows the sustainable guidelines level 1
- It can be realized in the same manner
- Prioritize your criteria for your new product or service
- Give the priority to guidelines associated with the most important criteria
- Detail your system

Example of Sustainability guidelines (level 2) for the first aspect of the environmental dimension

A.1 System life optimisation

Introduce aesthetic/cultural up-gradability of support products

Introduce service/functionalities for shared use of the support products and infrastructures

Favour user care for long lasting of physical supports products and infrastructures

Introduce services/functionalities service for supporting products adaptability to a context changes

Introduce services/functionalities for technological up-gradability of support products and infrastructures

Introduce services/functionalities for maintenance, reparability and substitution of supports products

Introduce take back services for supports products re-using

Introduce take back services for supports products re-manufacturing

Use digital re-configurable supports products

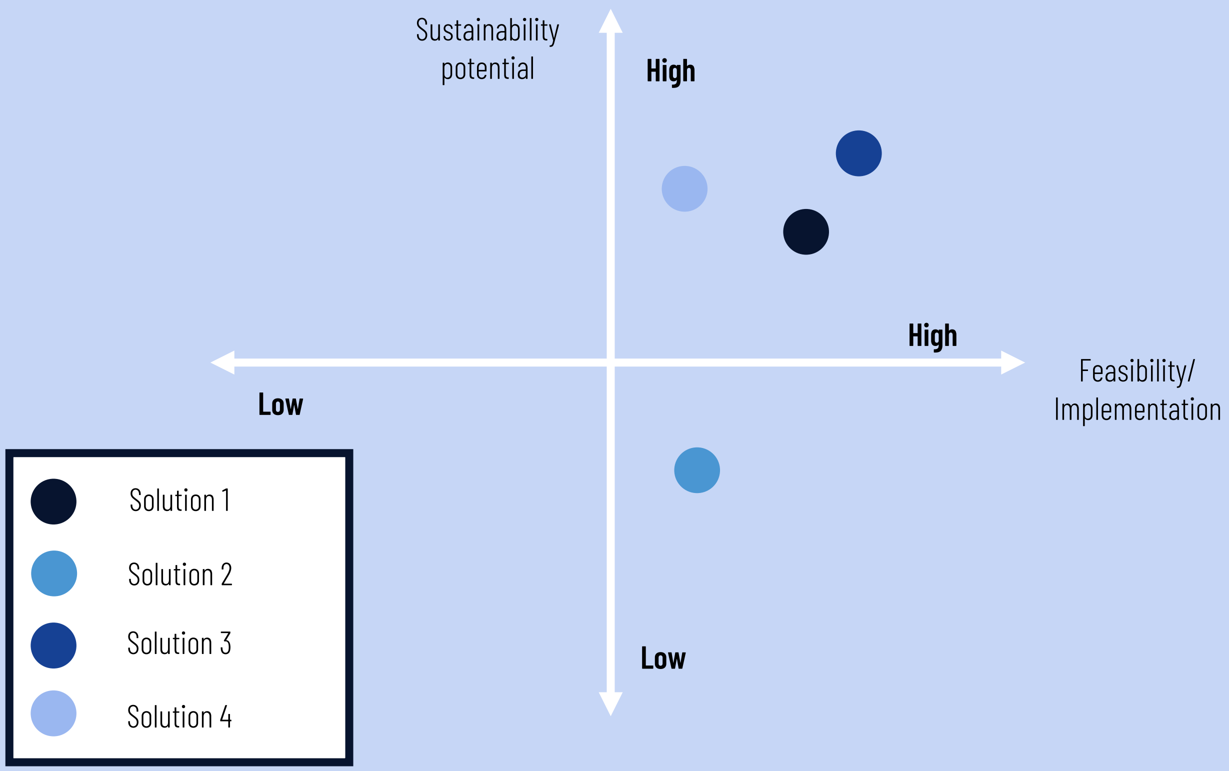
Portfolio Diagram

- Identify the most promising market potential
- Put your different ideas on the following matrix

Small change necessary, No new technology necessary Short-term solution	Medium change necessary Needs some new technology Medium-term solution	Big change necessary A lot of new technology Long-term solution

Small feasibility/ Implementation very difficult	Medium feasibility/ Implementation possible	High feasibility/ Implementation simple

- Talk about implementation and feasibility issues
- Summarize yours results in the following diagram
- Assess your portfolio according to the feasibility and sustainability dimensions



- Keep solutions localizing in the upper right
- Abandon solutions in the lower left

CASES

We have taken cases from the literature which will help you to understand better the practical application of each one. Some methods have been developed step-by-step and others on the whole, depending on the information we had accessed.

Products

Case study : The MGE2 application

Company presentation

In this case, the company has not been presented. It allows the application of the MGE2 method in a general way

The stake

As the company has not been quoted, we cannot identify its stakes

The method

Step 1. Realize a life cycle analysis of existing products

- See the LCA method
- The study covers the entire life cycle, taking into account all stages from the cradle to the grave of the product involved.
- For this case study, by following MGE2 and thanks to the study of material and substance flow, this LCA now covers the life cycle from the cradle-to-cradle.
- The main objective of this tool within the model is to determine the environmental impact of product performance in relation to the 3E vectors. From this stage, improvements are established that determine the product strategy.

Step 2: Establish a product strategy under C2C

Once the LCA data and possible applicable improvements are known, then a systemic, autopoietic, environmentally compatible and metabolizable strategy of the product is established through the exploration of the value and innovation of the 3E pyramid, which constitutes the basic tool for eco innovation. The generation of the set of 3E values enables the establishment of the premise that defines the product strategy; this situation in turn enables the parameterization of the environment of the generic design, through techniques and tools for this particular project.

This strategy focuses on:

(1) Systemic (or holistic) integration for bio-inspired design; the different scenarios of the chair throughout its life cycle are considered in this phase with the aim of promoting and equitably integrating all three aspects of the 3E pyramid.

(2) Sustainable and eco-friendly. Improvement of the metabolism by decreasing the ratios of environmental impact on the Naturesphere, in order to minimize the impact on the environment (or rendering the ecological footprint assimilable). This is achieved by increasing the flows of material on the Technosphere by means of upcycling (minimizing those flows related to infra-recycling as much as possible), eliminating possible toxic or polluting substances with the incorporation of innovations from green or sustainable chemicals. Finally, features that are cooperative with Naturesphere are incorporated, thereby creating environmental value.

(3) An autopoietic character is obtained by taking the concept of "genetic intelligence" into account and by supplying it to the product with the aim of facilitating tasks of use, manufacturing, logistics (forward and reverse), and of its regeneration at the end of the life cycle. In a particular way, this intelligence incorporates innovation into phenotypic interactions, thereby enabling regeneration, reuse, and recovery in successive generations of products.

Step 3: Design and develop the product genotype

Study of the Phenotype and associated criteria: Once the data of LCA, the phenotype required, and the product strategy are all determined, then the redesign is performed under the principles of C2C. To this end, the genomic design is carried out, with the detailed study of each domain, (need, functional, conceptual, and materialization), and in the fields of Eco-innovation, Eco-compatibility, and Metabolization. In each domain, a series of individual eco-design strategies is applied, as are the tools necessary for the definition of all the requirements that render the product sustainable.

Step 4: Validate the genotype and phenotype optimization

Concurrent with the previous stage, the verification and validation of the genomic design of the product is performed based on the requirement demanded by the system that it be associated with the life cycle of the product, which in turn determines the procedures for interaction of the genome with the environment. This results in the initial phenotype which develops and optimizes over the life cycle and those of successive generations of products. The stages of manufacture and of the end of useful life hold special interest, since the metabolic pathways and biological and technical nutrients are investigated and defined, and fix the associated processes from the disassembly diagram of the genotype. The final solution is the ECOS office chair.

Step 5: Realize a new LCA of the product with the objective of Environmental Product Declaration C2C

The last stage in the implementation of the MGE2 model corresponds to the completion of a new LCA of the redesign of the product. The objective of this analysis is the confirmation of the proposed improvements in the design process and the knowledge of all the information necessary in order to obtain an eco-label for the product from any of the existing certification programs (including C2C certification). In the case study carried out, the second application of LCA verifies whether the product meets the criteria to qualify for C2C certification. The results awarded a GOLD eco-label to the chair. All the information is collected for the writing of the Environmental Product Declaration in which the environmental information of the chair is presented. It is also quantified throughout its life cycle to allow for its comparison with other products that fulfil the same function, all of which cause a greater impact on the environment.

Case study : The QFDE application

Company presentation

No company has been quoted, the authors have taken a general case of hair drier to apply the QFDE method.

The stake

We are going to analyze the design of a hair drier by considering environmental aspects and consumer needs. Thus, the matrix-based modelling scheme and analysis methods are applied to the engineering and analysis of a consumer hair dryer. The design of a hair dryer is chosen because it is sufficiently complex to demonstrate the value of the modelling scheme.

The method

Step 1: Identify the target of design improvement

- The first step for analyzing and re-engineering the hair dryer is the identification and modelling of the customer requirements.
- Table 1 shows the deployment of VOC to Engineering Metrics (EM) (Phase I). VOC items in the table include the environmental VOC items such as "less material usage" as well as requirement items from customers such as "dries quickly" and "quiet." Usually VOC items are weighed based on market surveys to show the "Customer Weights." "9" shows that it is very important, "3" shows it is important, and "1" shows it is relatively important. On the other hand, EM items include new items such as "amount of energy consumption" as well as traditional items such as "air flow." At crossing points between VOC items and EM items are shown numbers indicating magnitude of both factors called "Relational Strength" determined by the designer, Similar to the weighing of VOC items, "9" shows the relation is strong, "3" shows it is relatively strong and "1" shows a certain strength. Here, at the crossing points between the environmental VOC items and environmental EM items the values of relational strength prepared by the working group are provided for designers to help their decisions. The total of the sum multiplied by "Customer Weights" and "Relational Strength" is the "Raw Score" for each EM item. Furthermore, "Relative Weight" for each item is obtained by the Raw Score / Sum of the Raw Score.
- This example shows that "air flow," "air temperature" and "amount of energy consumption" are relatively important as EM items to satisfy customer requirements such as "less energy consumption," "high durability," and "harmless to living environment" as well as traditionally required quality items such as "dries quickly" and "comfortable to hold."

