# Digital transformation as an opportunity for life cycle assessment

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***Sum up— Life Cycle Assessment (LCA) is a well-known methodology for eco-designing product and services. However, its use is limited by difficulties such as availability of high-quality data, involvement of the whole stakeholders of the lifecycle, or the cost of LCA licence. At the same time digital transformation change the way software implying communities can communicate and share. In this framework and mainly based on literature review, this paper seeks to analyse the potential link between digitalization and life cycle assessment development. The goal is to consider the evolution in industries regarding the uses of digital tools and elaborate bridges with environmental analysis. Thus, three specific areas will be bound together: LCA software, ecodesign process, and digital use in order to formulate assumptions and proposals on LCA software evolution including new digital uses***

***Key words— Digital transformation, Life Cycle Assessment, software, design***

## I. Introduction : LCA interests and limits & digital transformation

Environmental issues are more and more taken into account by industrials, usually thanks to environmental norms and certifications. It even became a competitive factor and some companies focus their business strategy around ecology [1]. This progress can also be helped by the willing from companies to maintain a good image among their associates or their consumers. Among the environmental norms available for industrials, the ISO 14040 regarding Life Cycle Assessment (LCA), is well acknowledge. According to this norm, LCA is defined as “the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle” [2]. LCA is an environmental approach which brings a global vision of environmental impacts of a service or a product from its cradle to its grave [3].

Nevertheless, the incorporation of LCA in companies is most of the time slow and costly [4]. Indeed, it takes a lot of time and energy for LCA experts to gather the data needed in order to produce a complete and reliable analysis of a product (life cycle inventory). LCA software are very complicated to handle and most interfaces haven’t been thinking as user-friendly: an LCA expert is crucial to carry through a LCA. Those inconvenience to LCA software can be reluctant for industrials and maybe even a brake to their competitiveness [1]. Furthermore, LCA is said to not be “an adequate tool for the designer” [5]. This means LCA software doesn’t help the designer to create a product because LCA software usually intervene at the very end of the design process. It can even bring restriction in the innovation capability of a team [5]. For all of these reasons, LCA software has some problems to spread among the industrial fabric.

Another revolution is taking place nowadays: the digital transformation. Digital transformation designates the processes within an organisation of fully integrating digital technologies in the globality of its activities. The phenomenon tends to spread among the industrial world in such a way that is now even defined as *the fourth industrial revolution* [6]. This “revolution” is characterized by the use of digital technologies in all kind of physical product and the extraction of large amount of data. This data is produced in such a big quantity that the term “Big Data” has emerged. Big Data is characterized by its volume, its Variety, and its Velocity [7]. Digital transformation has even changed industrial work by giving to information systems a higher importance: software accompanies employees in their daily tasks [8].

The first part of this document will present some effects of digital transformation on industries and on the action of design. The second part will detail some reasons why LCA struggle with breaking into the industrial fabric and how digital transformation can resolve this issue. The third part will introduce some proposals.

The scientific assumption made is that the transformation of digital experience in LCA software will increase the use of LCA in industrial processes. This paper won’t bring the answer but will open new avenues on what will be the possible next generation of LCA software.

## II. Impacts of digital transformation

This part deals with several effects of digital transformation on industries in general. This list of effects is non-exhaustive. Firstly, the aspects of digital transformation on product design are detailed. Then the phenomenon of Big Data is analysed. Finally, the social aspect of digital transformation is tackled.

The concept of digital transformation has been created in the years 2000 to define the changes linked to the impact of digitalisation and the Internet [9]. Digital transformation conceptualizes the increasing influence of technologies on organizations (companies but also associations or public organizations).

### *A. Impact of digital transformation on products*

Boundaries of a product design are not as fixed as before due to digital technologies. Indeed, it is easier to add functions to a product thanks to digital tools then it was before. An update of the software integrated to a physical engine is enough to totally change the functions of this engine. In addition, a software can remain incomplete [10]: it is possible to add and remove applications to a software and change its capabilities. Product boundaries seem permeable and future boundaries of a product are definitely uncertain.

