ENVIRONMENTAL ASSESSMENT OF INTERNAL COMPANY TRANSPORT BASED ON LIFE CYCLE ASSESSMENT METHODOLOGY

STAŠ David[1], BURCHART-KOROL Dorota[2], LENORT Radim[1], WICHER Pavel[1], HOLMAN David[1]

[1]*ŠKODA AUTO UNIVERSITY, Mlada Boleslav, Czech Republic, EU*
stas@is.savs.cz, lenort@is.savs.cz, wicher1@is.savs.cz, david.holman@savs.cz
[2]*Central Mining Institute (GIG), Katowice, Poland, EU, dburchart@gig.katowice.pl*

Abstract

Transport is one of the areas having considerable potential within the scope of the implementation of the environmental friendly (green) practices. Green transport is a worldwide processed, described and developed topic, but only from a multinational and national perspective, especially for the area of urban or public transport. Unfortunately, green transport from the viewpoint of industrial companies is researched only sporadically and marginally. The aim of the paper is to analyze possibilities for an environmental assessment of the internal transport in an industrial company using the Life Cycle Assessment method.

Keywords: Green transport, internal transport, Life Cycle Assessment

1. INTRODUCTION

Transport is one of the areas having considerable potential within the scope of the implementation of the environmental friendly (green) practices, since it occupies top positions in negative impacts on the environment. At present, the public has been increasingly aware of a number of negative effects transport produces.

The proactive concept, which is focused on reducing the transport CO_2 emissions, other exhaust gases and noise, a congested transport infrastructure, transportation costs, and, last but not least, on complying with the legislative transport restrictions is called Green Transport (GT). An active and effective solution of the issues of GT must be seen not only as a challenge, but especially as an opportunity offering the possibility of significant competitive advantage, improving the image of the company in the eyes of the customers, region, state and the general public.

GT is a worldwide processed, described and developed topic, but only from a multinational and national perspective, especially for the area of urban or public transport. Unfortunately, GT from the viewpoint of industrial companies is researched only sporadically and marginally. The company transport can be divided into three basic categories:

1. Outbound - a transport from suppliers to the industrial company.
2. Internal - a transport inside the industrial company.
3. Outbound - a transport from the industrial company to customers.

The aim of the paper is to analyze possibilities for an environmental assessment of the internal transport in an industrial company using the Life Cycle Assessment method.

2. LITERATURE REVIEW

2.1. Life Cycle Assessment

Life Cycle Assessment (LCA) isn't a completely new concept, the topic is researched for more than 40 years [1]. A framework for LCA, as it is known today, was created especially by two organizations: the Society for

Environmental Toxicology and Chemistry (SETAC) in August 1990 [1] and the International Organization for Standardization (ISO) in June 1997 [2].

The SETAC report summarizes the current status of the field and outlines the technical basis for life cycle studies. LCA definition according to SETAC seas that LCA 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 [3]. This definition is adopted by wide spectrum of other authors (see e.g. [4], [5], [6], [7]).

ISO standards in LCA provide the following definition and guidelines [8], [9]: LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave). There are four phases in an LCA study:

1. The goal and scope definition phase - the scope, including system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA.
2. The life cycle inventory analysis phase (LCI phase) - it is an inventory of input/output data with regard to the system being studied. It involves the collection of the data necessary to meet the goals of the defined study.
3. The life cycle impact assessment phase (LCIA phase) - the purpose of LCIA is to provide additional information to help assess a product system’s LCI results so as to better understand their environmental significance.
4. The interpretation phase - in this phase the results of an LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

The general categories of environmental impacts needing consideration include resource use, human health, and ecological consequences.

LCA is then can be seen as a methodology used for selection, design and optimization of processes. The assessment includes the analysis of product’s entire life cycle, encompassing extraction and processing raw material, manufacturing, distribution, use, recycling and final disposal. Thus, the economic and environmental evaluation through LCA is performed on the process alternatives to identify the best option that could further be subjected to process optimization [10].

