LCA Case Studies

Transportation in LCA

A Comparative Evaluation of the Importance of Transport in Four LCAs

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Abstract

The purpose of this paper is to investigate whether transport and logistics substantially contribute to the environmental interventions and impacts identified in LCAs. Four LCAs, encompassing very different products in different countries, were screened for the relative contribution of transport to the overall environmental interventions and impacts. Aside from this, the contribution of transport within individual life cycle phases was investigated.

In none of the LCAs did transport contribute to less than 5% of the energy related interventions or impacts, whereas contributions with more than ten percent occurred regularly, especially in events involving NO_x related impact. The importance of transport strongly depends on the kind of product studied. It seems to be especially important for agricultural products. With respect to individual phases of the life cycle, the study indicates that special attention is required for the transport of raw materials, for use phase of electronics and for the disposal phase of recyclable products.

Keywords: Transportation, relative contribution to environmental impact; inventory, relative contribution to emissions; impact assessment, relative contribution of transportation to impact areas; life cycle phases, relative impact of transportation

1 Introduction

In the life-cycle of a product, raw materials, intermediate products, consumer goods and waste are transported. Experience shows that manufacturers know a great deal about their production processes and the use of their products, although very little is known about the environmental implications of transport and logistics associated with the production, or the use and disposal of their products. A cursory comparison of LCAs has nevertheless indicated that transportation is the origin of some 5 to 15 % of some major environmental impacts, which is in no way insignificant. The overall aim of this project has been to remedy some of the lack of research into transportation and logistics in relation to LCA. Attempts have been made to answer three main questions about transport in the context of life cycle analysis:

- How important is transportation in LCA?
- Which phases of a product's transportation life cycle are of special importance, and which are insignificant?
- How can complex logistics be handled in a consistent, manageable and relevant manner? Is it possible to construct 'rules of thumb' to be used when data is insufficient or to check the possible validity of uncertain data?

In order to answer these questions, four LCAs for different products (coffee milk[1] packaging (glass bottles and cardboard packages); a tv; flax fleece and glass fiber mats) were screened for information on their manner of dealing with and the importance of transport in the life cycle. Only in two of the LCAs (IPU, 1996; YWEMA, 1994) could the relative importance of transportation be determined for all environmental impacts. In two other LCAs (for flax fleece and glass fiber mats, HOFFMANN & KARSTEN, 1995), only the importance for energy use and greenhouse effect could be determined.
In this paper, the results of the screening are summed up, providing as full as possible an answer to the above mentioned questions.

2 The Importance of Transportation

From the four LCAs studied it is evident that transportation is of significant, but rather varied importance for the total environmental effect of a product.
Below, the findings concerning the relative contribution of transportation in both the inventory and in the impact assessment have been summed up in **Tables 1** and 2. LCAs in which the contribution of transportation was not calculated have not been included. As is evident, this contribution was only calculated in the TV case for both inventory and impact assessment. For the other cases, transportation figures were missing for either inventory or impact assessment.
Calculating the average relative contribution of transportation in the inventory (glass fiber mats 3.4 %; flax fleece

[1] Condensed milk used as coffee creamer

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Table 1: Inventory, relative contribution of transportation to emissions/consumption

Intervention	Glass Fiber Mats	Flax Fleece	TV
Total Energy	2.9 %	12.1 %	1.3 %
Total CO_2	3.8 %	14.3 %	2.0 %
Total NO_x	(10-18 %)	(40-60 %)	8.6 %
Total SO_y	–	–	2.4 %
Total CO	–	–	13 %
Total Soot/particles	–	–	2.7 %
Total N_2O	–	–	0.5 %
Total HC	–	–	41 %
Total VOC	–	–	0.4 %

Note: [-] Indicates that the relevant figure was not available. [( )] Indicates that the relevant figure is an estimate. Estimates on NO_x are extrapolated from the TV-inventory on basis of the relationship between CO_2 and NO_x.
Sources: IPU, 1996; HOFFMANN &KARSTEN, 1995

Table 2: Impact Assessment, relative contribution of transportation to impact areas