*Procrastinating binding* [11] is the term used to define the fact that a product can be changed after its actual production. The action of design is then transformed by digital transformation. Digital transformation doesn't only affect "technical services" but also the business models (Matt, 2015). Indeed, companies where more likely to sell products fifty years ago. Now it seems that they sell services to which their customers have to subscribe. The company delivers a service that the customer chose to take or not, without really buying it. This phenomenon can be seen in the bike industry for instance. Some people decide to not buy a bike because they won't stay in a city (Erasmus students for instance) so they prefer to rent a bike for 4 months. The trends of products to be transformed into services is steadily increasing [12].

### *B. Data production*

Nowadays, purely physical materials are often upgraded with software. This provides digital materiality and is one of the main expressions of digital transformation. This phenomenon leaves digital traces in industries which are used as by-product. Indeed, data coming from digital materiality can be very useful to watch over a business, giving values, thresholds and more generally industrial information. This huge quantity of data, also called "Big Data" is gathered by the Internet of Things (IoT). Raw data is gathered and transformed into smart data, which means that this data is carrying knowledge understandable for business professionals.

One consequence to this data deluge is the obligation for industrials to use data visualization in order to better understand their data and extract their meaning. Huge progress in data visualization has thus been made, with many front-end frameworks developed to display real-life data on interfaces. Recently, a lot of JavaScript libraries have taken the leadership in front-end development: React, Vue are two well-know examples.

### *C. Social changes*

Two subsections will be presented here. The first one deals with the change of object use thanks to digital technologies. The second one will explore the change in interaction between people.

Digital technologies can be added into physical materials to transform the way users actually use those physical materials. For example, a watch was originally designed to check the time. But nowadays, a digital watch can receive messages, send them, check notifications, emails and it is linked to our smartphone. This is due to a software that has been implemented inside the watch. Due to the development of those "upgraded" objects, the impact of software has to be taken into account: e.g. the development phase, the servers, and the emission or reception of messages.

Digital technologies allow different users to share the same experience on digital platforms. This phenomenon brings separate users and even separate industries together [13]. It favours collaborative work within teams. A more flexible way to work is also increasing: people can now work from home, or from other places. They are not obliged to stay at their office (mobility of people is increasing). A more agile way of working can take place. In the years 1990, agile software development methods are defined: the main principle is the rolling wave meaning that the project planning is guided by waves. There are no fixed plan and there can be as many waves as it is needed to finish the project. This adaptive project management method is opposed to predictive ones [14].

## III. Has LCA been transformed by digital transformation ?

Regarding what was presented in the previous section, the impacts of digital transformation on LCA will be presented.

### *A. How to define product boundaries ?*

The functional unit is the first element of a life cycle study. Its definition is crucial for the results of the LCA itself. It is a delimitation in terms of quantified reference unit [15]. Indeed, if an electronic product is studied, it will be specified:

- The number of hours the product will be studied while working
- Its electrical power

This unit is the boundary of the whole system that will be analysed. This functional unit specify how long the system will be analysed, for instance "a kettle working during xx minutes with a power of xx" can be a functional unit.

If now we apply the thesis from which the boundaries of products functions are easily malleable nowadays [16], this thesis can disturb the relevance of this functional unit. As an environmental analysis can be expensive for an organization, it could be a problem if the functional unit doesn't correspond anymore to the actual product. On the other hand, having the possibility to change a product after its production can help industrials to improve their products very quickly. LCA software should begin to think about the possibility to change LCA more easily (without the need of an LCA consultant). Some flexibility could be necessary of LCA democratisation.

### *B. Add new data samples*

As we said in the section II.C., the impact of software has to be taken into account in the environmental impact. So it is also important to gather data related to the different impacts of this development. In this way digital transformation can bring a change in the type of data needed by LCA experts to carry on their work. A better performance in the software integrated into a connected object can either reduce or expand its life expectancy. This issue concerns in particular green IT experts.

A software layer can be thus a lever for action to reduce the environmental impact of telecommunication [17].

