

Communication

Prospects and Challenges for Disseminating Life Cycle Thinking towards Environmental Conscious Behaviors in Daily Lives

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Abstract: We examined the existing practices of various media to ascertain the usability of information based on life cycle thinking (LCT) which can be key to changing consciousness and behavior of consumers towards pursuing a sustainable society. Such information has been provided to consumers in various forms in various places at various times. Nevertheless, a number of issues, such as understandability, selectability, reliability, transparency, and costs *etc.*, must still be addressed before consumers will be able to use such information as guidelines for pro-environmental behaviors in their everyday life. Further, it is also of critical importance that the consumers can culture LCT by encouraging themselves to be actively engaged in the design and evaluation processes of the upstream of productions and in the entire product life cycle. Another crucial challenge is finding ways to connect LCT with, not just product selection or designing and manufacturing, but lifestyle transformation. We need to encourage ourselves and others to think about what a sustainable life really means.

Keywords: life cycle thinking; environmental conscious behavior; consumer; visualization; personal fabrication

1. Introduction

Consumers can play a crucial role in achieving a sustainable society, and changes in their consciousness and behavior are essential. Towards that end, various initiatives, including green-consumerism, green purchasing, and environmental education, have been ongoing. These initiatives increased the provision of information on the environment and contributed to the enhancement of consumer knowledge and consciousness. For example, carbon footprint measurements have been recently utilized to visualize environmental burdens [1]. Private initiatives visualize environmental impacts of whole supply chains, from manufacturers to consumers. Indeed, it is being discussed at the United Nations environment programme (UNEP) how life cycle thinking can be used to change the behaviors of the governments, private sectors and consumers. The relevant initiative is called “Life Cycle Initiatives” [2,3].

While these cases are important in disseminating life cycle concepts and knowledge among general consumers, potential major challenges still exist. First, knowledge and consciousness alone tend not to lead to behavioral changes, but various factors, including tangible effects or economic incentives, shall also be associated with the changes [4,5]. While knowledge about LCA/LCT and research networks have grown [6,7], the influence and recognition of life cycle assessment (LCA) and life cycle thinking (LCT) is insufficient to facilitate environmentally conscious consumer behavior, in part because of the movement’s inability to disclose its know-how and collected data to the public in an effective manner. Furthermore, the credibility and availability of data necessary for calculation of LCA impact differs substantially across regions and cases. These elements hinder the usability and applicability of LCA and its concepts.

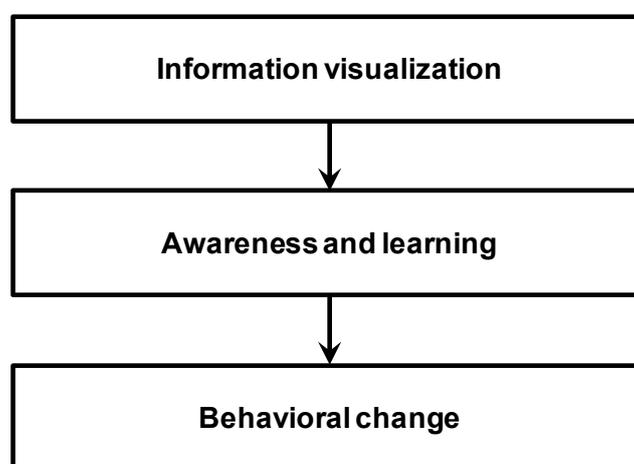
In the meantime, factors that affect environmental conscious behavior have been studied in various fields of literature such as marketing and environmental engineering. One factor is referred to as perceived effectiveness; people make environmentally conscious actions when they know such an action actually reduces environmental burdens [8–11]. Some studies provide evidence that people who have more social responsibility tend to engage in environmentally conscious behavior [12–16]. Hondo *et al.* [17,18] argue that much effort has been made for raising awareness and knowledge whereas educational initiatives addressing change in attitude, skills and participation is insufficient. However, few studies have explored how we effectively foster environmentally conscious behavior.