2.2. Well-to-Wheels LCA

The LCA 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. [11]

The specific LCA used for transport fuels and vehicles is called as Well-to-Wheels (WTW) LCA. To allow comparison with conventional analyses covering only vehicle operations, results of a WTW assessment are often separated into two groups (see **Fig. 1**) [12]: Well to Pump (WTP) and Pump to Wheels (PTW). WTP stage starts with fuel feedstock recovery and end with fuels available at refueling stations (recovery, processing, storage, and transportation of feedstocks and production, transportation, storage, and distribution of fuel). PTW stage covers vehicle operation activities (refueling and operation).

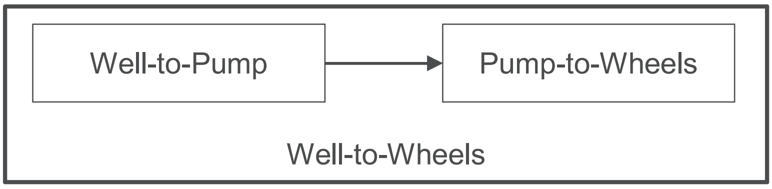

Fig. 1 Well-to-Wheels LCA concept for fuel/vehicle systems

3. EXPERIMENTAL PART

A model situation based on the particular internal transport of an industrial company was created to meet the aim of the paper. The LCA was conducted following the requirements of the ISO 14044:2006. Internal transport is carried out by diesel trucks. A maximum traveled mass is 24 ton. The total traveled distance is 965 400 km per year. This value was used as the functional unit (FU) of this LCA study.

3.1. LCIA methods

The LCA of the internal transport was carried out using the LCA software SimaPro v.8 (Pre Consultants B.V) and the Ecoinvent database 3.1 within the program. The study performed an environmental evaluation according to two LCIA methods: the IPCC 2007 GWP 100a (Intergovernmental Panel on Climate Change 2007, global warming potential, 100 years), and the ReCiPe. IPCC 2007 GWP 100a method was chosen, because one of the most important negative aspects of the transport are greenhouse gases (GHGs) emissions. The IPCC method allows assessing the impact of GHGs on the greenhouse effect as a function of the CO_2 (CO_2 eq) released during the assumed time horizon of 100 years [13]. ReCiPe method was chosen to model next very important aspect of the transport, which is negative impact on human health, ecosystem, and resource consumption.

ReCiPe is the most complex method, which shows the analyses of the environmental impact in various impact categories and damage categories. The primary objective of the ReCiPe Midpoint method is to transform the long list of life cycle inventory results into a limited number of indicator scores. These indicator scores express the environmental impact categories. In the ReCiPe Endpoint, the indicators are determined at three endpoint indicators [14]. In ReCiPe Endpoint the Damage to Human Health is measured in units of Disability-Adjusted Life Years (DALY), which express the number of years lived disabled and the number of years of life lost. In this impact category, climate change, ozone depletion, photochemical smog production, humans' toxicity, ionizing radiation and the particulate matter formation have been taken into account. In ReCiPe Endpoint the Damage to Ecosystem Quality is reflected by the diversity of species within, and the damage to an ecosystem may be expressed in terms of the number of species that disappear in a given area as a result of contamination. This category includes acidification, eco-toxicity, eutrophication, and land occupation. In ReCiPe Endpoint the Damage to Resources category, connected with the use of fossil fuels and minerals, is based on the assumption that non-renewable resources should be available for future population.

3.2. LCA results

Results of the internal transport LCA are divided into two stages: WTP (Diesel production) and PTW (Operation). Operation stage takes into account direct airborne emissions of gaseous substances, particulate matters and heavy metals. Heavy metal emissions to soil and water caused by tyre abrasion are included as well. The life cycle inventory was taken from Ecoinvent database 3.1.

The results related to GHGs emissions of the internal transport using the IPCC GWP 100a method are shown in **Table 1**. Total CO_2 eq emissions are 1059 tons per year (per 965 400 km). The share of Diesel production and Operation stage in GHGs emissions is presented in **Fig. 2**. Higher GNGs emissions was indicated for Operation stage (86.1%).

