(INstruments and NEtworks for developing logistics towards Sustainable Territorial Objectives)

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Life Cycle Analysis and the logistics issues

"A contribution to District Logistics Analysis"

Contents

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1. Introduction

Life Cycle Assessment is an important methodology for the evaluation of material and energy fluxes and their impact on the environment. In most cases Life Cycle Assessment has been utilised on industrial processes to determine the environmental impacts of the life cycle of a specific product, including an analysis of each stage of the product manufacture, transport, utilisation and disposal. As the Life Cycle Assessment approach is aimed at improving the ecological efficiency of a process or product, it has a wide range of potential uses.

LCA definition according to SETAC is "Life Cycle Assessment is a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and materials used and releases to the environment; and to identify and evaluate opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing, extracting and processing raw materials; manufacturing, transportation and distribution; use, re-use, maintenance; recycling, and final disposal".
(Guidelines for Life-Cycle Assessment: A 'Code of Practice', SETAC, Brussels, 1993)

The origin of Life Cycle Assessment can be found in the research that began in the 1960s in relation to the efficiency of industrial processes, in particular with respect to energy consumption.
The approach originally developed was based on the "net energy analysis" which considered not only direct energy consumption but the indirect consumption related to a specific process.
These energy focused analyses were followed by the first emission based study commissioned by the U.S. National Science Foundation in the 1970s aimed at examining alternative methods for packaging.
In recent decades, international organisations such as SETAC and the International Standard Organisation (ISO) have worked to develop a standard analysis procedure. In fact, the UNI EN ISO 14040 is "a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle." (*Source: ISO 14040: Life cycle assessment – principles and framework, 1998*).
Both the ISO as well as the EU guidelines identify the object of the analysis as not only a product of an industrial process but also a system of services.

The structure of a LCA, as proposed in the ISO 14040 can be synthesised in four principle steps:

1. *Goal and scope definition* is the first step in an LCA study. Defining the goal of the study should address issues like intended applications, reasons for doing the study and the intended audience.
2. The *inventory phase* forms the core of an LCA and is the most time consuming part. It involves data collection and calculation procedures to quantify relevant inputs and outputs of a process.

3. *The impact assessment phase* relates the outcome of an inventory to the relevant environmental impact categories. The aim of this phase is to evaluate the significance of the impacts resulting from the inputs and outputs summarised in the inventory list.
4. The *interpretation* is the last phase of an LCA and the aim of this phase is to provide an improvement assessment with the conclusions and recommendation.

The overall goal of the analysis is to determine a clear inventory of raw materials and energetic resources necessary for a specific productive system. Using such an inventory for each resource consumed and waste (emission) generated, a tally is made according to a series of categories of environmental impacts.

Criticism towards the Life Cycle Assessment process has been made with regard to the comparability between studies of the same process and the weighting criteria between different impacts. The first criticism was raised by Avyres (1995) where he described studies showed different results of LCAs performed by different research groups on the same process. Such a criticism highlights the need to conduct a rigorous mass and energy balance to verify the validity of the data used for the analysis. The second criticism is common to any integrated analysis, in that difficulty arises in assigning a weight for a specific impact in relation to another (eg. level of toxicity, eco or human, chronic or acute,…). A step forward was made with the publication of the guide "Environmental Life Cycle Assessment of Product" (Heijungs ed 1992). Presently the environmental impact categories used in the Life Cycle Assessment are:

- Global warming potential
- Stratospheric ozone depletion
- Acidification potential
- Eutrophication
- Photosmog formation
- Human and eco-toxicity
- Resources depletion

2. Life Cycle Assessment and decision support

The Life Cycle Assessment approach can furnish a support to decision making in both the private and public contexts through the use of Life Cycle Assessment methodology to:

- Analyse alternatives for the technological design of a product (R&D) in relation to the comparative evaluation of product and processes focusing on improving the impact of the product over its life span (Verschoor and Reijnders 1999).
- Develop process improvement strategies focusing on the reduction of energy and material consumption (Procter and Gamble 1990).