These observations indicate that issues exist in different stages and occasions in the process within which information is created, transformed, and perceived by people. Specifically, this study first overviews and analyzes initiatives related to LCA and identifies the challenges and research needs, aiming to facilitate and encourage use of LCA/LCT in the consumers’ daily activities as a guideline for pursuing sustainability. Specifically, we identified technical and system issues in the establishment of visualization systems and tools, and pursued the standardization of an LCA database. We looked into existing practices of various media, including web applications, and relevant papers and documents, to examine the transparency, usability and accessibility of LCA related databases, and identified research agendas to foster disseminating LCT towards promoting environmentally conscious behaviors.

2. Review

This section reviews initiatives and practices related to LCT. To derive meaningful implications from the review, we define the process of behavioral change by three stages; (1) information visualization; (2) awareness and learning; and (3) behavioral change (Figure 1). We argue that the definition is one of the ways for theorizing behavioral changes, while there are some frameworks about how to discuss the process of behavioral change [19–23]. In the real world, LCA/LCT-based information is first created in various forms and conveyed consumers through different media. The type of information and visualization affect the extent to which consumers receive information. We have to notice that these two stages further influence consumers' behavior.

Figure 1. Process of behavioral change: how information leads to environmentally conscious behavior.



Following this process as a framework for analysis, we searched for various initiatives and practices through different information sources in order to discuss the current status and challenges regarding LCT and ended up selecting more than 30 initiatives that shall be the most relevant references to fulfill the purpose. These initiatives are taking various media including the Internet (Web), labeling, data book, TV, magazine, animation and video. Table 1 reports the medium and contents summary of selected initiatives. We categorized them into three types based on which stage in the entire process of behavioral change in consumers they address. The first type of approach or method can be thought of as a first stage toward behavioral change, focusing on visualization of information. The second type more directly addresses learning in order to enhance consumers' consciousness. The third type of initiative focuses more on the change in consumers' behavior, many of which address the role of information design and evaluation of the information. The rest of this section introduces and explains specific examples of them in greater detail.

Table 1. Reviewed initiatives and practices of Life Cycle Thinking.

| Category | Title | Media | Country | Inaugural year | References |
|--|---|----------------------------------|-------------------|-----------------------|-------------------|
| Information visualization | PAS 2050 | Label | U.K. | 2007 | [24,25] |
| | EcoLeaf Environmental Label | Label, Web | Japan | 2002 | [26] |
| | Carbon Footprint of Product (CFP) Program | Label, Web | Japan | 2012 | [27] |
| | Environmental Profit & Loss Account (E P&L) (e.g., PUMA and PPR HOME) | Statement | Global | 2011 | [28] |
| | The Footprint Chronicles, by Patagonia | Web | Global (U.S.) | 2007 | [29] |
| | Sourcemap | Web | Global (U.S.) | 2009 | [30] |
| | World Resource Flows around Japan: Third Edition, by NIES | Databook | Japan | 2006 | [31] |
| | Material and Carbon Flow of Harvested Wood in Japan, by NIES | Databook | Japan | 2004 | [32] |
| | How It's Made, Science Channel | TV Program, Web | Canada and US | 2001 | [33] |
| | Films for “TEMA HIMA: the Art of Living in Tohoku”, 21_21 DESIGN SIGHT Exhibition | Movie (Onsite) | Japan | 2012 | [34] |
| | Videotheque database, National Museum of Ethnology, Japan | Videotheque (Onsite) | Japan | 1977 | [35] |
| | Awareness and learning | Global warming even in you bag?! | Education Program | Japan | 2008 |
| TELEVI-KUN NO ISSHO, by Panasonic | | Picture Book, Education Program | Japan | 2004 | [36] |
| The Travels of a T-Shirt in the Global Economy | | Book | U.S. | 2005 | [37] |
| The Story of Stuff Project, by Anne Leonard | | Animated Film, Web | Global (U.S.) | 2007 | [38] |

Table 1. Cont.