Table 1 GHGs emissions per year (per 965 400 km)

Unit	CO_2 eq in tons per FU
Total (WTW)	**1059.070**
Diesel production (WTP)	147.414
Operation (PTW)	911.656

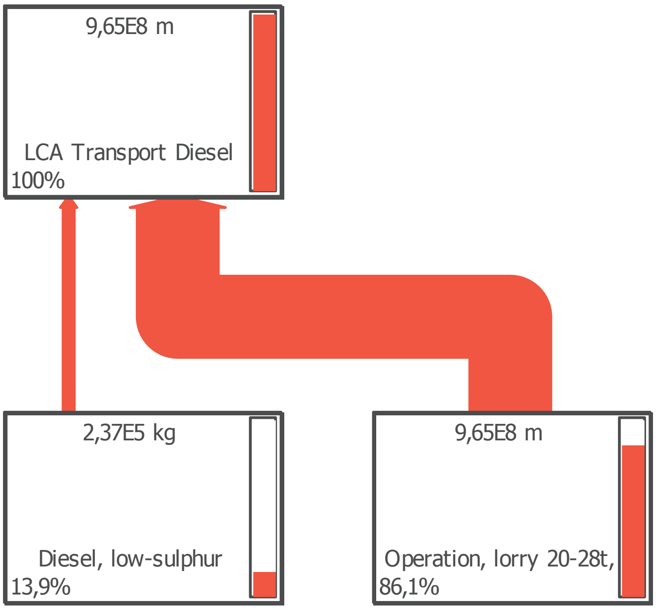

Fig. 2 The share of the GHGs emissions from the considered stages

Table 2 Results of LCA analysis using the ReCiPe method per year (per 965 400 km)

Impact category	Unit	Result
Ozone depletion	kg CFC-11 eq	0.14
Terrestrial acidification	kg SO_2 eq	6263.50
Freshwater eutrophication	kg P eq	20.44
Marine eutrophication	kg N eq	390.47
Human toxicity	kg 1.4-DB eq	30256.34
Photochemical oxidant formation	kg NMVOC	10875.96
Particulate matter formation	kg PM10 eq	2687.46
Terrestrial ecotoxicity	kg 1.4-DB eq	51.20
Freshwater ecotoxicity	kg 1.4-DB eq	740.10
Marine ecotoxicity	kg 1.4-DB eq	1007.48
Ionising radiation	kBq U235 eq	16853.12
Agricultural land occupation	m^2a	507.48
Urban land occupation	m^2a	1405.94
Natural land transformation	m^2	321.35
Water depletion	m^3	2728.27
Metal depletion	kg Fe eq	3259.81
Fossil depletion	kg oil eq	292035.45

The results of LCA of the internal transport according to ReCiPe are shown in **Table 2**. Share of the elements in given impact categories are shown in **Table 3**. The results of the damage categories for Human Health, Ecosystem and Resources for the internal transport are shown in **Table 4**. Higher impact of the internal transport is for Human Health and Ecosystem is observed in Operation stage. On the contrary, the stage has no impact on Resources category.

Table 3 Share of the impact categories using the ReCiPe method from the considered stages

Impact category	Diesel production (%)	Operation (%)
Ozone depletion	100.0	0.0
Terrestrial acidification	16.6	83.4
Freshwater eutrophication	100.0	0.0
Marine eutrophication	7.4	92.6
Human toxicity	74.7	25.3
Photochemical oxidant formation	10.3	89.7
Particulate matter formation	11.8	88.2
Terrestrial ecotoxicity	23.5	76.5
Freshwater ecotoxicity	92.3	7.7
Marine ecotoxicity	70.8	29.2
Ionising radiation	100.0	0.0
Agricultural land occupation	100.0	0.0
Urban land occupation	100.0	0.0
Natural land transformation	100.0	0.0
Water depletion	100.0	0.0
Metal depletion	100.0	0.0
Fossil fuel depletion	100.0	0.0