Impact area	TV	Coffee milk bottle (return glass)	Coffee milk package (cardboard)
Global warming	1.9 %	15 %	15 %
Acidification	4.3 %	32 %	13 %
Eutrophication	8.5 %	30 %	8 %
Human toxicity	5.8 %	27 %	6 %
Eco-toxicity	-	1-2 %	1 %
Resource depletion	-	1-2 %	2 %
Smog	10 %	27 %	6 %
Smell	-	0 %	0 %

Note: [-] Indicates that the relevant figure was not available.
Sources: IPU, 1996; YWEMA, 1994
For the TV, impact assessment was performed according to the method advocated by the SETAC Working Group on Impact Assessment. For the coffee milk packaging, it was performed according to HEIJUNGS e.a. „Handleiding voor Milieugerichte Levenscyclusanalyses voor produkten", October 1992

13.2 % and TV 8 %, excl. estimates) and in the impact assessment (TV 6.1 %; coffee milk bottle 14.9 % and coffee milk package 5.7 %) it is evident that the contribution of transportation to environmental interventions and impacts is substantial. It seems unlikely to be less than 5 %[2], whereas a contribution of about 10 % or more does not seem to be uncommon.

Evidently, transportation is of special importance when considering such environmental impacts as global warming (from CO_2), acidification (from NO_x), eutrophication (from NO_x), smog (from NO_x, HC & VOC) and human toxicity (from NO_x). This is primarily due to the substantial emissions of CO_2 and CO related to the burning of fuels and, more importantly, the emissions of NO_x, which are especially related to combustion engines.

From the findings of this study, it is difficult to say much about the kind of products for which transportation is of special importance. The very substantial contribution related to transportation for the return glass milk bottle and flax fleece may, however, suggest a number of points which must be taken into consideration:

- The weight and 'packaging efficiency' of the product (glass bottles are relatively heavy and occupy relatively much space, are difficult to pack efficiently; flax fleeces have a low density so that only part of the loading capacity of vehicles can be utilised)
- Recycling or reuse of a product, or special demands as to the manner of disposal (e.g. disassembly), may give rise to relatively more transportation
- Special attention should be paid to agriculturally based products such as flax fleece since substantial amounts of fertilisers have to be transported over relatively long distances in order to produce raw materials for these. For most other products, the production (extraction) of raw materials in itself demands little transportation. Also important in relation to the agriculturally based product studied here (flax fleece) is that the production of the product itself costs relatively little energy, whereby the contribution of transportation may become remarkably large[4].

3 The Importance of Individual Phases in the Life Cycle

It is very difficult to say anything general about the importance of individual phases in the context of this study since the relative importance of transportation in specific phases was only calculated for the TV-LCA (using primary energy consumption as an indicator).

In the TV-LCA, however, it turned out that transport (to the phase) contributes with 1.0 % of primary energy consumption to materials and subcontractor production; 6.4 % to production at the manufacturer; 1.1 % to the use phase and 52 % to disposal (FREES, 1996). Especially the disposal phase is thus remarkable[5]. It should, however, be noted that the total amount of energy consumed in the disposal phase is very small *(→ Table 3)* in comparison to what is used in other phases.

Looking at how transportation within each phase compares to the overall contribution of transport in terms of primary energy consumption, three LCAs can be applied. The figures from these LCAs have been summed up in Table 3.

A number of points are especially noteworthy. First of all, the large contribution of the use phase of transportation

[2] In the one case where the relative contribution of transportation to total emissions and consumption of energy (*Table 1*, glass fiber mats) is below 5 %, this is due to the fact that the contribution has only been calculated for energy use and emission of CO_2 (HOFFMANN & KARSTEN, 1995). If the estimate for NO_x would have been included in the average this would be substantially higher.

[3] In the case of flax fleece, 0.934 kg fertilizer per kg flax fleece have to be transported 300 km (HOFFMANN & KARSTEN, 1995).

[4] It should be emphasised that the extent to which this is the case depends on the refinement of the product. The production of certain food products (e.g. pre-made dishes or bread spread) for instance may cost substantial amounts of energy (DALL & TOFT, 1996).

[5] In the disposal scenario used in this LCA, the TV is disposed of without being dismantled or (partly) recycled. If this had been the case, transport might have been even more important as there would have been more phases of transport to the final disposal. On the other hand, the total environmental impact of the disposal of the TV might have been lower. If this be so, the importance of transportation to and in the disposal phase would have been still more important than first expected (IPU, 1996).