| Category | Title | Media | Country | Inaugural year | References |
|-------------------|---|----------------------|----------------------|----------------|------------|
| Behavioral change | The Toaster Project, by Thomas Thwaites | Book | U.K. | 2011 | [39] |
| | Instructables | Web | Global (U.S.) | 2005 | [40] |
| | Cookpad | Web, iPhone/iPad App | Japan | 1998 | [41] |
| | ifixit | Web | Global (U.S.) | 2003 | [42] |
| | Solidworks Sustainability | Software | Global (U.S.) | 2010 | [43] |
| | GaBi Software | Software | Global (Germany) | 1993 | [44] |
| | SimaPro | Software | Global (Netherlands) | 1990 | [45] |
| | MiLCA | Software | Global (Japan) | 2010 | [46] |
| | JEMAI-LCA | Software | Japan | 2000 | [47] |
| | Sustainable Minds | Software | Global (U.S.) | 2008 | [48] |
| | Greenfly | Software | Global (Australia) | 2003 | [49] |
| | NO IMPACT MAN Project | Movie | U.S. | 2009 | [50] |
| | CFPMAN Project | Live streaming | Japan | 2012 | [51] |

Note: The countries in the parenthesis indicate the places (countries) where the operating companies are located.

2.1. Information Visualization

According to the ISO 14040 [52], LCA is a tool to assess the potential environmental impacts and resources used throughout a product's life-cycle. The unique feature of LCA is the focus on products in a life-cycle perspective. LCA is carried out in four distinct phases: goal and scope definition, inventory analysis, impact assessment, and interpretation. It is of critical importance to understand the whole picture of life cycle processes and their relationships particularly for cultivating life-cycle perspectives of products and services.

LCA/LCT-based data actually combines the whole picture of life cycle processes and individual components (processes), and visualization of LCA/LCT-based data shall help consumers' understanding. There are four major forms of such information: quantitative numerical value (information expressed in numbers), life cycle flow chart (information showing steps and processes), supply chain map (information displayed on maps), and documentary and narrative form (information telling scenes and stories).

2.1.1. Quantitative Numerical Value

Information is disclosed as numerical data, such as the environmental burden of a product throughout its life cycle (e.g., Environmental Product Declarations (EPDs) Type III Labels to ISO14025: Ecoleaf Environmental Label (Japan) [26], and Carbon Footprint of Products (CFP)

Program (Japan) [27]), the food miles calculated by multiplying the weight of a food product with the distance for transporting the food from the production site to the dining table at the consumer's location, and the monetary value of the environmental burden throughout a product supply chain called the Environmental Profit & Loss Account (E P&L) [28], or as charts and graphs representing breakdowns by life cycle stage. To make it possible to compare different products on equal footing, CFP programs in and out of Japan stipulate calculation rules called Product Category Rules (PCRs), set forth per product category [53], to define the subjects to be evaluated and the boundaries between subjects. Another example is the Ecodesign Strategies Wheel, a cobweb chart created for use in design software [43]. This representation shows a distinct difference in performance between new and existing products at each life cycle stage.

2.1.2. Life Cycle Flow Chart

A life cycle flow chart illustrates all the life cycle stages of a product (goods and services), from raw material acquisition to manufacturing, transportation and distribution, use, maintenance, reuse, recycling, and disposal [27]. Manufacturers use detailed flow charts to ascertain the positioning of different life cycle stages and the input and output quantities at each stage, prior to organizing LCA inventory data. These charts are developed into more abstract diagrammatic illustrations and schematic diagrams by removing and modifying certain information to allow general consumers to understand the processes at a glance. In the primary sectors, the flow is described by a rough annual work schedule that ties life cycle stages with seasons.

2.1.3. Supply Chain Map

In this method, the entire supply chain flow of a product and estimated results of material flow analysis (MFA) are mapped on a supply chain map. The map then allows consumers to visually learn where the product comes from and where it goes to by showing each life cycle stage of the product in context of geographical information (e.g., "Footprint Chronicles" by Patagonia [29], an outdoor clothing company in the United States, and "Sourcemap" operated by the MIT Media Lab, a crowd-sourced directory of product supply chains and carbon footprints [30]). The flow rates of materials and carbon derived by MFA are indicated with different widths of the lines connecting from stage to stage. Consumers may track down chronological changes using these data (e.g., Material Flow Data Book by NIES, Japan [31,32]).

2.1.4. Documentary and Narrative Form

In this method, a stage of the life cycle or supply chain of a product is explained in a photo article (e.g., "Footprint Chronicles" [29]) or in a documentary film that covers the production and distribution stages of a product (up to completion and delivery of the product) (e.g., "How It's Made" videos [33], documentary films created for the "TEMA HIMA: the Art of Living in Tohoku" exhibition [34], and the videotheque database by the National Museum of Ethnology, Japan [35]).