Table 1 QFDE Phase I[4] of a hair drier

QFD for Environment Phase I — Voice of Customer	customer weights	air flow	air temperature	balance(torque)	weight	volume	numbers of parts	numbers of types of materials	likelihood to get dirt	hardness	physical lifetime	amount of energy consumption	rate of recycled materials	noise, vib, electromagnetic wave	mass of air pollutant	mass of water pollutant	mass of soil pollutant	biodegradability	toxicity of materials
		Engineering Metrics																	
dries quickly	9	9	9									9		9					
quiet	3	9										9		9					
operates safely	3	1	9	3					1	3	9			9					
operates easily	1			3	1									1					
comfortable to hold	9		1	9	9	9			1		3			1					
reliable	3	1	1				3	3		9	9	1		1					
portable	1				3	9													
less material usage	1				9	9	1	3					9						
easy to transport and retain	1				9	9						3							
easy to process and assemble	3						9					9							
less energy consumption	9	9	9									9							
high durability	9								1	9	9								
easy to reuse	1								9		9								
easy to disassemble	3						9	9				3							
easy to clean	1								9			3							
easy to smash	3									9		9							
easy to sort	3						9	9				3							
safe to incinerate	1							3							9	3	1		9
safe to landfill	3							3							3	9	9	9	9
harmless to living environment	9	9	9							3				9					
safe emissions	1				9	9						3			9	9	9		9
possible to dispose at ease	3				1	1							3						9
	raw score	276	282	93	115	120	91	78	39	171	171	273	18	229	27	39	37	27	72
	relative weight	0.13	0.13	0.04	0.05	0.06	0.04	0.04	0.02	0.08	0.08	0.13	0.01	0.11	0.01	0.02	0.02	0.01	0.03

Step 2: Deployment engineering metrics items to Components of Product

- In the second stage, the relative importance for each component of the product is obtained in the same way as Phase I. As shown in Table 2, it is found that "motor" is most important and then "housing" is important. To environmentally improve existing systems, compare the results obtained here with the QFD results without the environmental VOC and environmental EM items.
- When design engineers improve their product from a viewpoint of the environment, evaluating effects of candidates of design changes on environmental aspects is an effective process after identifying the important components.
- In this section, a method to evaluate the effects of design changes for parts or components on environmental aspects (Phase III and Phase IV) is introduced.

Step 3: Estimate the effect of design changes on engineering metrics (EM)

- The effect of a set of design changes on engineering metrics (EM) items are estimated. Design engineers can make several alternative plans.
- There are two approaches when design engineers will decide where they should first focus on. One approach originates from a target VOC. If they have already had a target of "less energy consumption" VOC for example, they should seek the parts which can be suppressed in terms of "amount of energy consumption." The other one is examining the most important components identified in phase II. Table 3 shows an example of phase III for a hair drier.

Here, we gave priority to an environmental aspect, and the design improvement plan was mainly set from the viewpoint of the amount of energy consumption.

If it is assumed that the energy consumption of a motor and a heater are reduced and then the noises of a motor are suppressed, the numbers indicating the relational strength in phase II (Table 2), at crossing points between the target engineering metrics and parts, remained as shown in Table 3. The improvement rate to each EM item mr, is obtained from the equation.

(j =I, ..., J)(1) k=I

$$mr_j = \frac{\sum_{k=1}^{K} b_{j,k} c_{j,k}}{\sum_{k=1}^{K} b_{j,k}} \qquad (j = I, \ldots, J) \qquad (1)$$

Where K is the index number of a component and J is the index number of an EM item. b,, is the relational strength between EM item j and component k in phase 11. C,, is the improvement rate of EM item j to component k and originally allowed to take the real number from 0.0 to 1 .0. In this paper, to make it simple, C,I can take the binary numbers:

$$C_{j,k} = 1 \text{ (improvement possible)}$$
$$C_{j,k} = 0 \text{ (improvement impossible)}$$

Table 2 QFDE Phase II of a hair drier

QFD for Environment Phase II Engineering Metrics	Phase I relative weights	Component Characteristics: motor	fan asm	heater elements	switch / wiring harness	housing
air flow	0.13	9	1	1	1	1
air temperature	0.13	3	3	9	1	1
balance(torque)	0.04	9	3			9
weight	0.05	9	3	3	1	9
volume	0.06	9	3	1	1	9
numbers of parts	0.04	1	1		1	9
numbers of types of materials	0.04	1	1		1	9
likelihood to get dirt	0.02				3	9
hardness	0.08					9
physical lifetime	0.08	9	1	9	3	9
amount of energy consumption	0.13	9	1	9		
rate of recycled materials	0.01					9
noise, vib., electromagnetic wave	0.11	9	3			9
mass of air pollutant	0.01	9		9		1
mass of water pollutant	0.02	3			3	1
mass of soil pollutant	0.02	3			3	1
biodegradability	0.01	3				9
toxicity of materials	0.03	3			3	1
	raw score	6.15	1.58	3.48	0.94	5.14
	relative weight	0.36	0.09	0.20	0.05	0.30

Step 4: Translate the effect of design changes on EM into environmental quality requirements (environmental VOCs)

- The mission of the phase IV is to translate the effect of design changes on EM into environmental quality requirements (environmental VOCs).
- Table 4 shows an example of phase IV for a hair drier. In this table, the numbers of customer weight and relational strength between VOC items and EM items are the same as shown in phase 1 (Table 1). The improvement rate for EM items obtained in the phase 3 are at the bottom of the table. The improvement rate for each environmental VOC vr, is obtained from the following equations.

where J is the index number of an EM item and I is the index number of a VOC item. a,J is the relational strength between VOC item i and EM item j in phase I. The improvement effect for the environmental VOC considering customer weight is obtained by multiplying vr, and customer weight i together. We consider that this evaluation method for design improvements can help design engineers select the most effective design changes' plan.

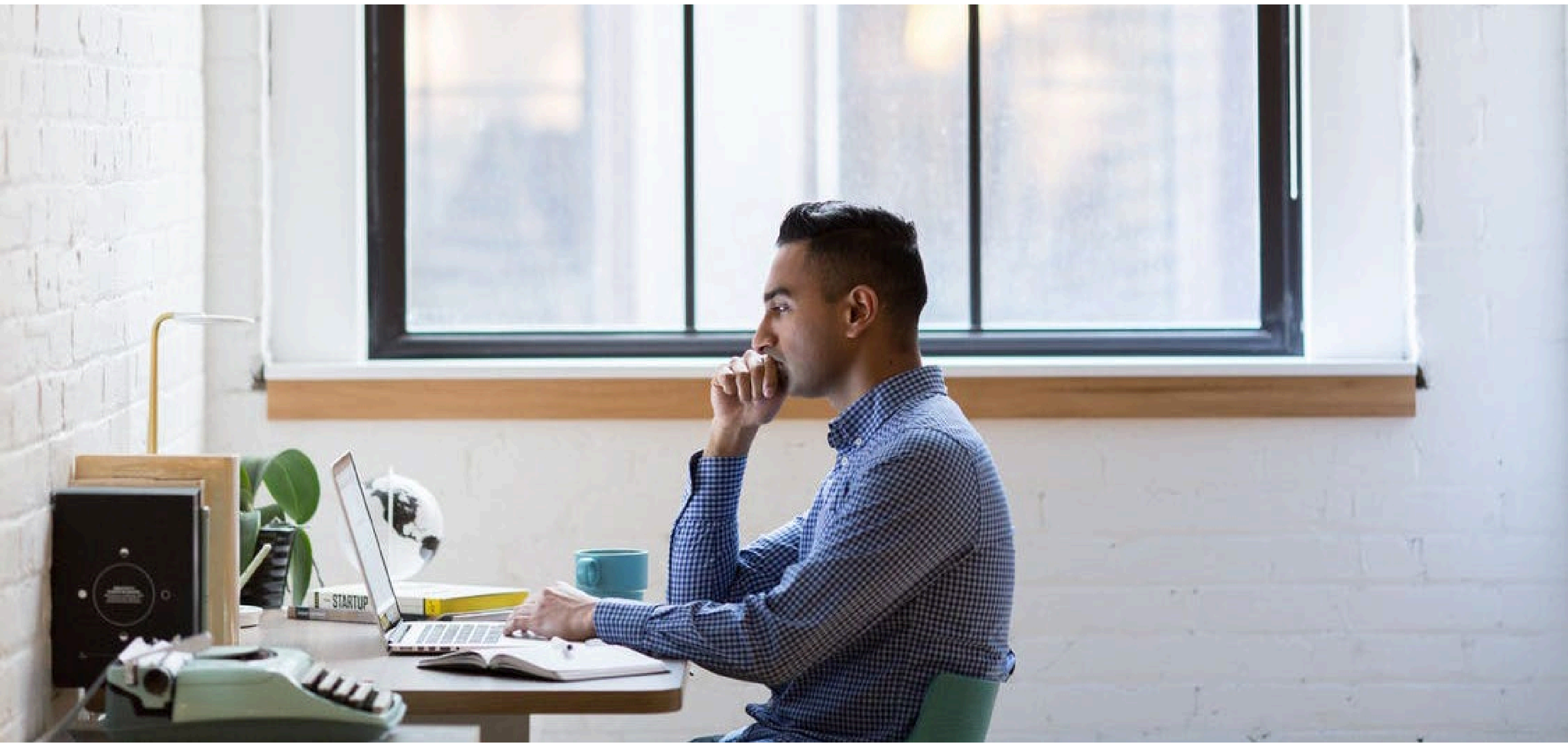
$$vr_i = \frac{\sum_{j=1}^{J} mr_j a_{i,j}}{\sum_{j=1}^{J} a_{i,j}} \qquad (i = 1,\ldots,I) \qquad (3)$$

Table 3 QFDE Phase III of a hair drier

QFD for Environment Phase III Engineering Metrics	Component Characteristics: motor	fan asm	heater elements	switch / wiring harness	housing	score	improvement rate of engineering metrics
air flow						0	0.00
air temperature						0	0.00
balance(torque)						0	0.00
weight						0	0.00
volume						0	0.00
numbers of parts						0	0.00
numbers of types of materials						0	0.00
likelihood to get dirt						0	0.00
hardness						0	0.00
physical lifetime						0	0.00
amount of energy consumption	9		9			18	0.95
rate of recycled materials						0	0.00
noise, vib., electromagnetic wave	9					9	0.43
mass of air pollutant						0	0.00
mass of water pollutant						0	0.00
mass of soil pollutant						0	0.00
biodegradability						0	0.00
toxicity of materials						0	0.00

