ANALYSING AND COMPARING DIFFERENT TRAFFIC ENVIRONMENTAL IMPACTS

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Abstract

Each human economic activity has the direct goal to help increasing the population quality of life. The developments in the last time did show that beside positive desired effects of these economic activities, also negative undesired effects on the environment and society can appear. With the goal of assuring the sustainable development of our human society it is therefore necessary to recognise, analyse, evaluate and compare these unwanted impacts of technological applications, not only on the environment, but also on the society. Currently there is a debate on a global level regarding the environmental impact assessment of different economic activities. Among these ones the transport field does play an important role concerning its impacts on the environment. Especially traffic engineering, particularly consisting of public and cargo transport, will be approached in the present paper. The Life Cycle Assessment (LCA) of a product will be presented, emphasing the emergence of this concept, as well as its usage in the context of different industrial applications. Concretely it will be mentioned that on a global level there is an ISO standard for using and applying the Life Cycle Assessment, that has to be carried out in different stages and for different cycles of a product. Regarding traffic engineering several transport means will be chosen and the pollutants emissions in their utilisation phase will be assessed and compared. Conclusions regarding the Traffic Environmental Impacts will be drawn as well as measures to reduce these impacts will be emphasised.

Keywords:*, environmental impacts, life cycle assessment, sustainable development, traffic engineering, utilisation phase*

1. Introduction

After the Conference for Environment in Stockholm in 1972 and after publishing the first report to the Club of Rome „The Limits of the Growth“, also in 1972 was finally understood that besides wanted effects of technological progress, undesired and negative effects can appear [1]. Nowadays we confront us with a series of global problems, which can be grouped in three categories: world population growth, growth of energy and natural resources consumption and environmental pollution [2].
The concept of sustainable development was defined 1987 in the Brundtland Report of the World Council on Environment and Development and accepted as a possible solution for the global complex ecological, economical and social problems [3]. On the Conference for Environment and Development in Rio de Janeiro 1992, as in the closing document „Agenda 21“ sustainable development was very much debated, as well as 2002 during the Johannesburg Conference [4].
Part of what engineers do is to evaluate developments in technology. Their evaluation has up to now been focused almost without exception on technical and economic

aspects following legal and financial boundary conditions [2]. With respect to sustainability more criteria have to be considered, as: environmental quality, social and human values, quality of life [5]. The activities of engineers when evaluating technologies can be sustained by the pretty new discipline called Technology Assessment (TA) [6]. Although in the last 20 years it was a lot of progress in the field of Technology Assessment especially due to several studies which have been carried out in the USA, Japan, Germany and other European countries, there is still a real need in developing integrative methods for assessing technologies [7].

2. Tools for Environmental Impact Assessment

Technology Assessment means after [6] the methodical, systematic, organised process of analysing a technology and its developmental possibilities, assessing the direct and indirect technical, economic, health, ecological, human, social and other impacts of this technology and possible alternatives, judging these impacts according to defined goals and values, or also demanding further desirable developments and deriving possibilities for action and design from this and elaborating these, so that well-founded decisions are possible and can be made and implemented by suitable institutions if need be [7].
In order to assess possible impacts of human activities, especially industrial ones on the environment, several tools, so-called *instruments of technology assessment* can be used [7]. The most used ones, as presented in Figure 1 [8], are the followings:
- Environmental impact assessment
- Life-Cycle-Assessment
- Ecoaudit
- Ecobalances

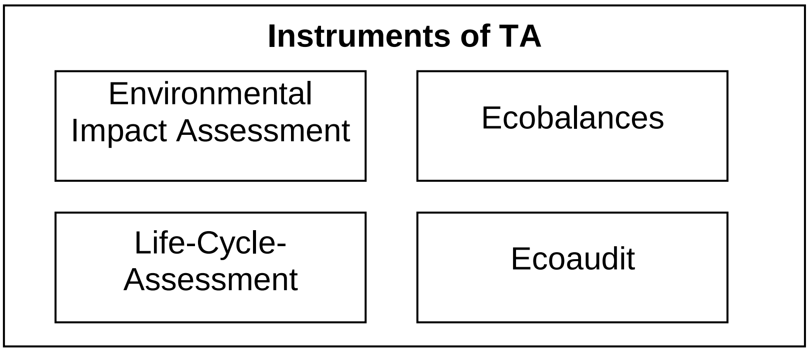

Figure 1: Instruments of technology assessment

3. Life Cycle Assessment, LCA

The LCA is an analysis which registers all the effects on environment of a product during its life, from the production to the consumption and recycling. The general life cycle of a product is presented in Figure 2 [7]. It can be observed that besides production and consumption processes also transport processes are taken into account [8]. With "T" transport processes are stated within the life cycle of a product.