2.2. Awareness and Learning

The provision of the abovementioned information may take place in the purchase decision-making process, the data information gathering (purchase planning) process, exhibitions, and/or during observational tours, environmental education programs, and so forth.

In the purchase decision-making process, a highly-visible environmental label on a product or menu provides symbolic information, such as a single number showing the carbon footprint (or something similar), is inserted into the consumer's consciousness at a retailer, based on the expectation that it will influence the decision-making process and promote environmentally conscious behavior [26,27].

During the process of gathering information through catalogs, magazines, websites and other means, more than one form of information provision can be adopted because more space is available for including information than on the surface of a product itself. Additionally, on websites, various attempts are being made to deepen consumer understanding by adding dynamic representations, such as animations and videos, and by accommodating comments from viewers from time to time [29,30].

At exhibitions and site tours, manufacturers provide opportunities for consumers to obtain experiential information by touching the actual components and materials of a product, or by examining the production and dismantling lines for a product, and also by communicating directly with staff of the manufacturing company.

Schools and corporations are encouraged to develop environmental education programs and implement examinations based on LCA/LCT in their curricula or internal training courses. Educators and trainers strive, through trial and error, to ensure their programs raise awareness of the current situation at each stage of a life cycle, which is basically difficult to fully comprehend, through various experiences. These include, for example, adopting active learning programs such as those that prompt the learners to perform simplified environmental impact calculations by themselves (Hondo [17], Aoe [36]).

Other than these, a book called "The Travels of a T-Shirt in the Global Economy" [37] and a short film titled "The Story of Stuff Project" [38] are available for use as educational materials. Both highlight issues faced by today's global capitalist economy, including global environmental issues, throughout the entire life cycle of a product. Whereas the book focuses on a particular product and reports on it documentarily from multiple perspectives, the film adopts a hand drawn animation technique to provide a humorous setting. In both cases, they provide an opportunity for consumers to learn through vicarious experience. Incidentally, there are an increasing number of Webinars for similar purposes in recent days.

2.3. Behavioral Change

2.3.1. Personal Fabrication and Information Support

While there is a trend toward developing environmental information based on LCA/LCT, as was described in the introduction, increasing numbers of consumers are becoming prosumers who do not just make decision on purchase, use and disposal of products, but also produce and consume necessary quantities of goods and services based on their needs [54]. This movement is called Personal Fabrication [55].

Against this backdrop, one might consider culturing LCT by encouraging themselves actively engaged in the design and evaluation processes of the upstream of productions and in the entire product life cycle. One good example is “How I built a Toaster,” the Toaster Project by Thomas Thwaites [39], a story of a designer who produced a toaster from scratch. Here, Thwaites manufactured the end product (toaster) by starting with ore mining and plastics refining. Perhaps we are now expected to hammer out the concept of information suitable for reference by individuals in their activities in order to produce a necessary quantity of products, instead of mass production by corporate operations. For instance, in recent years, a sizable number of open source communities have emerged.

Such communities support the consumer’s active involvement in the processes of each stage, such as production methods at the production stage (e.g., the “how to” and DIY community site “Instructables” [40], and the community recipe site “Cookpad” (Japan) [41]) and repair procedures relevant to the use stage (the free repair manual “ifixit” [42]). Besides the LCA software [44,45] (or [46,47] for Japan) traditionally used by LCA engineers in corporations, universities and research institutions, tools for on-line analysis [48,49] have been developed and analysis tools for helping practice LCA, such as Solidworks [43], has been implemented as add-ins in design software. In this way, the base of LCA practitioners is expanding.

2.3.2. Lifestyle Change

Another crucial challenge is finding ways to connect LCT with, not just product selection or designing and manufacturing, but lifestyle transformation. Even if the environmental burden per unit product is reduced, if more units of the product are consumed, the total environmental burden may actually increase. In this regard, individual consumers are expected to carefully examine and choose what is really necessary in their everyday life.