Table 4 QFDE Phase IV of a hair drier

QFD for Environment Phase IV		Engineering Metrics																			
Voice of Customer	**customer weights**	air flow	air temperature	balance(torque)	weight	volume	numbers of parts	numbers of types of materials	likelihood to get dirt	hardness	physical lifetime	amount of energy consumption	rate of recycled materials	noise, vib., electromagnetic wave	mass of air pollutant	mass of water pollutant	mass of soil pollutant	biodegradability	toxicity of materials	improvement rate of customer requirement	improvement effects of customer requirement
dries quickly	9	9	9									9		9							
quiet	3	9										9		9							
operates safely	3	1	9	3					1	3	9			9							
operates easily	1			3	1									1							
comfortable to hold	9		1	9	9	9			1		3			1							
reliable	3	1	1				3	3		9	9	1		1							
portable	1				3	9															
less material usage	1				9	9	1	3					9							0.00	0.00
easy to transport and retain	1				9	9						3								0.14	0.14
easy to process and assemble	3						9					9								0.48	1.43
less energy consumption	9	9	9									9								0.32	2.85
high durability	9								1	9	9									0.00	0.00
easy to reuse	1								9		9									0.00	0.00
easy to disassemble	3						9	9				3								0.14	0.41
easy to clean	1								9			3								0.24	0.24
easy to smash	3									9		9								0.48	1.43
easy to sort	3						9	9				3								0.14	0.41
safe to incinerate	1							3							9	3	1		9	0.00	0.00
safe to landfill	3							3							3	9	9	9	9	0.00	0.00
harmless to living environment	9	9	9							3				9						0.13	1.16
safe emissions	1				9	9						3			9	9	9		9	0.05	0.05
possible to dispose at ease	3				1	1							3						9	0.00	0.00
improvement rate of engineering metrics		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.43	0.00	0.00	0.00	0.00	0.00		
amount																				2.09	8.10



Case study :The TRIZ-Lean application

Company presentation

This case has been elaborated thanks to the study of an industrial unit in the food industry.

The stake

The ham production line contains several machines. They have noticed that customers' orders have increased. Therefore, the throughput level was higher than usual. The teams have realized that applying innovative methodologies was necessary to improve product quality and reduce waste because they realized that current methods comprise possible failures and some shortcomings.
The issue with this production line is that it requires non-scheduled stops. The maintenance technicians are mandatory to solve the issues quickly. Consequently, the managers have decided to implement the TRIZ methodology with the aim of reducing or getting rid of those stoppages and assessing the functioning of maintenance tasks to possibly transfer them to workers. Among the potential tools in the TRIZ methodology, they have chosen to specifically rely on the Su-Field Analysis. With this tool, they would identify improvement opportunities, pick some of them, implement the retained actions within the organization and assess the results due to those changes.

The method

In this case, you will become aware that they did not use the exact same steps than the ones you can find in the method. We have elaborated this method based on several articles and try to find the best way to implement the project. Nevertheless, you can also adapt your approach according to your needs, requirements, and information available, as they did in this case.

The following steps are elaborated after the steps of defining the situation (step 1) which can be found in the stake paragraph and analyzing the company state of play (step 2). Then, they have decided to realize the ideality matrix, one of the fundamental principles in the TRIZ methodology. This technique allows them to study the difference of the increase or decrease of the level of the ideality of the system. The goal of the most suitable action is to increase the level of the ideality of the system to achieve the company requirements.

In order to know if there is any improvement, the team has listed the most important criteria for this production line. You can find them below:

1) Increase productivity;
2) Reduction of the number of faults or unscheduled stops;
3) Cost reduction (costs associated with overtime to meet production orders, maintenance costs, consumable or raw material costs);
4) Reduction of errors made by machine operators due to lack of training;
5) Increase the final product quality;
6) Increase equipment maintainability;
7) Reduction of the time related to the assembly and disassembly of equipment;
8) Increase workers' safety.

Based on the defined parameters, it was possible to create an Ideality Matrix to identify the negative interactions (represented by the sign "–"), the positive interactions (represented by the sign "+") and nonexistent interactions. Table 1 presents the matrix of ideality and the respective interactions. The ideality level of the described scenario was calculated by applying the following equation:

$$Ideality = \frac{\sum number\ of\ positive\ interactions}{\sum number\ of\ negative\ interactions}$$

Then, the matrix has been built and you can find the result below:

Table 1 Matrix of ideality applied to the defined parameters

Parameters	1	2	3	4	5	6	7	8
1. Productivity		–	–		–	–		
2. Reliability	+		–		+		+	
3. Costs	–	–		–	–	–	–	–
4. Lack of training	–	–	–		–	–	–	–
5. Quality			–					
6. Maintenance	+	+	–		+		+	+
7. Mounting/dismounting time	–		–					–
8. Safety	–		–				–	

After having done this matrix, they have evaluated the results. They become aware that the level of ideality is 8/27 ≈ 0.296 which is thus less than 1. This means that the amount of harmful or negative interactions is greater than the number of positive interactions. The table above reveals that the "Productivity", "Costs", and "Lack of training are negatively affecting the final result. Then, improvements have to be done mainly on those parameters to increase the final level of ideality. They have put in place three types of actions to resolve this issue:

A) Autonomous maintenance checklists: this solution will decrease the lost time of production, the small stops for replacement of parts and it will better forecast the future faults or maintenance needs. Moreover, the machine operators will realize the first and second level maintenance intervention, that is, some competences and responsibilities will be transferred from maintenance technicians to machine operators. Then, the maintenance technicians will gain time by being discharged from this task and will have more time to plan and perform other maintenance dysfunctions.

B) 5S methodology: another problem identified is the lack of work procedures standardization. The resolution of this issue will bring more organization and systematization. The solution has been found thanks to the application of the 5S methodology, a lean tool. The main objective is to reduce any kind of waste. In the picture below, you can observe that they have removed movement waste by simplifying their working place.

Fig. 2 An example of before (left) and the current practice (right) after 5S implementation

A) One point lessons tool: This method will be used to create a manual containing the procedures of all the equipment operating on the production line. This solution will solve the lack of training of inexperienced employees which negatively affect the line production.

Thanks to those three solutions, the level of ideality of the system has increased to 22/12 ≈ 1.83, which means that the positive interactions are above the harmful or negative interactions (>1).
After having completed all the improvements, the company has used the Kano Model to identify the factors with the greatest influence on the change in workers satisfaction. A questionnaire was developed to gather the worker opinion on several factors, such as follows:

- If the level of motivation to work has increased;
- If the level of motivation to work has not increased;
- Can accomplish the tasks in less time;
- Cannot perform tasks in lesser time;
- The tools and materials needed for your work are more organized;
- The tools and materials needed for your work are no longer organized;
- Use point-to-point lessons or One Point Lessons (OPLs);
- Does not use point-to-point lessons or OPLs;
- Can move faster from one location to another on the line;
- Cannot move faster from one location to another on the line;
- The machines would malfunction less;
- The machines would not malfunction less;

You can find the results of this method in the table below. In rows, the questions asked to employees go from 1 to 8 and in columns, that are the following indicators meaning that: —Linear attribute; A—Attractive attribute; R—Required Attribute; I— Indifferent attribute; C—Contradictory attribute; Q—Questionable attribute.

The results are that by observing table 2, the satisfaction increases when the level of motivation is higher. As well as increasing the feeling of ownership in relation to the machines, since they increasingly interact with them, not only at the level of production, but also at in: (i) maintenance, (ii) lubrication; (iii) small adjustments, (iv) filling work orders until then carried out exclusively by employees assigned to the maintenance department of the company.
It is possible to realize the Kano Model before the implementation of the selected actions. In this case, it would serve to verify that the new changes are aligned with the company's needs.
To conclude, those techniques allow them to increase the ideality of the system and observe the positive correlation between the employees satisfaction and the motivation level. In overall, the company has improved its workers' productivity, reduced waste and structured the working procedures. In this case, the TRIZ-LEAN method solves a process issue.

Table 2 Results of the application of Kano Model surveys

		Attributes	L (%)	A (%)	R (%)	I (%)	C (%)	Q (%)	Total (%)
Q1	L	Level of motivation	40.0	23.8	8.8	6.3	11.3	10.0	100
Q2	A	Tasks performed in less time	11.3	45.0	13.8	13.8	16.3	0.0	100
Q3	R	Organized tools and materials	11.3	6.3	75.0	2.5	1.3	3.8	100
Q4	A	Point-to-point lessons	2.5	55.0	26.3	5.0	5.0	6.3	100
Q5	I	Faster moves in the workplace	20.0	18.8	17.5	37.5	6.3	0.0	100
Q6	R	Machines have lesser failures	17.5	16.3	31.3	16.3	6.3	12.5	100
Q7	I	Help with machine maintenance	13.8	16.3	16.3	40.0	6.3	7.5	100
Q8	A	Improved job security	2.5	45.0	28.8	6.3	8.8	8.8	100

Case study : The LCA application

Company presentation

This case study is the practical application of the LCA methodology in a real construction site in Brazil, analyzing the quantities of materials consumed and the basic considerations of the most critical inputs in this scenario, such as steel, ceramics, cement, and wood, through the same design and technical recommendations. It is in accordance with regulatory requirements and uses SimaPro software and the LCA methodology, providing results that will be interpreted and analyzed.

The stake

The objective of this study is to analyze the environmental impacts of a functional unit using the LCA methodology to evidence and compare environmental impacts when using different construction materials. This functional unit has a living room, kitchen, utility area, bathroom, two bedrooms, garage, and a deep yard, with a total built area of around 56 m2.

