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# A method and tool to assess sustainability for decision-making in product development

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Sustainability is becoming increasingly important for manufacturers to adhere to. Overconsumption is depleting the earth's resources. Sustainable Development Goals (SDGs) were created to reduce global impact. According to these SDGs, manufacturers must transition to a circular economy to remain in business. Though long-term SDGs are defined, manufacturers must set short-term goals to assess sustainability through clear requirements and measurement methods. The current Life cycle Assessment (LCA) framework is unclear to product developers, and LCA programs are difficult and time-consuming, particularly during the conceptual development stage. To solve this problem, the Product Development LCA (PD-LCA) method was developed to support the redesign of a product to reduce its impact. The PD-LCA method is applied in the sustainability assessment tool (STAT) to support sustainable product development. The research utilizes a case study to identify the problem and to test and enhance the method and tool in practice. The LCA method and tool can be integrated into the product development process through change management.

Sustainability, SDG, LCA method, LCA tool, environmental impact, change management, product development

## 1. Introduction

Since the industrial revolution, the number of goods produced has increased rapidly. As a result, the use of materials, energy, and the amount of waste is increasing. The economic system has evolved into a "take-make-use-waste" model, or linear model, of consumption [1]. This linear model cannot cope with the future as we use and throw away more than nature can contain and sustain. Thus, many resources will run out within a generation. [2].

In the current linear consumption model, a product's lifetime can be deliberately decreased to increase revenue, which is called ‘planned obsolescence. This system originated back in 1920 when light bulb manufacturers decreased the life span of a bulb from 2500 to 1000 hours [3]. This model generates more waste and consumes more resources, which is harmful to the environment.

In 1960, Papanek and Fuller saw planned obsolescence and the linear consumption model as problems. They promoted economic and environmental design and engineering as a way to get more done with less [1, 4]. In 1970, Walter Stahel proposed that resources should be managed in a "closed loop". Waste becomes a raw material, which he called the 'cradle-to-cradle' system. He also recognised the need to extend a product’s life through repair and remanufacturing [5].

Papanek, Fuller, and Stahel had concerns with the linear mode early on. (Non-)governmental organizations are trying to catch up by following in their footsteps. The United Nations introduced the Sustainable Development Goals (SDGs), in 2015. The 17 goals aim to end poverty, protect the planet, and ensure peace and prosperity by 2030 [6]. The goal for emissions is to decrease 49% of the carbon footprint, compared to 1990, and in 2050 to be net zero.

The SDGs are long-term goals, but short-term goals are needed to apply sustainability in manufacturing environments [7]. 80% of a product’s environmental impact during its life is determined within the product development stages [8]. Focusing on sustainable development is needed by determining SMART requirements [9]. As a result, measuring sustainability within product development is essential, which can be accomplished through life cycle assessments.

### *1.1. LCA*

Life Cycle Assessment (LCA) quantifies the impact of the product throughout its life cycle. This is within the material, process, transport, use, and disposal of the product [10]. By performing an LCA, it becomes possible to compare the product (parts) in its function unit (FU). The FU compares LCAs according to the function to which the products are set [11]. The LCA framework is visualised in Figure 1. This framework is hard to understand with its unclear starting point and back-and-forth arrows. Nevertheless, this framework forms the basis of LCA programs.

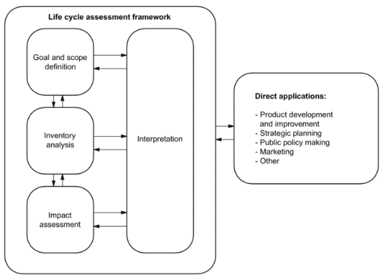


**Figure 1.;** The LCA Framework [10]

LCA programs make the LCA framework tangible for users. The LCA programs differ in accessibility and quality. Programs such as SimaPro and GaBi are extensive but very time-consuming. The user needs to have experience to understand and assess the LCA. EduPack, Solidworks, or Eco-It are easier to use. Less expertise is needed to assess a product [12]. These programs use different measurement methods to obtain the required data per life cycle stage. The methods classify and characterise environmental impacts, such as ReCiPe, Eco-Indicator 99, and CML 2001 [13].