- Perform analysis for ecolabelling or ecomarketing in relation to overall environmental impacts of a specific product (eg. Volvo, ACAM)
- Evaluate the efficiency of environmentally focused technological innovation, resource utilisation in specific sectors such as waste treatment (Finnveden et al. 1995) and road transport (Eriksson at al. 1996).
- Create a set of indicators for environmental decision making comparing different activities in a specific territory (Tillman 1995, Huybrechts et al. 1996, Forsberg 200 Lundin and Morrison 2002).

When applied to territorial decision making, Life Cycle Assessment contributes to each of the major processes of decision support:

1) the formulation of problem
2) the formulation of the alternatives
3) the evaluation of the best alternative
4) the determination of evaluation indicators of the chosen alternative for long term monitoring.

Life Cycle Assessment is particularly useful for complex processes that have impacts that extend over time and space and utilise several different types of matter and/energy over the course of their life cycle.

3. Life Cycle Assessment, transport and logistics

The Life Cycle Assessment methodology was originally devised for the analysis of an industrial productive system. However, the flexibility of the approach has made it useful over a wide range of uses. As an instrument of analysis, Life Cycle Assessment can provide an interesting approach for the analysis of the environmental impacts of transport chains and logistics in general. In such an analysis, the particular focus on material and energy flows can be focused on a determined geographic area. Life Cycle Assessment analysis can highlight those processes or flows that have the highest resource consumption or the highest environmental loads. From such an analysis, one can identify and evaluate alternative hypothesis for specific processes to reduce territorial and environmental impacts and optimise resource utilisation in a particular logistics sector.

The analysis of territorial logistics using a Life Cycle Assessment could be constructed using the following methodology:

1) The delineation of the geographical or sectoral area of a specific logistics chain in which to focus the study.
2) The creation of an inventory of all flows, storages and indirect costs (flows) of a defined logistics system.
3) An evaluation of the environmental impacts of each flow, storage and indirect action that have been inventoried.
4) The evaluation of alternative development scenarios to examine improvements in the local logistics efficiency and the reduction of identified impacts.

The Life Cycle Assessment approach applied to a logistics chain will provide a detailed account of the impacts of each aspect of the process. Such an analysis is particularly useful in the determination of a set of indicators that can be used to monitor changes in the environmental load of an evolving territorial logistics system. Such an analysis, when applied to long distance transport systems (Knoepfel 2001), road construction and fuel technology (Lave et al. 2000, Mroueh et al. 2001) have proven to be quite useful.

The results of the Life Cycle Assessment analysis provide quantified impacts in particular environmental areas, therefore such analysis can provide specific information which can be combined with the available information on the state of the environment to elaborate integrated programmes to improve quality, in particular regarding:

- Production of waste
- Land use impacts
- Resource use management
- Air quality and noise related impacts
- Landscape management and conservation

To further explore the possibilities of Life Cycle Assessment in a territorial analysis, the following example has been created. The example primarily focuses on a local transport system.

In a rural geographically closed area, the present road system is considered insufficient to support the logistics requirements of the local actors. Three alternative scenarios have been presented to the local planners to evaluate.

1. Expansion of the present road system, by increased the number of lanes in the main road.
2. Increase the areas served by the railroad line to service the main transport actors
3. Decrease the overall transport requirements by optimising local production to reduce transport
0. No change in the present system

Through the use of a Life Cycle Assessment analysis, it would be possible to evaluate the present system, determine its impacts and identify areas in need of development, optimisation or elimination. The results of this analysis could then be used to determine development alternatives that could reduce those impacts considered most important.

With further analysis using the same Life Cycle Assessment information base (expected trends in transport and local territorial characteristics), one could compare the costs and benefits of each alternative in relation to their impacts on the local and global environment and, determine which alternative best responds to expected future scenario. This analysis would require the following activities:

- Detailed analysis of the impacts associated with each component of present transport system (transport, administration, infrastructure, storage)
- Identification of the components which have the highest environmental impacts
- Analysis at a territorial level of the most sensitive, most compromised or most highly valued aspects of the local environment
- Construction and detailed analysis of alternative scenario, impacts and benefits.