The method

Step 1: Guidance, Goals and scope

The boundary established for the system under study was delimited by extracting, manufacturing, distributing, demolishing, and end of life, excluding all other steps. A significant period and impacts related to the consumption of energy and water in the use phase of buildings were excluded from the analysis. The functional unit is the set of features that should be the same when comparing different design options, and for this study we defined a functional unit as one family unit of the five family units of the selected construction site. This functional unit has a living room, kitchen, utility area, bathroom, two bedrooms, garage, and a deep yard, with a total built area of around 56 m2 on average. The objective of this study is to analyze the environmental impacts of the selected functional unit using the LCA methodology to evidence and compare environmental impacts when using different construction materials.

Step 2: LCA Inventory

Stage 1: Inventory

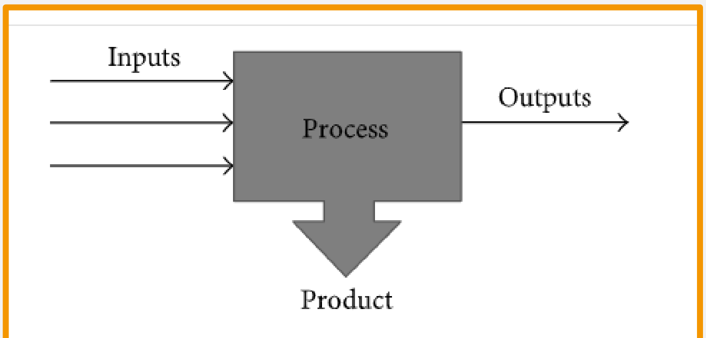
At this stage, the identification of nonelementary streams and quantification of elementary streams occur. These differ in that they are inputs and outputs of existing processes in the different stages of the life cycle, occurring between the agents and the environment. In other words, this phase documents data inputs and outputs systems reported in the study, which was performed in SimaPro software.

Stage 2: Data collection

Quantification of the materials was based on the 13th edition of TCPO (Tables for Compositions of Prices for Budgets), which is considered one of the reliable databases in Brazilian building construction. The amounts of each material can be observed in Table 1.

Material	Quantity (kg)
Steel	5,034.37
Ceramics	131,798.13
Cement	28,369.30
Wood	
Paraná Pine	5,853.76
Peroba-Rosa	4,197.82

The life cycles of materials were modeled on flows of inputs and outputs of the processes, as shown in Figure 2 below. Note that the inputs and outputs were based on the databases used in this work.



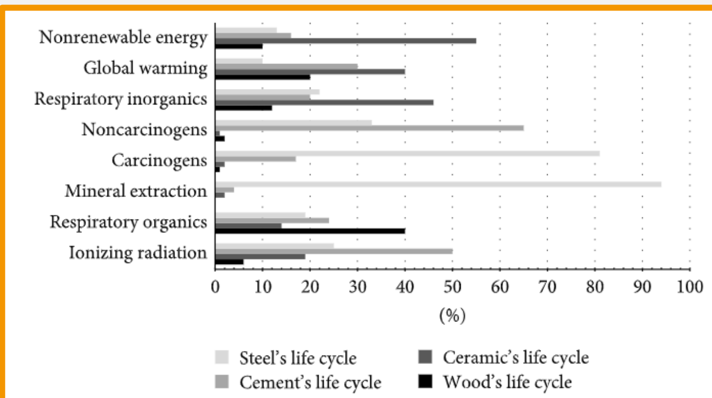
The transportation model used for all construction phases is the road transportation, once this mode of transport is easy to reach and the area next to the site has a large road system connecting the country. In the manufacturing phase, the construction site is considered the same location for construction and extraction of raw materials. For the distribution phase, it was considered an average of the distances between existing suppliers nearby the construction site, which resulted in a range of 10 km. At the end-of-life stage, only the scenarios in which the waste is destined for a landfill or to be processed for recycling are taken into account, having displacements of 12 km and 55 km, respectively.

Step 3:Impact assessment

The assessment of impacts translates consumption and waste identified in the inventory phase environmental impacts, such as the greenhouse effect, hole in the ozone layer, smog, acid rain, eutrophication, and toxicity. To manage those elements, the method of calculation IMPACT2002+ was used, because it proposes a combination of classical approaches (midpoint) and targeted to the damage (endpoint), thus grouping the strengths of methods, such as IMPACT2002, Eco-Indicator 99, CML 2000, and IPCC. Further observation categories were those related to global warming, natural resource consumption, consumption of nonrenewable energy, and toxicity to human health.

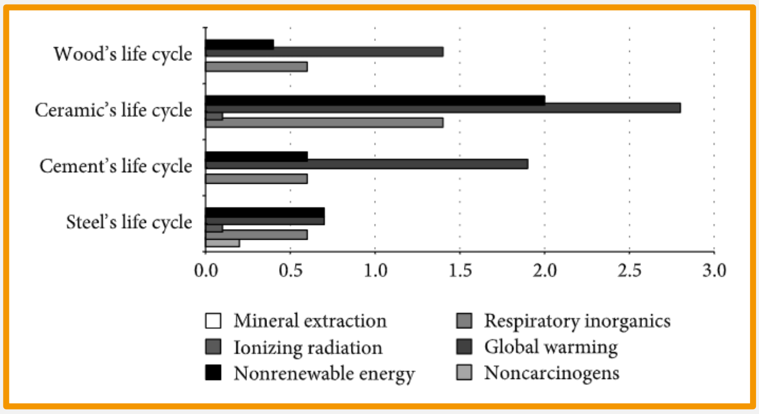
The IMPACT 2002+ methodology combines midpoint/damage approaches linking all types of life cycle inventory results via 14 midpoint categories (human toxicity, respiratory effects, ionizing radiation, ozone layer depletion, photochemical oxidation, aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acidification/nitrification, aquatic acidification, aquatic eutrophication, land occupation, global warming, nonrenewable energy, and mineral extraction) to 4 damage categories (human health, ecosystem quality, climate change, and resources).

The results presented in this paper were based on the comparison and analysis of the materials used in the functional unit of one family unit in the selected construction site of this study. In Figure 3, through the type of characterization, the translation of incoming and outgoing flows in the impact IMPACT2002+ method version 2.05 is presented.



The most significant impacts are life cycles of steel, cement, and ceramics. In 2 of the 15 analyzed impact categories, carcinogens (toxicity to human health) and mineral extraction (consumption of nonrenewable energy), the life cycle of steel is almost exclusively characterized as the most significant agent. Global warming and the use of nonrenewable energy, which are somewhat interconnected, have the life cycle of ceramics as the main agent. The noncarcinogen categories and ionizing radiation were those in which cement showed greater expressiveness. Steel, concrete, and ceramics are characterized as major causes by impacts. Applying the method of standardization by the IMPACT2002+ methodology, it is observed that the most significant impacts, taking into account all materials, are related to global warming and the use of inorganic nonrenewable and respiratory energy (air emissions of NOX and SO2).

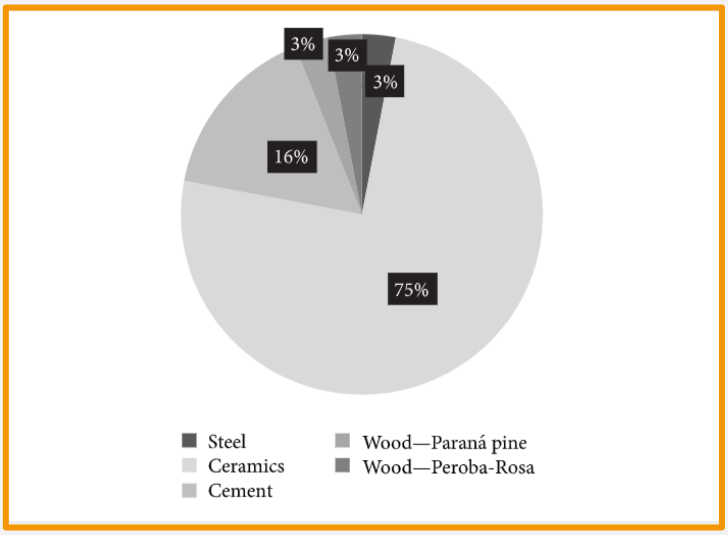
As shown in Figure 4, when applied to the single score, global warming has the most obvious impact on the life cycles of all materials considered, followed by the use of inorganic nonrenewable energy and breathing. The functional unit considered is one family unit in the selected construction site of this study.



Step 4 :Impact interpretation

The final phase of the LCA, inventory results, and the assessment of life cycle impacts are summarized and discussed to reach a decision based on findings and recommendations as the definition of objectives and scope. Based on that and analyzing the data and results of those materials' life cycle, the most severe impacts are related to global warming, consumption of nonrenewable energy, and toxicity to human health. This global warming impact is more representative by the life cycle of ceramics.

In fact, global warming occurs largely by burning fossil fuels, which are used in manufacturing processes and in distribution, transport, and utilization. Moreover, it is important to note that the ceramic material was in greater quantities, corresponding to about 75% by weight of the materials considered for the construction of the site studied, as shown in Figure 5, so this higher impact was expected.



In the context of global warming, the life cycle of cement also stands out. This can be explained by the natural process of manufacture of clinkers, called calcinations, that is responsible for significant emissions of carbon dioxide, which contributes significantly to global warming. Regarding toxicities, considering the effects of steel and cement effects in human health, the most significant impacts were cancer and respiratory inorganic substances. The former is, for the most part, from the life cycle of steel, and the latter is from the life cycle of pottery. Despite this high impact, steel and cement are key materials that are difficult to replace in the traditional system of construction, especially in Brazil.

Taking a closer look at the impacts, it is possible to note that ceramic stood out as the most responsible for the impacts, perhaps because it requires a larger amount of mass between materials. Moreover, the life cycles of cement and steel also had significant impacts, most often related to toxic substances. Wood does not present greater consumption of fossil fuels than the other materials studied, once it does not need large dislocations during the construction phases. However, analysing the dislocations in the global supply chain, cement and steel consume more fossil fuels than ceramics, and yet, the ceramic has higher total intake compared to cement and steel.

Case study :The EIA application

Company presentation

This case study is drawn from Inter-American Development Bank (2010). The project is called "Technical Reconversion in San Jacinto-Tizate (Nicaragua) to generate 72MW of electric energy" and was elaborated in 2008.