Table 4 Damage categories caused with the internal transport per year (per 965 400 km)

Damage category	Unit*	Total	Diesel production	Operation
Total	kPt / FU	94.86	41.18	53.68
Human Health	kPt / FU	43.58	5.98	37.60
Ecosystems	kPt / FU	19.84	3.75	16.08
Resources	kPt / FU	31.45	31.45	0.00

* kPt - thousands of eco-points

4. CONCLUSION

The article shows that LCA can be a suitable methodology for assessment of environmental impact of an industrial company internal transport from the global viewpoint. Presented results demonstrates a wide gamut of impact categories, which can be obtained using the LCA in transport area. As a practical problem can be seen the fact that the LCA doesn't differ between long-haulage and internal, stop and go, transport in the PTW stage. Next problem is that the aggregated damage categories measured in an eco-points aren't intelligible for the managerial practice.

ACKNOWLEDGEMENTS

The work was supported by the specific university research of Ministry of Education, Youth and Sports of the Czech Republic at SKODA AUTO University No. SIGA/2014/01 and No. SGS/2015/02.

REFERENCES

[1] KLÖPFFER W. The role of SETAC in the Development of LCA. The International Journal of Life Cycle Assessment, Vol. 11, No. 1, 2006, pp. 116-122.

[2] ISO 14040:1997 Environmental management - Life cycle assessment - Principles and framework. Genève: International Organization for Standardization, 1997.

[3] Guidelines for Life-Cycle Assessment: A 'Code of Practice'. Brussels: SETAC, 1993.

[4] TUKKER A. Life cycle assessment as a tool in environmental impact assessment. Environmental Impact Assessment Review, Vol. 20, 2000, pp. 435-456.

[5] WIDIYANTO A., KATO S., MARUYAMA N. Environmental impact analysis of Indonesian electric generation systems. JSME International Journal, Series B: Fluids and Thermal Engineering, Vol. 46 No. 4, 2003, pp. 650-659.

[6] BENETTO E., ROUSSEAUX P., BLONDIN J. Life cycle assessment of coal by-products based electric power production scenarios. Fuel, Vol. 83, No. 7/8, 2004, pp. 957-970.

[7] SADIQ R., KHAN F.I. An integrated approach for risk-based life cycle assessment and multicriteria decision-making. Business Process Management Journal, Vol. 12, No. 6, 2006, pp. 770-792.

[8] ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework. Genève: International Organization for Standardization, 2006.

[9] ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines. Genève: International Organization for Standardization, 2006.

[10] SUGIYAMA H., HIRAO M., MEDIVIL R., FISCHER U., HUNGERBUHLER K. A hierarchical activity model of chemical process design based on LCA. Process Safety and Environment Protection, Vol. 84, No. 1, 2006, pp. 63-74.

[11] PRINCIPI I., SUSANI L., LOISELLE S. Life Cycle Analysis and the logistics issues: A contribution to District Logistics Analysis. Florence, 2003. Available from: http://www.districtlogistics.net/download/Life-cycle-analysis.pdf. Accessed on 24 October 2015.

[12] KLIUCININKAS L., MATULEVICIUS J., MARTUZEVICIUS D. The life cycle assessment of alternative fuel chains for urban buses and trolleybuses. Journal of Environmental Management, Vol. 99, 2012, pp. 98-103.

[13] IPCC Climate Change Fourth Assessment Report: Climate Change 2007. IPCC, 2007. Available from: http://www.ipcc.ch/ipccreports/assessments-reports.htm. Accessed on 05 October 2015.

[14] GOEDKOOP M.J., HEIJUNGS R., HUIJBREGTS M., De SCHRYVER A., STRUIJS J., Van ZELM R. ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation. PRé Consultants, 2013. Available from: https://www.pre-sustainability.com/recipe-report. Accessed on 05 October 2015.