- Re-evaluation of the alternative scenarios to determine if new alternatives, or mixed alternatives would provide lower impacts in the identified key environmental areas
- Selection of the best alternative
- Creation of a set of indicators for long term analysis of the alternative selected.

One example of a possible analysis flowchart can be found in the following figure (Figure 1), the overall three phases of the analysis are given, Analysis of present transport system, evaluation, and analysis of alternatives.

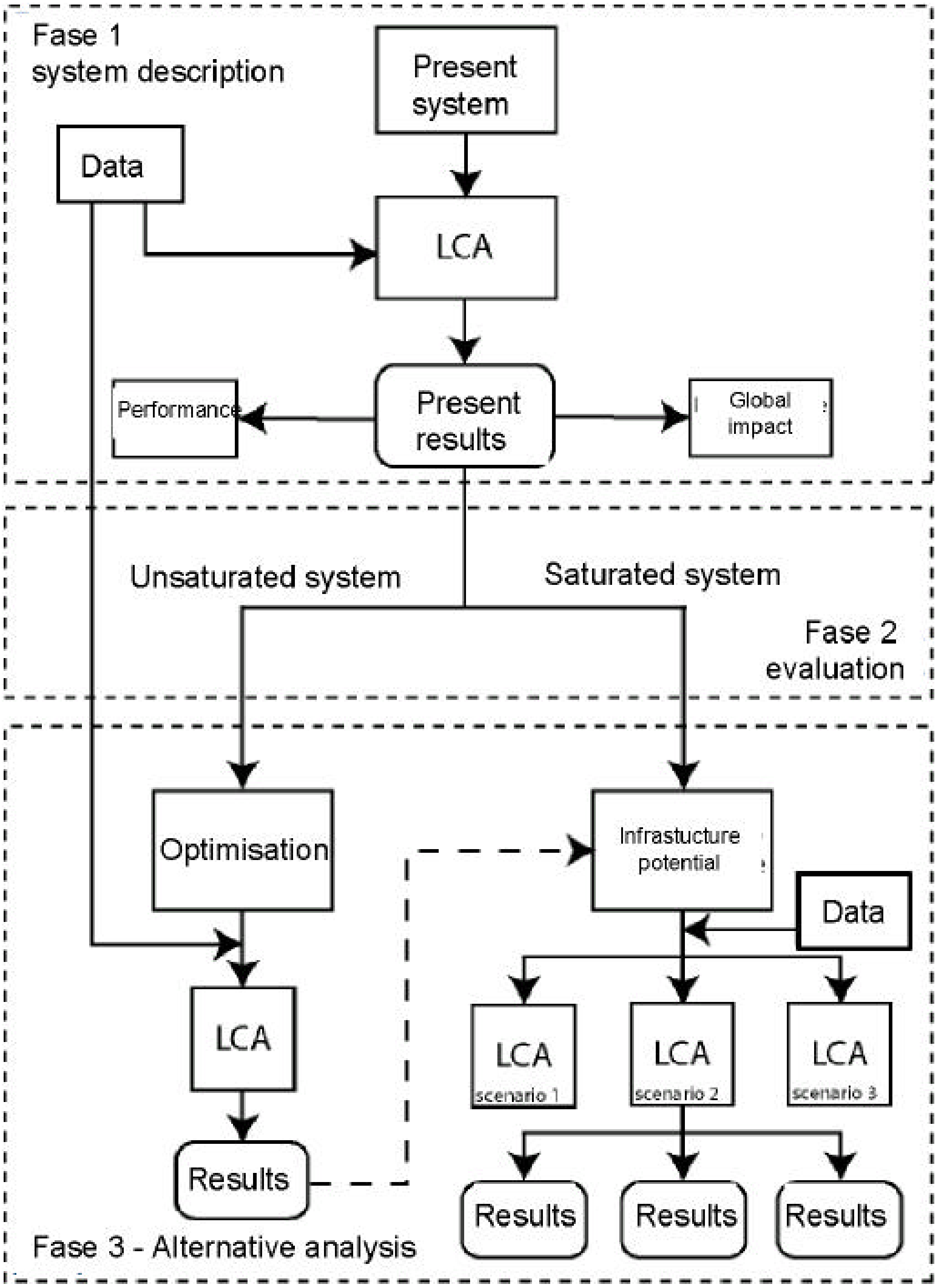

Figure 1. Flowchart of Life Cycle Analysis applied to a local transport system.

To initiate such an analysis, a significant amount of information about energy, material and information flows is necessary. An adequate description of the logistics networks, nodes and flows would be necessary, as would a detailed understanding of the local territorial system.

The results of this data gathering will supply the fundamental information for the Life Cycle Assessment analysis. Additionally, long term indicators that could be used for both scenario analysis as well as monitoring;

- Energy/person-kilometre (Toe/pkm) (MJ/pkm)
- Energy/ton-kilometre (Toe/tkm) (MJ/tkm)
- Inventory of local global pollutant emissions/transportation unit (gr/pkm, gr/tkm)
- Resource consumption/transportation unit
- Waste production/transport unit

4. Conclusion

The Life Cycle Analysis approach is based on the analysis of all the resources consumed and material (wastes) generated in a particular process or product, considering its entire life cycle.
The results of the analysis are a series of environmental indicators that consider both the local as well as global environmental impacts of the studied process.
When applied to territorial logistics, applying a Life Cycle Assessment analysis entails determining the impacts of the material, energy and information flows that that are related to all aspects of the local transport system, inventory and warehouse systems and administration. These impacts may be dominated by transport related emissions in some cases while in others (multimodal centres) significant emissions may be related to warehousing and administration activities.

As such processes have far reaching effects, a complete Life Cycle Assessment would require a large scale study, using published values for many of the impacts related to resource consumption (fuel, vehicle, construction material, electricity, ….) use.
Furthermore a clear geographical boundary would need to be defined as material flows can involve distances that exceed the dimensions of the local territory.