The stake

This project was originally operationalized in 1994 under declaration no. 18-94, Public Utility of the Construction of the Project "San Jacinto-Tizate." Concessions were awarded for a 20-year period to run a geothermal energy plant. This project would achieve to main goals:

1. Increasing energy generation capacity to sell energy to the National interconnected system by amplifying the installed capacity from 10MW to 72MW through changes to more efficient technology.
2. Growing in the market of Certified Carbon Emissions promoted by the mechanism for clean development of the Kyoto protocol through increasing the capacity of geothermal energy production.

The main activities to be carried out in this project are to perforate 13 new production and reinjection ponds and to increase the installed capacity and the technological reconversion of counter pressure units (BPUs) by switching to modular condensation turbines (MCT) which are more efficient and cleaner.

They have decided to make an EIA study because of the project's localization in a protected area.

The method

Step 1: Screening

As a requirement for the screening process in Nicaragua, it is necessary to fill out an environmental form to assess all projects, works, activities and industries.

All projects are classified into four categories, three of which require an EIA:

1. Special projects considered for their national or regional importance and high impact on the economy, social activity and the environment
2. All projects that pose a potential high impact on the environment

3. All projects that may cause a moderate amount of impact to the environment but may generate cumulative effects and so therefore require an environmental assessment, but not a full-blown EIA

4. All projects with low potential impact are regulated by article 25 of the General Law on the Environment and Natural Resources. An environmental form must be filled out and submitted to local authorities and permissions be obtained. No EIA is necessary.

Step 2: Scoping

Assessment Method Used Throughout the EIA

The Rapid Impact Assessment Matrix (RIAM) is a systematic approach using qualitative data that can be expressed in a semi-quantitative way. The process of RIAM permits to identify significant changes (positive and negative) caused by the project, establish a baseline for the monitoring plan, identify mitigation strategies and design a monitoring and evaluation system to determine the effectiveness of the mitigation strategies. Public participation is carried out at the data collection and mitigation stages of the process during the RIAM method. Both of these stages are directly followed by quality control measures during the analysis and program monitoring stages. The multidisciplinary team which allows data from different sectors to be analyzed at the same time in one common matrix, to have a rapid and clear evaluation of the most important impacts the project may have. This matrix allows the team to compare different development options according to how the four aspects of the environment may react to an action.

Step 3: Potential Project Impacts analysis

The following table displays all the potential impacts of the project, categorized by the type of impact (physio-chemical, biological-ecological, sociocultural and economic-operational), the phase of the project and the impact level.

Type of Impact	Phase	Impact level	Details
Physio-chemical	Construction	Negative/ Moderate	**Residual solids:** Generation of residual solids from construction of buildings (can control and mitigate, national standards to be followed).
		Moderate	**Residual Liquid:** All fluids coming from the project's reservoir after electricity is generated will not affect the surface environment as they will be reinjected into the subsoil.
		High	**Changes in soils and subsoils**: Wind and water erosion, and waste from the removal of vegetation, caused by the movement of soil for construction, contribute to the degradation of soils. Chemical elements that may be present include mercury, boron, and arsenic. This can cause problems for vegetation and agriculture in the area. The removal of trees and vegetation will increase the risk of erosion. Mitigation plan will be put in place.
		Moderate/ negative	**Changes in noise levels**: Due to the use of heavy machinery, noise levels in the area will increase. This may have a negative effect on workers and the local community.
		Moderate/ negative	**Changes in air quality**: An increased use of machinery and movement of soil will produce emissions.
		Positive	**Changes in quality and quantity of water:** There will be a temporary and localized change in the pattern of the stream surface drainage. However, as the work will be carried out during the dry season with strategic installations to improve drainage year round.
	Operation	Negative/ moderate	**Residual Solids**: Waste from the perforation of the geothermal pools will generate mud and small rock fragments that will need to be brought to the surface.
		Negative/ Moderate	**Residual Liquid:** Grey water will be produced from the temporary construction, brine water from electricity generation and leaking of oil/gas from heavy machinery and transformers.
			Changes in air quality: Geothermal generators produce far less CO_2 than other thermal plants. The release of radon and mercury are estimated to be very minor based on the concentrations of vapour.
Biological-ecological		Positive	This project works within the Plan to Manage the Telica-Rota Protected Area and helps to reduce reliance on use of wood products for firewood and furniture. Most trees and vegetation have been altered by agricultural production. This project will not significantly impact the flora and fauna of the area.
Sociocultural			There will not be any major differences in the sociocultural area at any stage of the project. While there are no negative impacts in this area: because the project is located within a risk zone, it will be integrated into the local plan of prevention, mitigation and attention to disasters.
		Positive	**Employment**: approximately 700 people will be employed in phases I and II of the project.
		Positive	**Access to basic services:** potable water is an issue in San Jacinto. The PRNSA helps part of the community by allowing them to use a tap on the outside of their offices and helped purchase tubes to install potable water in the rest of the community.

Step 4: Impact Assessment and Mitigation

The RIAM methodology was used in the identification, prediction and analysis of all potential direct and indirect impacts connected to the project. Using this model, the four major impact areas are analyzed: Physio-chemical, biological-ecological, sociocultural and economic-operational.

We can observe two alternatives of the project:

Without the project :

In a situation where the project is not undertaken, the most significant impacts are found in the economic arena in the form of lost job opportunities, dependence on fossil fuels, lost opportunities for carbon credits and an alliance to help manage the Telica-Rota protected area.

With the project:

The most significant impacts found in the analysis with the project in place are in the physical-chemical environment. Most impacts will be felt during the construction phase and will therefore be temporary. Mitigations strategies were identified for all impacts throughout all stages of the project. Magnitude is estimated using experts' judgment based on the information collected in most cases. The EIA provides a detailed description of all the elements that may be affected by the construction and operations phases.

These elements range from houses, schools and health centers to roads, agriculture land, forests and water sources among others. The report shows the number of units directly and indirectly affected by the project and other important observations such as town names, or water sources. Using the RIAM method both direct and indirect impacts are identified. The group uses GIS to estimate a radius around the project identifying areas of direct and indirect influence at each stage of the project. The areas of impact were estimated using the principal transmission line where the principal risk—the hydro cables—is found.

Areas of influence are most greatly impacted by:

- Noise and gas emissions in the construction zone.
- Activities involving removal of vegetation where the platforms and access roads are situated.
- Moving equipment and materials.
- Contracting construction workers and services.

In the case of this EIA, all impacts, no matter their significance, are monitored and mitigated when necessary to avoid negative cumulative impacts. Because this is a project seeking to expand operations, ongoing monitoring and analysis previous to this assessment allow for more reliable data and predictions, allowing for some margin of error.

Step 5 : Reporting Impact Management

The Socio-Environmental Management Plan laid out in this project was developed using observations and studies in the area of influence, site visits and public consultations within the municipality of Telica. The impact management plan has five objectives:

- Strengthen all the components that make up the social and environmental areas of influences throughout all phases of the project.
- Establish mitigation measures and a monitoring plan to prevent and reduce any significant negative impacts to acceptable levels and strengthen all positive impacts caused as a result of the project.
- Define the responsibilities of all the different actors to properly implement the mitigation measures during all phases of the project.
- Comply with the established environmental and social regulations in order to obtain environmental license.
- Protect the health and safety of all the workers and citizens living in the project area.

The plan includes sections to address mitigation measures, monitoring, a contingency plan, a waste management plan, a reforestation plan and an implementation plan.

Table 2. List of Mitigation Measures

Impact Details	Standards	Mitigation Methods	Residual Impact
Physio-chemical **Residual solids:** Generation of residual solids from construction of buildings can potentially cause erosion and loss of topsoil as well as possible contamination.	None indicated	• Plant bushes on slopes and embankments to reduce erosion risk • Build gutters and energy sinks for storm and rain water • Build gabion walls for areas with moderate slopes • Irrigate the access roads in the dry season • Reforestation of native species • Monitor seismic activity • Continual lab analysis to test toxicity in muds • Muds will remain in an impermeable tank until total dry • Use water based chemicals mixed with the drilling sludge • Treat the sludge with bio-remediation • Build emergency pools to avoid overflow of sludge in the case of extreme storms	*Impact Reduction* • Along with reforestation, mitigation efforts for all physio-chemical impacts will help to control and reduce impacts to acceptable levels
Residual Liquid: The project could be affected by its own activities, either by sediment or residual liquids and solids.	Decree 33-95: Provisions for the control of pollution from domestic, industrial and agricultural discharges and wastewater None indicated	• Implement a Toxic Waste Management Plan • Reinject the drilling fluids to maintain hydrothermal balance in the aquafer • Monitor pressure and temperature • Avoid overflow of residual waters into surface drainage by using reinjection methods • No run-off or dumping sites for final wastes within 200 m of any streams near the project • All maintenance done in shops, off-site • No dumping grey waters directly into water sources • Discharge and run-off from construction will be reduced using sediment traps • Residual waters reinjected directly into the reservoir for production ponds • Impermeable lagoons built to avoid seepage of waste water • Build drainage system able to capture and reinject water from vapour drainage lines and cooling towers into cold water • Hydrological study to determine the configuration of the aquafer to decide where the ponds will be drilled	
Changes in noise levels: Due to the use of heavy machinery, noise levels in the area will increase. This may have a negative effect on workers and the local community.	None indicated	• Precautions will be taken during the drilling period to not contaminate the aquafer with chemicals • Monitoring of temperature and pressure in all production ponds • Reinject all residual waters into the reservoir • Build emergency run-off pools to avoid overflow of storm water	
Changes in air quality: A minor amount of			

Impact Details	Standards	Mitigation Methods	Residual Impact
CO_2, radon and mercury may be emitted		• Build sewers to avoid residual water contact with soils while passing to the emergency lagoons • Ensure machinery is working properly • Install sound barriers to reduce noise around generating plants • Ensure use of safety equipment for all workers on site at all phases of the project • Use silencers for the blowers in the entrance of the turbine • H_2S detectors installed to detect 500 parts per billion (ppb) within 15 seconds • Periodically monitor CO_2 and H_2S emissions in the proximity of areas of emission potential • No burning wastes of any kind. All waste to be deposited in municipal garbage sites	
Bio-Ecological Because of overall human interventions in the area, ecosystems are fragmented and vulnerable	None indicated	• Reforestation plan	*Positive impact:* increased numbers of migratory birds, improved connection of the Pacific Biological Corridor, positive changes in the migratory patterns of land and air fauna.
Sociocultural and Economic-Operational **Health issues**: contact with escaping vapour from pipes, accidents dealing with the transmission lines, fires that could affect the plant and infrastructure	None indicated	• Occupational health standards and risk mitigation on-site • Undertake studies to promote the economic production of some local species (i.e., iguana) to substitute hunting over harvesting • Finance forest rangers and co-manage a program with government agencies, the municipality, local communities • Control and preventive measures for all activities that are significantly damaging the potential in the area especially deforestation, fires and poaching	*Positive impact:* Reforestation efforts in the area will help the community qualify for carbon sequestration credits and government agencies can sell carbon credits for having reduced emissions. Part of the money raised will go to a conservation fund for wild flora and fauna and an environmental education plan for the area.

