Application of life cycle assessment in service industries: a review

Sabrina Rodrigues Sousa[1,2],*, Aldo Roberto Ometto[1]

[1]University of São Paulo, School Engineering of São Carlos, São Carlos, Brazil

[2]Ministry of Science and Technology, Center for Information Technology Renato Archer (CTI), Campinas, Brazil

*sabrinarsousa@gmail.com

Abstract The introduction of services in the economy adds value in an intangible way while promotes dematerialization. As products, services are developed to fulfill customers' needs, being representative also in economic and social concerns. But, despite of their non-physical attributes, they may also give rise to, direct and indirect, environmental impacts. The intangibility of services added with the fact that, in most cases, the environmental loads of service companies are not produced at the site of activity, difficults the assessment of environmental contribution of this sector. Thus, this paper aims to understand how services are being studied using Life Cycle Assessment (LCA), to present an overview of the case studies obtained during the literature review and to start a discussion about the methodological issues which difficult the application of LCA methodology in this sector.

1 Introduction

A sustainable society in the future should use only about 10 percent of the resources that industrialized societies are using today (per capita) [1]. In many situations, most of resources end up as waste even before being processed into products. This scenario exposes the need of a reformulation to move from the prevailing economic system of manufacturing goods and inducing customers to buy them based on dematerialized consumption patterns towards a sustainable society.

Approaches focused on cleaning and remediation, as treatments accomplished at the end of industrial processes ('end-of-pipe'), have become insufficient, requiring their integration with pollution prevention strategies, giving them a broader perspective, as proposed by industrial ecology [2]. Industrial ecology systematically analyzes the interactions between human activities and the environment, seeking to optimize the overall cycle of industrial materials [3], by means of dematerializing the economy and creating eco-parks.

Aligned with the principles of industrial ecology, the United Nations Environment Programme - UNEP [1] highlights three strategies to sustainable development, namely: (i) dematerialization, which addresses the need and functionality rather than the product alone, tracking throughput of materials and energy in industrial and consumption processes, and increasing the resource productivity; (ii) life cycle management, which integrates existing tools and concepts to support the decision making processes about sustainable goods and services in a structure that encompasses all stages of the life cycle and communicates relevant information to stakeholders, and; (iii) product-service systems, which consists in the development of a marketable mix of goods and services that are jointly capable of fulfilling a client's need, with less environmental impact.

Currently, the service sector encloses one third of all the world trade and it is the biggest sector of economic growth. Due to the definition of service, added to the great profitable probability that the companies recorded in their contracts, it offers about 11 million jobs, corresponding to 16% of the total of workers from the private sector: one from each three jobs offered in the last decade was in outsourcing companies [4]. Services production and sales represent the major part of the economy in most industrialised countries (about 75% of the gross domestic product – GDP in the US and about 50% of the GDP in Europe) [5]. In Brazil, this scenario is not different: the service sector is responsible for more than 68% of national GDP, which corresponds to R$ 680 billion of net operating revenue [6].

The introduction of services in the economy adds value in an intangible way while promotes dematerialization. As products, services are developed to fulfill customers' needs and, as shown above, they have a great potential for economic and social contributions. But, despite of their non-physical attributes, which give us an idea of a clean industry, the service sector may also give rise to direct and indirect environmental impacts. These impacts are not easily identified because, in most cases, the environmental loads of service companies are not produced at the actual site of activity (indirect impacts).

Thus, considering: (1) the need of more dematerialized production and consumption patterns, (2) the potential of dematerialization promoted by a service associated with its significant contributions to economic and social spheres, and finally, (3) the lack of clarity concerning the environmental performance of service industries, this paper aims to understand how services are being studied using Life Cycle Assessment (LCA), to present an overview of the case studies obtained during the literature review and to start a discussion about the methodological issues which difficult the application of LCA methodology in this sector.

2 Methodology

Two literature reviews were carried out in order to achieve the main goal of this paper. A broader review was conducted looking for explanations about environmental implication of services, often presented as positive, i.e. that does not cause adverse impacts. The other one was focused on the determination of the state of the art in environmental assessment of services using LCA methodology. The International Journal of Life Cycle Assessment was the unique source considered in the second literature review because it is devoted entirely to Life Cycle Assessment, comprising papers on LCA methodology, social and political acceptance, governmental activities and examples from industrial applications, and also historical sketches, short version of actual LCAs and case studies.

The search for 'service' within this journal returned almost 600 papers. They were filtered considering their title, keywords, abstract and year of publication (between 2000 and 2011). Each paper should submit an application of LCA in service industries as case studies to be included or bring methodological considerations and contributions. As a result of this literature review, 22 papers were selected, classified into eight groups (service sectors), analyzed and summarized in table 2 (section 4 of this paper).

3 Services and their environmental impacts

Given the amount and complexity of services it is helpful to describe what services are not and some general key features summarize what is unique about services [9]. Services are not tangible, are not separable from consumption, cannot be stored or owned, are complex experiences and quality is difficult to measure [10]. Backmann [11] pointed out the differences between services and products, as shown in Table 1. Softwares are exceptions for this rule - they constitute products but do not have physical (material) characters [5].

Tab.1: Differences between a product and a service

PRODUCT	SERVICE
Produced	Performed
Material	Immaterial
Tangible	Intangible
Can be stored	Cannot be stored
Usually without client	Interaction with client

Consumption after production	Consumption=production
Defects in manufacturing	Mistakes in behaviour

However, in practice, the provision of services involves a number of tangible and intangible elements, while the supply of products relies on the culmination of a long chain of services [12], and so, it is not simple to separate services from products and vice versa.