A number of good, though small-scale, examples of lifestyle change initiatives include the “NO IMPACT MAN” Project [50], which encouraged families in New York City to try to live without placing any pressure on the environment for a full year. Similarly, in the “CFPMAN” Project [51], which took place in Tokyo, Japan, participants were allowed to use CFP-certified products only for one week. There have been other similar experimental entertainment events as well. In this manner, through these life-sized practices, we encourage ourselves and others to think about what a sustainable life really means. Further consideration, particularly on the above-described challenges, is vital for making LCA/LCT used by the general public as guidelines in their livelihood in the future.

3. Prospects and Challenges

As discussed above, LCA/LCT-based information has been provided to consumers in various forms in various places at various times. Nevertheless, a number of issues must still be addressed before seeing consumers will be able to use such information as guidelines for pro-environmental behaviors in their everyday life. The following shows some critical issues that should be addressed.

3.1. Understandability and Selectability

The first step is to assure understandability and resultant selectability of information for consumers as in the literature (Taylor [11]; Berger [56]). For instance, carbon footprints provide information in terms of absolute value of CO₂ equivalent emissions all through the life cycle of a product (per sales unit). Such a value will not be helpful in a consumer's purchase behavior unless he or she has an understanding of emissions values similar to a sense of monetary values. To make it possible for consumers to compare products on equal footing, the information needs to be further processed from the standpoint of consumers, so that they can utilize the information more easily. This can be accomplished by, for example, increasing the number of products that fall under the same PCRs, thus simplifying unit conversions (by giving more consideration to the value per unit volume of use—not just sales unit), and clarifying the relationship between the emissions and monetary values. There is also growing concern that the mix of various environmental labels in use today may cause confusion. Some argue that the information should be consolidated with existing environmental labels and that current efforts should shift emphasis to finding ways to achieve consumer-friendly communication [57].

The life cycle flow chart and supply chain map are also expected to secure transparency, and should thus be organized in visually simple ways so that consumers can accurately ascertain the circumstances of a product and consider their own lifestyles from environmental viewpoints. It is also expected that consumers will be able to make proposals for the selection of an alternative process at every stage of the life cycle, suggest possible improvements in the supply chain, and choose from multiple options.

3.2. Reliability, Transparency, and Costs

An expansion and further promotion of visualization of LCA/LCT-based information requires solving the issues of information reliability, transparency and costs (incurred for field surveys, information gathering, estimation of environmental burdens, and production of illustrations, photos video footages, and so forth). With respect to reliability assurance, among the subjects we examined in this study, we found information verified and certified by third parties, derived by simple calculations according to the information providers' own methods, provided via open source web applications where the posting individuals are responsible for the information they posted, and in other sources. The former is more reliable yet simultaneously more costly and labor consuming. The latter is less reliable and less expensive, which is therefore expected to contribute to large-scale dissemination (enhanced scalability) through collective knowledge. In any case, the information provider is called on to enhance transparency of the information and, in turn, reliability of the information, by disclosing the grounds and calculation processes so that third parties can verify it.

In terms of costs, sharing know-how on information visualization is called for. For example, the Type I environmental label system reduces costs by sharing information on the Global Ecolabeling Network (GEN) [58] for mutual certification among participating institutions, thereby curtailing reviews by third parties. Efforts of this kind need to be referred to in other cases of information visualization.

4. Concluding Remarks

We examined the existing practices of various media to ascertain the usability of information based on LCT which can be one of the keys for changing consciousness and behavior of consumers towards pursuing a sustainable society. Such information has been provided to consumers in various forms in various places at various times. Our review showed a number of issues, such as understandability, selectability, reliability, transparency, and costs etc., must still be addressed before seeing consumers will be able to use such information as guidelines for pro-environmental behaviors in their everyday life. Most practices and initiative currently taking place have only had a short history and lack thorough evaluation. Therefore, it is necessary to accumulate empirical studies that investigate to what extent each of the revealed issues is critical for achieving environmental conscious behavior and delve into similarities and differences among the practices. Finally, it is of critical importance that the consumers increasingly culture LCT by encouraging themselves actively engaged in the design and evaluation processes of the upstream of productions and in the entire product life cycle. A crucial challenge is perhaps finding ways to connect LCT with, not just product selection or designing and manufacturing, but lifestyle transformation. Of course, we need to encourage ourselves and others to think about what a sustainable life really means.

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