Step 6 : review of EIA

A. Contingency Plan

The Security and Emergency plan includes security policies, a plan for notification in case of an emergency, responsibilities for supervisors and workers, functions and duties for the health and safety committee, emergency training, rules and practices for workers relative to materials handling, transportation, work with electricity, soldering, using tools and machinery, anti-fire protection and handling chemicals. Here details are provided as to what each of these items entails, methodology for 8 evaluation and follow-up of the contingency plan and recuperation activities for all parties and elements affected. Included within the contingency plan are:

• Occupational health and safety plan

• Plan for prevention, mitigation and attention to disasters

• Waste management plan

• Hydrocarbon management plan

All plans identify measures taken to date and all regulations they are obligated to follow under national and local law.

B. Reforestation plan

While the impact analysis does not emphasize any significant impact to the natural landscape, the project has dedicated an effort to reverse the negative effects of human interaction in the area. As such, a reforestation and management plan is included in this document. This is done to strengthen the positive impacts the project has on the area.

C. Implementation plan

This plan outlines who is responsible for all aspects of the Socio-Environmental Management Plan to ensure that all mitigation measures are being implemented. It states that MARENA and other authorized bodies are responsible for monitoring compliance with the environmental management and monitoring plan and that all people contracted under the company, PENSA, must follow all policies outlined in this document including:

• Environmental monitoring programs.

• Health and safety plans.

• A continuation with the process of public consultation and participation when needed.

• Depositing of residual wastes in an adequate manner, meeting the needs of local authorities.

D. Budget

A brief budget is included, in U.S. dollars, to outline the costs for the construction and operation phases and monitoring programs.

Step 7 : post monitoring

Under the terms of the monitoring plan, experts are employed in their specific areas on a permanent basis: results are verified by a panel of consultants who convene every 18 months to ensure quality standards in data analysis. Detailed plans are in place to monitor air, water, soil, pH levels in rainwater, and geothermal activities because of all energy production operations. Each plan is written in detail, with specific elements being monitored, standards followed and how long monitoring has been carried out. As well, the existing baseline for all air, water and soil factors is updated on a regular basis.

Case study : EcoDesign Strategy wheel

Company presentation

The study was conducted as a segment of a research project developed in the company. The studied company can be characterized as small and was established in the mid-1990s. It has an extensive line of approximately 150 products, mainly focusing games to the market of corporate gifts.

The stake

This very specific market allows products to be developed from extensive research (carried out by the owners) about traditional games in Brazil and in the rest of the world. This makes their products expensive, but this aspect is offset by the high value associated with the products. They are usually intended for a consumer market that values and preserves the product for a long time; it is not considered a "fashionable" or disposable item (it is usually considered as a decorative and "good taste" item). These characteristics make it desirable that the product has a long useful life. Its immediate replacement is not an objective of the company. Many customers become collectors, so the company's portfolio of products is always in expansion.

These features significantly increase production costs, thus there is a need to prioritize a flexible production system and an appropriate system for product development. The product analyzed was the "Santa Cruz" Watch (Figure 2), consisting of a wooden base, with a display in paper (glued on the base), a "gnomon" (device whose shading indicates the hours of the day) of metal and dipping compass. The basic measurements are 11.5 × 11.5 × 5 cm. The production process is quite simple, with a base made of wood (in one piece), on top of which is pasted printed paper and affixed the dipping compass. Finally the gnomon is fixed, by fitting and gluing. The results of the analysis, made by following the steps in the method, will be presented below:

The method

Step 1: Premanufacture

A. Optimization of the function

According to the analysis, it was possible to identify improvement possibilities in two aspects of the product, namely: consumer expectations and use of resources in cascade. With regard to consumer expectations, the product has potential for upgrades, since the fragility of the material (gnomon) causes the product to deteriorate quickly, which is against its proposed durability. However, the company has realized this demand and is currently providing improvements. As to the package of the watch, there are possibilities for enhancements, such as a secondary use of the box. It could be used for embellishment and protection, changing its design to a configuration that allows the insertion of the game in it. Finally, an aspect that was perceived as being difficult to implement was the replacement of the product with a service. However, it is possible to provide a maintenance service for any defect of the product.

Figure 2. "Santa Cruz" Sundial. Source: Company portfolio.

B. Savings of natural resources

For the "saving natural resources" criterion, the possibility of encouraging remanufacturing is suggested, since the product is very new and nothing is reused in manufacturing. However, features such as product dimensions and use of recyclable materials were evaluated with maximum score. The product dimensions are suitable for the roles it plays and a size reduction could result in difficulty seeing the hours or a distortion of the pointers, for example. In relation to the materials used, the wood does not use varnish and is therefore recyclable but not recycled. The paper, according to the company's website, is also recyclable.

C. Use of renewable and sufficiently available resources

In this regard, all the criteria were evaluated with maximum score, as follows: use of renewable resources, use of enough resources and minimization of the use of scarce resources. This is because the materials used (wood, paper and metal alloy) are renewable and are not rare.

D. Prevention/minimization of hazardous substances' use

All criteria were evaluated with improvement opportunities as the sealant applied to the wood is toxic and needs attention. For the management of risks inherent in the application of the products, the group suggests the use of PPE - Personal Protective Equipment (mask) in order to minimize the harmful effects of substances in the human body.

Step 2: Manufacture

A. Streamlining consumption (raw materials, energy, water)

The criteria evaluated with improvement possibility were energy consumption and use of renewable resources. With regard to energy consumption, the suggestion is a planning of sequential production to assist in the consumption rationalization. Another point noticed was the fact that the energy used by manufacturing machines is electric energy. There is a possibility to check the use of renewable energy. The consumption of materials and water was evaluated with the maximum score. The sundial production process does not use water as an input, only in indirect operations such as cleaning, and the dimensions of the sundial maximize the efficient utilization of wood used as raw material. The remains of this wood are donated weekly to a community garden.

B. Prevention/minimization of pollution emissions and waste

As the production process does not use water as main raw material, the prevention of wastewater is considered efficient.

However, the prevention of exhaust air emissions can be improved, since the sealant at high levels can be toxic. Another improvement point observed was the waste prevention. Despite the fact that the sawdust is reused, the powder released in timber cutting steps can be harmful to joinery employees. The use of PPE (such as protective masks) in all operations in the woodworking shed is recommended. Finally, the prevention of noise emissions can be improved, since there is the presence of loud noise at all stages of production of the clock's wooden base.

Step 3: Distribution

A. Optimization of the packaging system

The sundial packaging (Figure 3) consists of a cardboard box of 20 × 17.5 × 4.5 cm. It is oversized for the product and does not protect it from any shocks or weights placed on the package. Research has identified that the parts that require protective packaging are on the top of the sundial (paper and gnomon). An improvement possibility is making a sort of lid covering only the top of the object, made of a similar wood from the basis. Another possibility raised was to shrink the package and to use a thicker cardboard, which protects the gnomon. Although the likelihood of the cardboard still being dispensed is high, this suggestion would preserve the positive aspects of the recyclability. A reusable packaging system was discarded, because most of the end users of the watch are not direct customers of the company. It would be necessary to transport it twice (company - customer - user). The implementation of the logistics of this system would be too complex, therefore not feasible for the company.

Figure 3. The product package. Source: Authors' file.

B. Implementation of an adequate logistics system

Few improvement opportunities were identified in this regard, as the company works with requests for the Santa Cruz Sundial usually in quantities smaller than 500 units. At the same time, a fact that complicates the logistics planning is that the sundial demand does not follow a predictable pattern. In this situation, the company can produce many pieces in a month and none in the following year. An opportunity for improvement is the ability to transport several different products altogether with the sundial, so that may be few trips from the joinery (where the wood pieces are produced) to the shed (where it is assembled). There is also the possibility of adding the delivery of the request of the Santa Cruz sundial along with requests from other products, reducing the logistics operations.

Step 4: Use

A. Increase of product durability

Regarding the product durability analysis, we identified both positive points and eligible improvements on the sundial. It has a "timeless design", i.e., the product does not depreciate over time, so this aspect was considered optimized and compliant. Nevertheless, there were found possible improvements regarding modular design. The product parts cannot be removed for cleaning, maintenance and repair. As to the cleaning, paper cannot be wet, making this procedure more difficult. One solution is the application of a material (for example, a special paper or plastic) that makes it impermeable and facilitates cleaning. In the aspect of ease maintenance, great difficulty was detected, since the gnomon and the compass are bonded and cannot be disengaged. And the aspect of facilitating repair, improvement opportunities are assigned as the gnomon is fragile and is not easily replaceable by the customer. Also, there is not a formalized maintenance service.

B. Prevention/minimization of product utilization impacts

Few variables were analyzed in this regard, since most of the items do not apply to the studied object. With respect to providing the user with information, maximum grade was assigned, i.e. the information provided is clear and meets the objectives. Along with the sundial, a small manual about the product use is provided to the user.

Step 5: End of life

A. Optimization of disassembly

In the aspect relating the removal of the product, there is ample scope for improvement, as the Santa Cruz sundial is not a detachable product. Thus, it is impossible to replace parts that can be damaged during use, which consequently causes the product to lose its usefulness when some of its pieces break. The main linking component used in the product is water based glue, which is permanent and confirms the statement that there's not a way of disassembling the product without breaking it. Another connection element found is a screw that joins two metal parts of the gnomon and is used only to give mobility of those parts and not to dismount the component. It is noteworthy that to remove this screw a specific tool is not necessary.