Service industries are responsible for a notable share of the environmental impact in our society [13,14]. It is estimated that service operations have almost the same energy use and global warming potential as the manufacturing sector [13].

Besides the dematerialization potential for positive environmental impact, promoted by replacing goods with services, service industries have tended to be ignored for environmental policy due to the relatively low emissions released at the point of generation, i.e. the loadings generally are not caused directly by the processes of the actual organization but occur in other parts of the supply chain instead [15,16]. In this context, it is especially important for companies to consider the environmental implications of their processes linked with those performed by suppliers and representatives, along the whole life cycle.

According to Rosenblum, Horvath and Hendrickson [13], the service sector can influence the environmental performance of all stages of the life cycle of a system, as described below:

Influencing suppliers to provide more environmentally conscious products and services;

Reducing resource inputs in their operations, for instance through energy efficiency programs and cutting business travel;

Educating consumers about the relative merits of different products (particularly in the retail sales sector);

Reducing resource use on the part of consumers by substituting more environmentally beneficial services or activities (like substituting teleconferencing services for business travel).

As service is one of the most important industries in the world economy, an accurate identification and assessment of the environmental impacts related to the life cycle of its deliverables to the environment is increasingly necessary, especially to ensure that improvements actions are taken.

4 Life cycle assessment of services

Life Cycle Assessment (LCA) is a globally recognized technique that provides support to decision making, developed to assess the environmental profile of product (good) and service systems considering its life cycle.

Established by ISO standards [7,8], LCA has been proposed as a means to include environmental impact more comprehensively in determining the environmental significance of the activities of an organization [17], but only a few researchers have used it to study service sector companies [18].

The indirect impacts of services have traditionally been rather difficult to assess or to recognize and methodological difficulties may arise during the execution of the study [17,19]. Some of the major hindrances of LCA application in service industries are the definition of systems boundaries and the choice of functional unit.

According to Brezet et al. [20], the life cycle of a service is very different due to the intangibility, and so, the limitations of what belongs to the service system are not always as clear as for products. An important difference in the definition of system boundaries is the inclusion of personnel and infrastructure to the analysis. Infrastructure determines a great part of the product share in service systems and personnel, that alone do not cause hard environmental impact, often determine a significant part of the added value. Also, the use of certain capital goods like computers are part of the analysis, while they are often regarded as negligible when physical products are analyzed.

The choice of functional unit strongly influences the outcome of the study and, as services often lack a well-defined unit of production, it is difficult to assess their relative performance over time or between companies [13]. Instead of a certain quantity of product, the functional unit should refer to an abstract function, like being clothed or having mobility, to a period of time [21], and consider the consumer behaviour.

Some authors, as Brezet et al. [20] and Aurich, Fuchs and DeVries [22] highlight the need of specific methods developed for LCA of services and state that these methods could be based on the same LCA techniques that are used with products. In this sense, the META matrix was presented by [20] as a first concept of a LCA method for non physical product components. This matrix stands for Materials, Energy and Toxic substances. On the vertical axis of the matrix, the phases of the product life cycle are reflected.

Despite all the difficulties and discussion, many studies concerning LCA of service industry can be found in the literature, as shown in table 2. They refer to eight different service sectors, namely: building and infrastructure, energy, food, telecommunication and media, tourism, transport and mobility, waste management and laboratory.

Tab.2: Case studies of LCA application to service industries

Service Sector	Author(s)
Building / infrastructure	Blengini and Di Carlo [23]
	Elghali et al. [24]
	Kofoworola and Gheewala [25]
	Oliver-Solà et al. [26]
	Paulsen [27]
Energy	Frischknecht and Stucki [28]
	Solli et al. [29]
Food	Baldwin, Wilberforce and Kapur [30]
	Jungbluth, Tietje and Scholz [31]
Telecommunication / media	Emmenegger et al. [32]
	Graedel and Saxton [33]
	Hischier and Reichart [34]
	Scharnhorst [35]
Tourism	De Camillis, Raggi and Petti [36]
Transport / mobility	Rozycki, Koeser and Schwarz [37]
	Spielmann and Scholz [38]
Waste management	Cleary [39]
	Del Borghi et al. [40]
	Del Borghi et al. [41]
	Liamsanguan and Gheewala [42]
Laboratory	Rynja and Moy [43]

5 Discussion and Final remarks

Service industries are very significant for the current economy and society, especially in industrialized countries. They permit the value creation in an intangible way at the same time that promote dematerialization, a necessary strategy for more sustainable production and consumption patterns.

However, there is a need for adequate assessment of environmental aspects and potential impacts of services, since they also contribute to environmental burdens, often difficult to identify because they are indirect.

Life Cycle Assessment (LCA) is a technique developed to study the environmental burdens associated with different stages of a good or service system. But, as shown in this paper, it is not so simple to use it for services.

A panel of experts or a survey should be conducted in future works to discuss other complicating aspects of LCA methodology for services than those already known as the definition of system boundaries, scope and functional unit. Databases development is of great value to facilitate and promote LCA performance, especially for decision-making purposes.

Extreme improvements towards sustainable systems can be explored by the incorporation of more services in the economy, and, in this sense, broadening the application of LCA to Product-Service Systems (PSS) is a tendency to be researched.

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