When compared to a Life Cycle Assessment for a specific industrially produced product, the analysis of a logistics system is more complex, especially when developmental alternatives are part of the objective of the study.
One important point is that a logistics system involves material and energy flows that are difficult to quantify and associate to a specific territory (eg. information flows, person transport, ..).

When considering the Sustainable District Logistics concept of logistics as the management of flows with respect to the sustainable access to goods, services, people and places, Life Cycle Assessment constitutes a useful tool in that the methodology for quantifying flows has been well developed and the approach to examine the full life cycle of a particular process in relation to the global and local environment is the basis of assessment approach.

However, as an environmental evaluation approach for transport or logistics systems, the current Life Cycle Assessment procedure would need to incorporate addition final indicators. Such indicators would need to focus on the local impact of energy consumption and transport activities (CO and particle production, noise), that are not considered in the standard definitions. Such additional final indicators would add to the usefulness of the approach in local transport analysis.

Nonetheless, a Life Cycle Assessment for a territorial logistics system presents numerous advantages for decision makers by presenting a common base for inter-temporal and interspatial comparison. The information that results from such an analysis can provide the groundwork for a continued process of development and management.

To meet the objectives of developing a sustainable territorial logistics system, Life Cycle Assessment analysis can provide the information and methodological base for the determination of the total environmental impact of a logistics system

Moreover, the integration of the Life Cycle analysis into the Sustainable Logistics District approach would allow researchers to create more complete indicator sets. Such material, energy, information driven indicator sets would be well linked to territorial perspectives while at the same time provide important information for the evaluation of business performance. These two dimensions are important elements of the District Logistics Analysis in the five case studies areas involved in the INNESTO project.

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