B. Optimization of product reuse

The product does not have possibilities for reuse. Its structure is simple, and is considered a "single structure", that is, you can only remove or access the other components with the destruction of the wooden base and the consequent destruction of the sundial as a whole. This characteristic brings difficulties to repair and replacement of these. Regarding the wear of components, it is emphasized that the metal part (gnomon) has a greater chance of wear over time, being extremely fragile, which may cause its rupture. The paper pasted on the wooden base has marks printed to aid marking time. Sun exposure can damage the printer and make it a lighter shade, which can greatly hinder the measurement of hours by the sundial.

C. Optimization of recycling materials

For minimizing the materials variety in the product, the elimination of the piece of paper pasted on the wooden platform is suggested, replacing it by crimped or printed markings on the timber. Thus, the use of glue for fixing the paper would also be eliminated, which would entail a high degree of recyclability. Since the product is composed essentially of wood, metal, rubber and paper, it is noted that the materials are compatible with future recycling. The lack of varnish in the wood also increases the recyclability of the product. However, the fact that the components are not easily separable complicates the recycling process. The materials are not marked to facilitate screening and selection of these parts for recycling the product. However, there is possibility of improvement: the elimination of paper and glue fixative, as suggested above, would reduce the number of components and facilitate the process of separation for recycling. Other suggestions, such as a locking system for gnomon instead of adhesive, would also facilitate the disassembly and recycling process.

D. Appropriate discard of unrecoverable materials

As noted earlier, all parts that make up the product are suitable for recycling. The Santa Cruz sundial does not use hazardous substances in any of its parts, thus the items referring to the table above do not apply in the analysis of this product.

Case study : The Product-Service Systems application

Company presentation

Diddi & Gori S.p.A. is a medium-size company located in Italia which produces manufactures for the shoe industry and textile flooring. They have an offer called Digodream which is based on a product-service approach.

Their textile flooring is manufactured thanks to waste raw materials and it can be then recyclable, since it returns as the original fibre. We can find their products in trade fairs and exhibitions, for example.

The stake

The manufacture of synthetic fibres and chemical goods require oil refining which have a negative impact on the environment.

The method

Their solution is to create manufactures without using chemical and harmful ingredients which can be recyclable and reduce their raw materials consumption. Then, they have developed a "d&g project" with the aim of reducing their negative impact on the environment by producing recyclable textiles from recycled processes, reusing production waste and finding a way to take care of any sort of waste.

Moreover, their Digodeam offer is different because it is promoted as a service offer from the supply and the installation to the removal. The customer does not own the product but he buys its utility. Therefore, this concept differs from the traditional approach by buying products and then transferring the property from the manufacturer to the consumer. The approach is different because in this new case, the customer buys.

- for the product or service functionality. The payment is the amount of product use. When the product arrives at its end-of-life, Digodream contacts the initial producer who will use the product into new fibres.

In this example, the company has assessed the traditional process in its industry (step 1). Then, it certainly has developed different ideas and chosen the most suitable (step 2).

- Afterwards, they have evaluated precisely the components of this new model and caught a new opportunity to benefit the company and its customers and reduce its negative impact on the environment (step 3 and 4). To finish, they have implemented the new idea by adding a service system and observed the positive effect of its business model (step 5).

Case study : The Innovation Factor 4 application

Company presentation

Blablacar is a french company created in 2006 by Frédéric Mazzella, Nicolas Brusson, and Francis Nappez in order to fill a void in the market. The principle is to put in relation drivers and travelers who are going to the same destination to share a ride and its costs. Nowadays, they are present in 22 countries and they register 90 million users. Carsharing reduces 1.6 tons of carbon dioxide each year.

The stake

The firm is launching a brand new app and service today. Named BlaBlaLines, this new app is all about short distance carpooling and daily commutes so that you can leave your car at home

The method

Step 1: Describe the innovative nature of the project

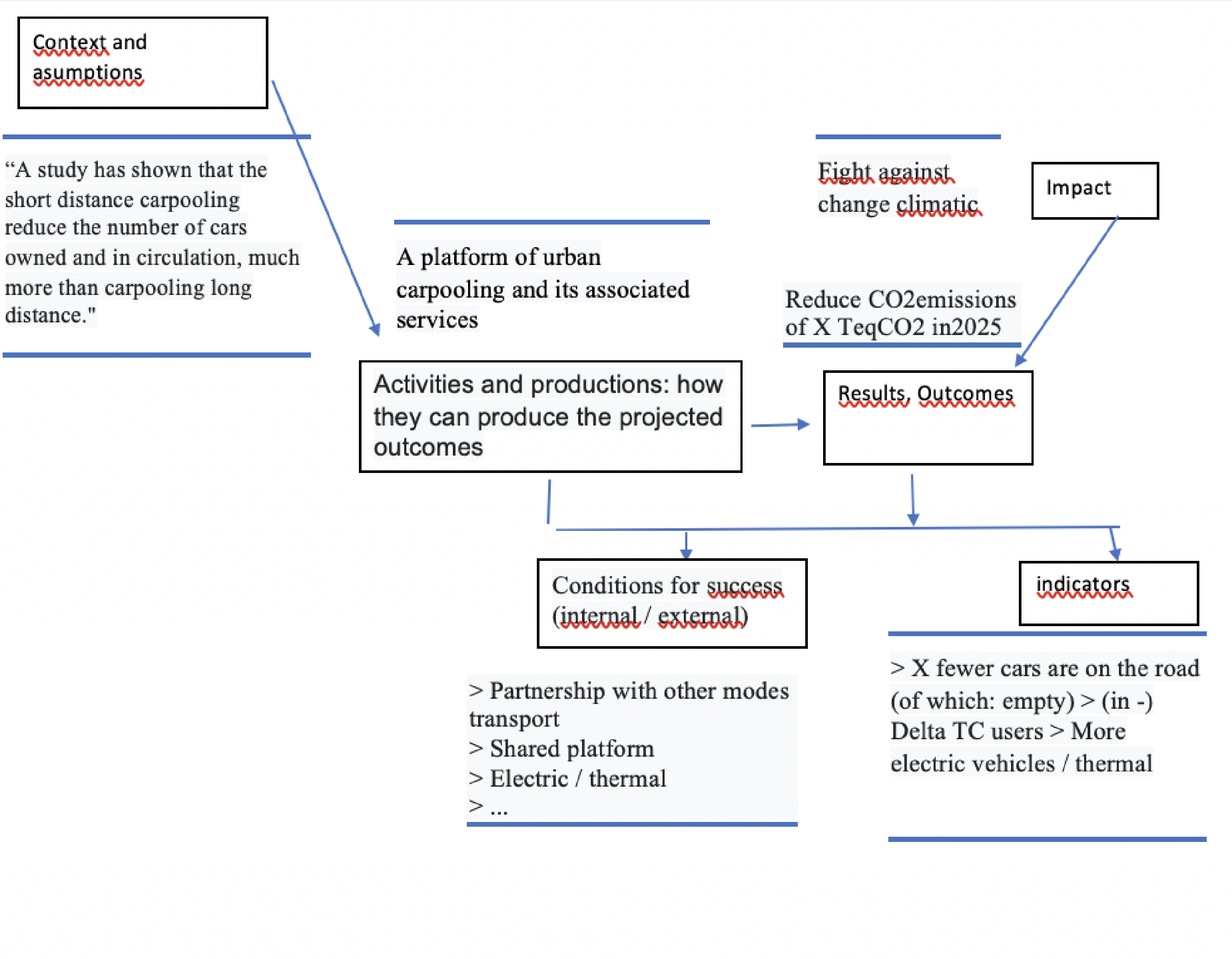
- What does the project bring new to its customers, users and beneficiaries?

BlaBlaLines offers a transport solution particularly suited to short trips, more or less regular (home-work, studies, sports, shopping, etc.). Economical, friendly and virtuous, this practice also meets consumer expectations.

- How does the project differ from what exists and / or its competition?

There were already few competitors in the market (klaxit, karos, smile and IDVROOM from SCNF) but blablacar have already a strong consumer base.

Step 2: The Theory of Change project



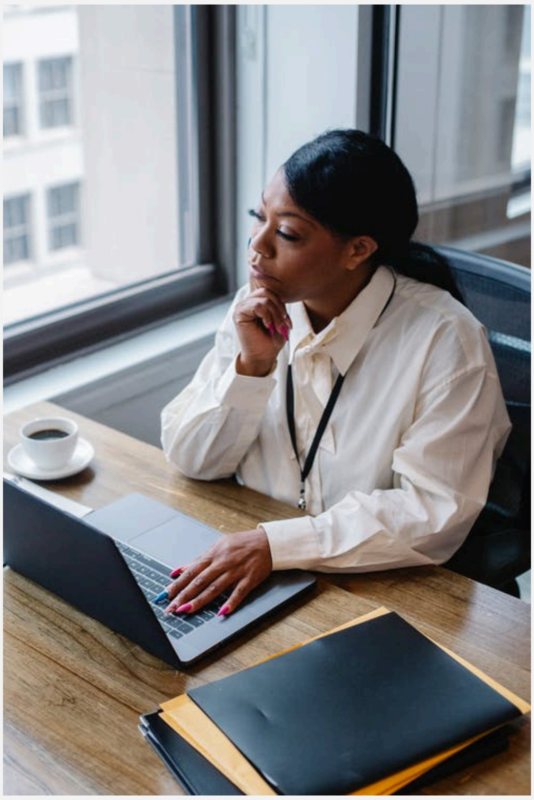
Step 3: Test the alignment between the business model and the impact model

Key success factors	Influence on the economic model (from very negative - to very positive ++)	Influence on ecological impacts (from very negative -to very positive ++)
Critical mass of drivers and passengers	++	+
Complementarities With other modes of transport	+	++
Promote electric vehicles	Neutral	++
Common Platform for the territory carriage operators	-	++

Case study : The ECO M2 application

Company presentation

An anonymous multinational company, with more than 40 years' experience, is one of the largest companies in its sector, employing around 20,000 people worldwide.



The stake

Driven by environmental legislation, business opportunities, customer pressures and by the advance of competitors in eco-design, the company assigned a senior manager to lead a project for eco-design implementation.