### *1.2. Problem Statement*

There is a gap between achieving the SDGs and taking concrete, short-term steps to achieve the goals for manufacturing companies. Therefore, this research will focus on product development and the decision-making processes. The product is designed by developers, but major decisions are also made by other stakeholders. LCAs can be useful in product development and decision-making. However, the LCA framework must be redesigned, and a suitable tool is required to support the user. As a result, this research answers the question: *"How can sustainability be integrated and applied for decision-making in product development?"*

This research applies the User-Focused Development (UFD) process, which is visualised in Figure 2. The method is established as the UCD, and the Design Thinking was missing the analysis and implementation stages [14-16]. The UFD combines both methods to develop a solution that is user-centred and will be implemented into the manufacturer's product development process.

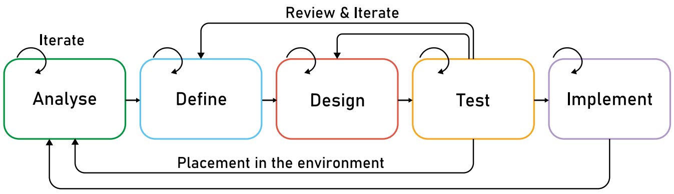


**Figure 2.;** User Focussed Development (UFD)

The structure of this research is based on the UFD process. The research topic is introduced in Section 1. Section 2 *analyses* the environment and *defines* the requirements for the solution. The *designed* solution and user *tests* are covered in Section 3. The solution *is placed in the environment* of the case study to examine its use in Section 4. For the *implementation*, change management is explained in Section 5. The conclusion and recommendations are found in Section 6.

### *1.3. Case Study*

The research employs a case study of an SME company that makes in-house bicycles for special needs. The company is growing fast, and sales have increased, especially because of COVID-19. The company focuses on innovation and quality. Yet, the application of sustainability is not clear. LCAs could be useful, but only if they are simple and of great value to use in decision-making. Nevertheless, many specifications, such as quality, price, time, and availability, are considered in decision-making [17]. Therefore, stakeholders, which include product developers, managers, and the board of directors, must be aware of the impact and value of sustainability. The company requires a solution to know where and how to apply sustainability to identify "low-hanging fruit" and make valuable changes.

## 2. Product Development

An analysis of the market is done to understand and define the meaning of sustainability for SME companies. In the market, manufacturers who used or did not use sustainability are identified. The target group consists of product developers, who are inexperienced with LCAs. They are interviewed to determine their need for support in implementing sustainability within their company.

### *2.1. Analyse the Environment*

Sustainability means, according to the European Union, 'providing a long-term vision for sustainability in which economic growth, social cohesion and environmental protection go hand in hand and are mutually supporting' [18]. However, manufacturing companies identify sustainability as a pain or a gain. Where one company used sustainability to distinguish itself from competitors, others were hesitant and more fearful of the changes. Although customers are willing to pay a premium for sustainable products [19]. The meaning and application of sustainability are hard, as studies have identified a gap in environmental sustainability between LCA programs and the industry [17, 20].

Despite the gap, some companies have adapted and implemented sustainability. Gazelle, for example, collaborated with Pré-Sustainability, the developer of eco-indicator 99, and ReCiPe to analyse the life cycle of their bikes [21]. TREK also performed LCAs of its portfolio of bikes [22]. This shows that LCAs are becoming more widely applied within the market, but only to assess final products.

For this research, two companies were visited, one that is leading in sustainability, Royal Auping, and one that is comparable with the case study, Huka. Royal Auping, a mattress manufacturer has developed 100% circular mattresses [23]. They mentioned that it is important for someone to lead the transition and identify strengths and improvements. At the other company, Huka, the approach to sustainability is not yet specified [24]. Royal Auping has a clear vision with its circular mattresses, and by collaborating with educational institutions and companies, they continue to improve processes. Still, there is no right path to circularity; it is a process of trial and error, just like many other developments.