Table 3: Transport to the phase relative to all transport, primary energy consumption

Percentage relative to all transport			
Life cycle phase	**TV**	**Flax fleece**	**Glass fiber mats**
Materials and subcontractor production	10 %	60.1 %	No materials are transported to this phase (mining)
Production at manufacturer	16 %	30.9 %	62.9 %
Use	71 %	9.0 %	37.2 %
Disposal	3 %	Not available	Not available
Total	100 %	100 %	100.1 %

Notes: The division of phases has been based on FREES, 1996. The starting point is the production of the final product based on the manufacturer, to which various semi-manufacturers are transported, and from where the final product is further transported to centres of distribution and thus the use phase. Thus, the first phase includes the production of all raw materials and semi-manufacturing; the second only the production (or assembly) of the final product; the third phase starts when the final product leaves the factory and the disposal phase begins when the user disposes of the product.
Phase 1 for flax fleece consists of seeds, fertilizer and pesticides being transported to the area of cultivation. Fiber finishing has also been included in this first phase.
Phase 2 for glass fiber mats consists of koalinit, colemanite, quartz and limestone being transported to the glass fiber mat production site from various mining sites.
Sources: FREES, 1996; IPU, 1996; HOFFMANN & KARSTENS, 1995

for the TV is remarkable, especially as it will be valid for most electronic products. The underlying cause is that the TV (and electronic products in general) consumes a very large amount of primary energy in its use phase in the form of electricity. The fuels necessary for the production of electricity have to be transported to the power station via pipelines and ships. This transport has been included in the calculation and has turned out to contribute substantially to the total consumption of primary energy (IPU, 1996).
Secondly, the above figures suggest that transportation is of larger importance for the phases where raw materials and semi-manufactures are produced (phase 1 and 2). In this connection, it should nevertheless be taken into consideration that for some types of products (e.g. electronic products and probably agricultural food products[6]), transportation to and in the use and disposal phases is likely to be of significant importance.

4 Conclusions

In this study, it has been confirmed that transportation is generally not something to be ignored in LCAs. In none of the LCAs reviewed did transportation contribute with less than 5 % to environmental interventions or impact. Contributions above 15 % may regularly occur for NO_x and HC and related impact categories. Whether such large contributions occur more generally cannot be concluded from this study. In this context, it should also be emphasised that a contribution to energy consumption and CO_2 emissions cannot generally be used as reliable indicators of the general contribution of transportation and logistics to environmental interventions and impacts.
Further, it is evident that transportation especially contributes to environmental interventions such as CO_2, CO, NO_x and HC. Transportation is thus of special importance when considering the impact categories of global warming, acidification, eutrophication, smog and human toxicity[7]. Considering the supposed seriousness of the effects of these environmental impacts, and the importance these impact categories are given among decision makers, transportation and logistics are certainly sufficiently important as to be more commonly considered when performing an LCA.
It seems difficult to construct any useful rules of thumb on the basis of the material which has been reviewed in this study; in order to do so, much more research must be performed. This study, however, does point to issues which should, at least, be studied further:

- The importance of transportation in various phases of the life cycle, especially the transportation of raw materials to producers and subcontractors. Special attention should be paid to agriculturally based products and to the importance of transportation of energy for the use phase of electronic products.
- The differences between various types of products. What are the characteristics of products for which transportation is a very important factor as compared to products where transportation only contributes little to total impacts.
- The importance of the disposal phase, especially whether the product is recycled or disposed of directly. This issue has not really been discussed here since only one of the LCAs dealt with transportation in the disposal phase. Considering the importance of transportation in this phase for the TV case, it does, however, seem relevant to undertake further research in this area, certainly when considering the possibility of reducing the total environmental impact of the disposal phase by means of recycling (see *footnote no. 4, p. 219*)

5 References

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[6] In this study, agricultural food products have not been investigated. In a forthcoming study by DALL & TOFT (1996) it has, however, been indicated that transport in and to the distribution phase is of major importance for the environmental impact of this type of products.

[7] It should be noted that this review is limited to the typically, well documented LCA-like subjects. The less well quantified nuisance-issues of transport, like congestion, space consumption of vehicles and roads and noise are likely to be much bigger environment influencing factors.