The method

Step 1: Diagnosis of the current maturity profile in eco-design

- **Stage 1: Product development processes (PDP) analysis**

  - A documental analysis of PDP-related documents (including process scope and overview; phases, macro-processes and tools description; roles and responsibilities definition; and product requirements) was carried out.

Eight key employees were interviewed, in order to understand how the process was performed in the day-to-day business and to clarify issues regarding the analyzed documents. The comments registered during these interviews expressed a strong recognition of the importance of eco-design in the company. The questionnaire for maturity assessment was adapted to the vocabulary of the company and the employees to be interviewed were jointly identified.

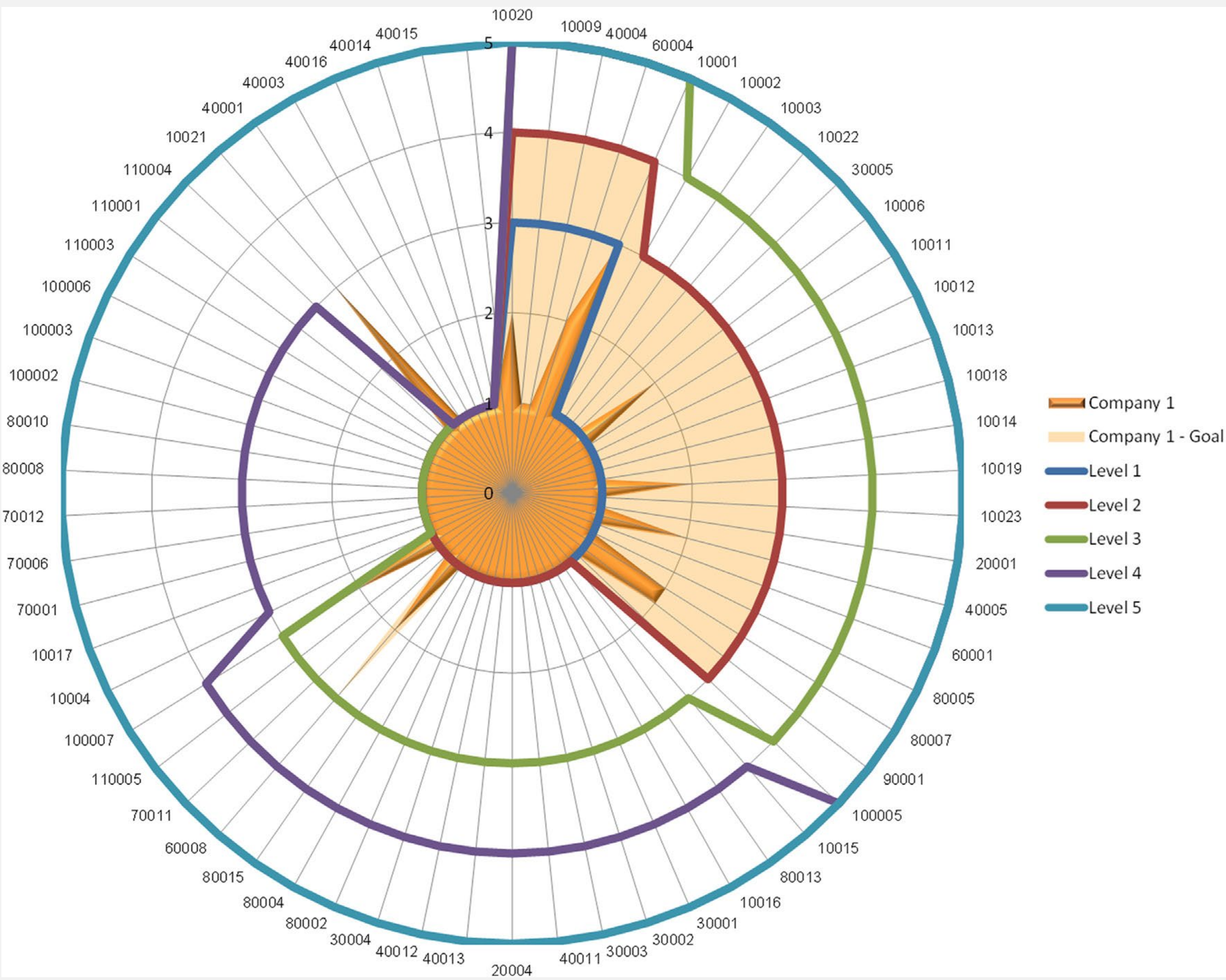
- In total 19 employees were selected, who were directly related to the PDP and who represented a variety of areas (such as quality, supply chain, after-sales, engineering, etc.), functions and hierarchical positions in the company. The company organized the schedule for the interviews, contacted the people to be interviewed, explaining the general context of the project, and provided the resources needed.

- **Stage 2:**

The goal was to evaluate which eco-design management practices were applied by the company and to which level of capability. The 19 employees selected in the previous step were interviewed in face-to-face meetings, lasting 105 min on average. During the 19 interviews, the management practices were evaluated according to the company's capability level, in order to determine the current maturity profile of the company.

- **Stage 3:**

  - The capability levels assigned by the employees were analyzed against their own commentaries, in order to ensure coherence and consistency. Whenever necessary, the capability level was changed, based either on the commentaries or the evidence of the documental analysis.
  - The consolidated results were plotted in the maturity radar. The orange solid area represents the current eco-design maturity profile of the company, i.e. it indicates which management practices are currently being applied and with which capability level, according to the perception of the interviewees.



Maturity Radar using the Ecodesign management practices (web link click here)

- The maturity profile indicates that the company does not apply or applies in an incomplete manner (capability level 1) most of the management practices (from the lowest to the highest evolution levels). Even the practices of evolution level 1 are not yet completely applied by the company.
- This means that the company has a low level of knowledge about eco-design and does not yet understand how it could be incorporated into its product development and related processes. There are, however, some practices that are applied in an ad hoc way (capability level 2) and also two practices applied in a formal way21 (capability level 3). In summary, the conclusion is that the case company had a low eco-design implementation maturity profile, at the time of measurement.

Step 2: Proposition of eco-design management practices and improvement projects

- Once the current maturity profile was determined, the most suitable eco-design management practices to be adopted were selected, based on a gap analysis and a selection of the process improvement approach (staged or continuous) to be adopted.
- In cases like this, where the maturity profile is characterized by low capability levels of the management practices, the staged approach for process improvement is suggested, i.e. following the stages defined by the maturity levels. In this sense, the company would better succeed in the application of eco-design if it starts the application of the management practices of the first maturity level and then proceeds to the application of the second maturity level.
- Based on the staged approach for process improvement, the company defined the second maturity level as the goal for its first improvement cycle.
- According to the maturity model, the company should apply the following practices in order to reach eco-design implementation maturity level 2:
    - Management practices of the first evolution level with a capability 4 (control); and
    - Management practices of the second evolution level with a capability 3 (formal)
- A cluster analysis was performed, in order to identify synergies among the management practices and to propose the improvement projects for eco-design implementation, based on the characteristics and culture of the company. The improvement projects were designed for the joint and integrated incorporation of the application of one or more practices.
- Once the projects were defined, the relationships and dependencies among the management practices, the operational practices and the techniques/tools were assessed.
- In total, eight projects for eco-design implementation were proposed to the company. Each project contains the description of the management practices, operational practices and tools and techniques that should be applied, in order to reach the second maturity level.

Step 3: Portfolio management of improvement projects for eco-design implementation

- The prioritization of the projects to be implemented was performed internally by the company, following their current practices for portfolio management. The decision making process was carried out considering its internal drivers, strategic alignment and available resources. As a result, a roadmap for the implementation of the projects was developed.

Step 4: Planning of the improvement projects for eco-design implementation

- Subsequently, the projects were further detailed by the company in the project planning stage considering internal elements such as culture, risks, costs, products developed, etc. Currently, the company is implementing five of the eight projects proposed (projects 1, 2, 3, 5 and 8). At the time of writing the other three projects are planned to be developed over the next year, in accordance with the roadmap for eco-design implementation.

Step 5: Implementation of the improvement projects

- The specific technique/tools to be used in order to implement the eco-design management and operational practices were selected during the implementation phase of the projects, considering the provided classification criteria. Subsequently, pilot applications of the selected tools were performed. Whenever necessary, customization and adaptation of the tools was carried out, in order to match the company's context.

Step 6: Assessment of the results

- At the end of the first improvement cycle described above, the company reported the intention to begin a new improvement cycle, reassessing its current maturity profile, in order to define new projects to be implemented towards higher maturity levels on eco-design implementation. A second diagnosis of the company's eco-design maturity level will enable the identification of the actual achievements accomplished by the company during the first improvement cycle, in comparison to its desired goal, which was to achieve maturity level 2.

Comparison chart

Methods	Feature	Phase	Goals	Targets
MGE2	Product	Conception	- Review an existing product - Create a new product	C2C projects
QFDE	Product	Conception	- Handle the environmental and traditional requirements - Identify components - Analyze conception change	Engineers
TRIZ-Lean	Product	Review / Improvements	- Improve product quality - Reduce waste - Eliminate defects - Reschedule tasks	Managers and engineers
LCA	Product	Conception	- Improve the environmental impact of a product - Compare products - Avoid negative impact transfer	Engineers and products designers
EIA	Product	Conception	- To adapt projects to suit local environmental and issues by giving options to decision-makers - Improve environmental and resources project efficiency - Consider the three aspects of project (social environmental and economic) both beneficial and adverse impacts to reduce negative impact	Engineers

Comparison chart

Methods	Feature	Phase	Goals	Targets
Eco design Strategy Wheel	Product	From ideation to production	- Improve the environmental impact through all possible stages	Managers
PSS	Service	Conception	- Integrate the product's life cycle - Increase products' lifetime - Win-win situation by creating value to the company and its customers - Change the paradigm from buying the product property to buying its function	Products and projects managers
Innovation Factor 4	Service	Conception	- Develop a radical innovation - Value proposition integrates the environmental impact - Prevent from rebound effects	Innovators
Eco M2	Process	Conception	- Analyze and assess the company maturity level - Implement projects - Improve the company maturity level in eco-design	Managers

References :

Case Eco M2

- See the reference after the method (mettre lien hypertexte)

Case MGE2

- See the reference after the method (mettre lien hypertexte)

Case PSS

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