Sustainability for manufacturers means being resilient for the future by establishing social, economic, and ecological cohesion to overcome hazards. For manufacturers, sustainability can be seen as an opportunity to differentiate itself from competitors while for others it is an unknown area. To apply and assess sustainability, there is a gap due to a lack of LCA programs that support sustainable product development and fit the product development process.

### *2.2. Define Requirements*

The requirements for the development of an LCA method and tool are defined by interviews with the target group. They value support in enhancing the product's sustainability and comparing concepts to determine which concept should be chosen. Furthermore, during this phase, changes are more impactful and easier to implement, and LCAs can be performed because the life cycle stages are already identified.

The most important requirements of the LCA method are stated in Table 1. The method must be understandable and iterative. The method focuses on comparing concepts because it adds value to compare results. In addition, it adheres to the design structure and assists inexperienced users in applying an LCA.

**Table 1.;** Requirements list for the development of an LCA method

| |
|---|
| Applicable for product development to compare concepts |
| The process needs to create added value |
| The redesign is needed for a more sustainable product |
| Meant for concept comparison |
| Good to understand and use for inexperienced users |

To make the LCA method tangible for manufacturers, an LCA tool is required. In Table 2, the main requirements are listed. The tool follows the steps of the LCA method and supports the redesign to reduce the concept's environmental impact. The tool scopes the data to make LCAs easier for the user. Because the users have limited experience with sustainability assessments, the tool must function as a platform for locating sources and defining the company's goals and vision.

**Table 2.;** Requirements list for the development of the tool

| | |
|---|---|
| General | Applicable for product development (focus on engineering) |
| | The tool can be used on a computer |
| | The tool makes use of an input-output structure |
| | The tool adds value to the organisation |
| Use | For inexperienced users, the tool is understandable |
| | The tool guides the user through its functions |
| | Relevant to the current development process |
| | Appealing design |
| | Results are presented to be used for decision-making |
| Tasks | The impact of products and parts can be compared |
| | Support (re)design process to reduce the impact |
| | There is a library where you can get more information |
| | The tool is adaptable to change or add data |
| | References for more explanation are provided in the tool |

## 3. Design Solution

Based on the requirements, the Product Development LCA (PD-LCA) method and the Sustainability Assessment Tool (STAT) were developed. The solutions are elaborated on in the next section, and a user test was done to assess the tool and method.

### *3.1 The Product Development LCA*

The PD-LCA method adapts life cycle assessment to the development process, which is shown in Figure 3. The method follows a circular process and integrates product redesign to help the user reduce the environmental impact of the concept or product. It helps the user structure the assessment and improvement of a product. PD-LCA makes product assessment understandable to inexperienced users of LCA processes.

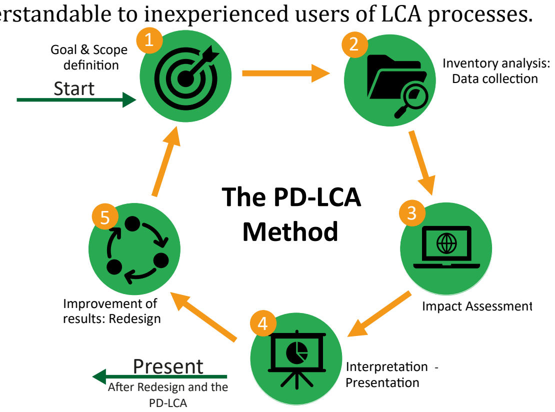


**Figure 3.;** The PD-LCA method

### *3.2. The Sustainability Assessment Tool (STAT)*

The STAT was developed based on the PD-LCA method. The tool closes the gap between LCA tools and the industry of product development by providing a platform that supports the user to apply and assess sustainability. The focus of the tool is within the PD-LCA for the concept phase. However, some general design strategies also help designers think ahead and develop more sustainable products. In Figure 4, the STAT is visualised by its functions of pages.