### C. *Social transformation*

Ecology is usually seen as a collaborative discipline. Even more than collaborative, ecology is transdisciplinary. Thus, data coming from different domains of expertise are needed. In this way ecological domains will have the opportunity to access a large quantity of data from very different areas (e.g. sociology, engineering, healthcare).

Also, one of the reasons why reliable data is difficult to find for LCA experts is that the information among an organisation is hard to find. As we said, ecology is transdisciplinary. It means that several branches of one company can be impacted with a single LCA. So information about how a product is created can be "lost" among this organisation or at least very hard to find if information isn't transmitted well from one service to another (or if some persons keep the information). Principles of transparency and traceability are real assets for LCA experts (in foods for example, traceability is usually mandatory).

## IV. Proposals and discussions

### A. *Combine LCA with industrial software ?*

As is it suggested by Chen et al, 2017, LCA could be associated with Computed-Aided Design (CAD) software [18]. Thus, LCA would be linked to the value chain of the company: some data entered into the CAD software would be reused into LCA thanks to an API. Or LCA could be a plug-in added to a CAD software. Data would thus be visualized directly through the CAD software:

- The amounts of materials used for the product designed would be more easily found because they will be directly integrated into the model designed. The environmental impact calculation would intervene at the beginning of the design process;
- The visualization of the product itself could be interesting so LCA experts could easier see if some data is missing: the drawing of the product could change its colors if the data corresponding has been entered into the LCA analysis.

This proposal triggers some issues like the capacity for LCA and CAD software to exchange data or the ability of design experts to choose correct environmental data. If different experts have to share the same interface, both study area will have to be taken into account in user experience design.

One other limitation is the possibility to design only concrete objects (no immaterial things). Services couldn't be taken into account in this option.

### B. *Bringing modularity in LCA softwares*

Some LCA software is presented below. There are divided into three categories [19] :

- Closed source commercial: Gabi, SimaPro, Umberto, Aveny
- Closed source freeware: CMLCA
- Open source freeware: OpenLCA

Thanks to this list, it becomes obvious that most of the LCA software is commercial. Only one open source LCA software currently exists among LCA tools: OpenLCA. All LCA software, no matter to which categories they belong to, are seen as too inflexible in their processes [19]. This could be explained by the lack of open source software competitivity. The development of a new kind LCA software can be very difficult and costly. Indeed, a very large number of processes are running in the background of each LCA software. Moreover, some of them are on the marketplace for more than 10 years (like SimaPro). Even if OpenLCA is open-source and free of use, it is very complicated to understand how it works and a costly formation session should be followed to learn how to use the software.

A software can be very difficult to develop: processes have to be defined, technologies have to be chosen, a programmer have to develop and test the whole system… A modular software can be thus a solution to avoid cognitive overloading and calculations issues. Such a software could be developed as independent bricks. Designing a scalable LCA software could help small and medium sized companies (SME) to adapt to environmental norms, especially companies who don't have the financial capital for an LCA expertise.

Some questions remain unsolved. For example: How modular an LCA software should be developed? Can a LCA software be compatible with Industrial Ecology (IE) or Material Flow Analysis (MFA) tools? Those issues would be tackled in following researches.

### C. *Validation d'une ACV*

La validation d'une ACV est l'assurance que le modèle épouse le système réel identifié. Actuellement la phase de validation est plus perçue comme une phase « en plus » d'un outil déjà bien rôdé. Cependant, l'ACV manque cruellement de validation empirique. Peut-être que la transformation numérique permettrait le développement de techniques capables de confirmer ou infirmer des résultats de modèles d'ACV sur la réalité. Cela permettrait de davantage lier l'ACV dans des expériences concrètes.

## V. Conclusion

To conclude, LCA experts should take advantage of the digital transformation to spread their expertise among the industrial fabrics. The norms and laws are forcing companies to act but solutions proposed by LCA experts have to live up to industrial needs. There is no doubt that LCA software has to evolve to match the industry of the future expectations. A modular, flexible and transparent software could help industrials to integrate LCA in their processes.

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