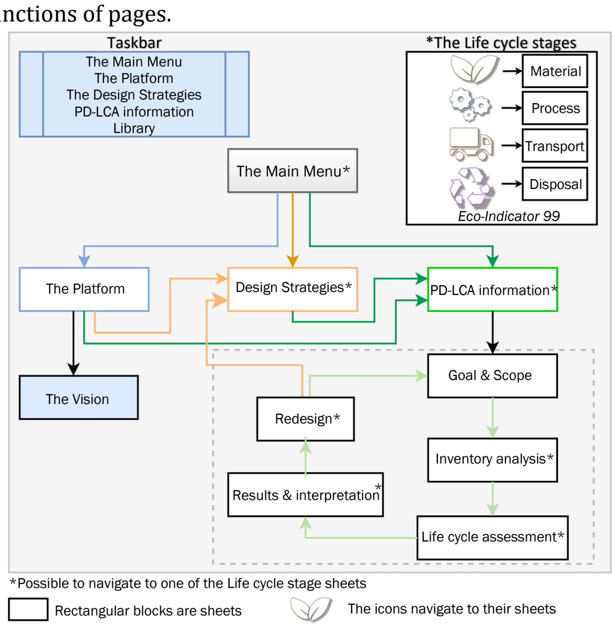


**Figure 4.;** *The STAT's flow of use*

The tool can assess the environmental impact because it extracts data using the eco-indicator 99 as a measurement method. This method is easy to understand for developers and has open access [25]. The disadvantage is that new materials and processes were not updated after 2008. However, the method is effective for this research. The tool is designed in Excel, as its advantage is to perform complicated calculations. Excel constrains the UX design, which could be improved. Nonetheless, Excel is widely used and understood by product developers.

The life cycle stages are visualised in different sheets to demonstrate the data behind the calculation. Within the scope of the STAT, the 'use' phase of the life cycle is implemented. Because the tool is not intended to assess electrical products, there is no impact made during the 'use' phase. However, 'use' is defined as the number of times a product part needs to be replaced in the product's total lifetime, as some elements will more easily deteriorate. To perform an PD-LCA, the user only needs to define the scope and goal, gather the necessary data, and enter it into the impact assessment. The outputs of the assessment are the results and the support for the redesign stage to improve the product's environmental impact.

### *3.3. User test*

To check whether the tool meets the requirements, three use tests are conducted. The tool was well received by the users. They saw great potential for the tool's application. However, they mentioned that it may be difficult to implement in an organisation. The STAT could be improved by using a different program and having it professionally programmed. Eco-indicator 99 did not include all the materials and processes, as was expected**.** The results were also not clear enough for decision-making. A label of impact could indicate how good or bad a concept is in comparison to similar products (parts). This interpretation of the findings is critical to the success of the research in terms of implementing sustainability. As a result, an in-house eco-label must be developed.

## 4. Case Study

Because an LCA is sensitive to data variations, the user must be aware of the important PD-LCA steps. A comparison of two products demonstrates this. The tool is then used to calculate the total impact of one of the bicycles to define the interpretation and presentation for decision-making purposes.

### *4.1 Product Assessment*

The product assessment compares two case study products to determine which one will be chosen. Product 2 is rated higher in terms of several product specifications, including quality, price, availability, and time of delivery of parts and manufacturing. So, using the STAT, the environmental impact can be determined and applied within the context of decision-making.

To assess the products, the PD-LCA steps are followed. First, for an FU, the purpose and scope should be clear. The FU in this case is for a typical 85 kg person to use the product for 10.000 hours under normal conditions. The user must collect the necessary data for the inventory analysis. The data is then entered into the tool for the impact assessment. As shown in Figure 4, the results become visible. Product 2 has nearly three times the impact of Product 1, whereas the material impact is enormous. To reduce Product 2's environmental impact, other materials should be considered. The EoL (end-of-life potential) is very low, around 20%; however, this can be improved to create more circularity in the product's life.

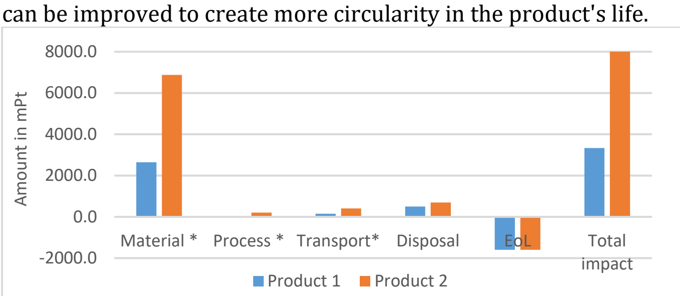


**Figure 4.;** The results of a life cycle impact assessment

The chosen product must still be redesigned to determine whether improvements are possible. When selecting Product 2, larger improvements are required. Product 1 is an option, but it is more expensive and provides less comfort. Furthermore, the results must always be double-checked by another product developer to ensure the accuracy of the inventory and assessment. As a result, the STAT is applicable.

### *4.2 Results: Interpretation and Presentation*

The results of the case studies are only comparable among themselves, making it difficult to set SMART requirements. In addition, the results need to be presented more clearly in context. This can be done by putting the eco-label concept into practice. Furthermore, in this case study, the STAT also evaluated a complete bicycle from the company. The result serves as a model for future products (parts) to understand the impact distribution. As a result, the impact of the bicycle, similar to the energy stop sign label, can be used to create an internal label (A - E label) of the impact of bicycles and product parts [26]. The label is not intended for marketing because it is not a verified label.

## 5. Implementation of the STAT

Changes must be managed during the development process to implement the STAT and the eco-label. To accomplish this, stakeholders must be aware of the urgency of reducing their environmental impact as well as the essence of applying the STAT [27]. The company needs to define clear goals and reasons to change, as people are more willing to participate in the transformation if they understand what will happen [28, 29]. Some people are less motivated to adhere, but it is critical to listen to them and discuss the criticism [30].

### *5.1 The Company's change*

Changes can create uncertainty, but they are needed to sustain as a company [31]. A company must consider organisational elements such as the vision for sustainability and who controls, influences, or engages in this. The long-term vision must be clear to define short-term goals. The circle of influence must then be defined based on people's functions and interests, so everyone understands their role of involvement. All these aspects should be led by someone who is managing the change and defining the implementation strategy.

### *5.2 Case study*

To create awareness and the urgency for change within Van Raam, interviews were conducted, several workshops were given, and meetings were held with all the stakeholders. To raise daily awareness, 'kneuzenplantjes,' are plants saved from disposal, were distributed to stakeholders to serve as a reminder of sustainability [32]. With this awareness, the board of directors also recognises that they must define a clear vision and identify who is in control. To achieve this, the knowledge domain "Sustainability" is established. This domain controls the sustainability changes and now has "ownership" of the STAT.

## 6. Conclusion & Recommendation

The research focuses on answering the question: *"How can sustainability be integrated and applied to decision-making in product development?"* The STAT makes sustainability tangible, accessible, and assessable for product developers, by following the PD-LCA method. The tool allows for the environmental evaluation of concepts and products to reduce environmental impacts through a redesign. By defining SMART requirements, the results can be presented through an internally created eco-label to support short-term sustainable goals. The eco-label provides a clear picture of a concept's or product's sustainability and can thus aid decision-making in product development. Many changes occur during the application of the STAT and the establishment of the in-house eco-label. These must be managed by someone who instils a sense of urgency in the stakeholders.

The STAT can be used in other case studies to determine its utility in future research. As more data becomes available, the measurement method and program could be improved. Nevertheless, the STAT supports all areas of the product development department and manufacturing companies in taking the first step toward integrating sustainability and transitioning toward a circular economy model.

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