As a tool of technology assessment, LCA is appropriate to improve the production lines of products, to compare different products and to ecologically optimise the life-

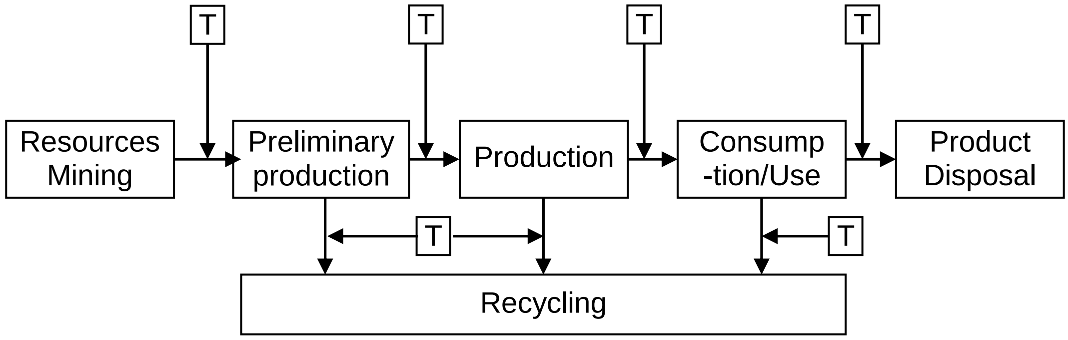

Figure 2: General life-cycle of products.

cycle of products. The LCA is in fact an ecobalance which can be performed as a singular study or as a comparative study [9]. The ecobalance registers material and energetical flows when producing something, or within a process, company or a region. Such an analysis needs several steps [7, 9, 10]:

- a) definition of goal and scope;
- b) inventory analysis;
- c) impact assessment;
- d) interpretation of results.

a) Definition of goal and scope - The goal shall unambiguously state the intended application, the reasons for carrying out the study and the intended audience, i.e. to whom the results of the study are intended to be communicated. In defining the scope of an LCA study, the following items shall be considered and clearly described: the functions of the product, the functional unit, the system boundaries, methodology of impact assessment, data requirements, assumptions, limitations.

b) Inventory analysis - It involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. These inputs and outputs may include the use of resources and also pollutants emissions by the system.

c) Impact assessment - It is aimed at evaluating the potential environmental impacts using the results of the inventory analyses. The impact assessment may include elements as assigning of inventory data to impact categories, modeling inventory data within impact categories and possibly aggregating the results. It is to be men-tioned that the methodological and scientific framework for impact assessment is still being developed [7]. Very often in the step of assessment aggregated indicators are used for allowing a transparent evaluation [10] (see application example, chapter 4).

d) Interpretation of results - in this phase the findings from the inventory analysis and the impact assessment are combined together. The interpretation should take the form of conclusions and recommendations to decision-makers [7, 8, 9].

With respect to LCA a difficult step is represented by getting on data and information about products and production processes [7, 8, 9]. To compare different life cycle stations of a product from the point of view of pollutants emissions there is a need to use different environmental indicators [6, 8, 9]. This process is still in development.

The life cycle of a product takes into account relevant steps in the existence and use of a product, as shown in Figure 2, starting with the extraction of mineral resources used to manufacture the product and ending with the disposal of the product:

- Resources mining: this phase refers to the extraction of mineral resources, that will become the raw material used to manufacture the respective product.
- Preliminary production: this phase includes the manufacture of components that will be assembled during production to get the desired final product.
- Production: in this phase the components are assembled, resulting the product in its final form.
- Consumption/Use: after the sale of the product, it enters in the stage of use.
- Product Disposal: after completing the period of use is reached the last stage in the life cycle of a product - the disposal, where the used product is directed to the phase of reuse or recycling and waste processing. [6, 7, 9]

4. Application example of LCA

By considering the consumption phase of different transport means, it is possible to analyse the transport field, by calculating the CO_2 emissions in the utilisation phase and by concluding which transport mean is the most „environmentally friendly" [8,10]. The considered transport means are the following:

a. Car
b. Coach
c. Train
d. Airplane

In order to emphasise the possible impact on the environment of these different transport means a travelling distance between two cities has been considered, cities which also have airports nearby, just to make possible also the consideration of flights between these two cities, i.e. the airplane transport as well. It follows that the pollutants emissions are calculated for the distance between the International Airport "Avram Iancu" in Cluj Napoca and the International Airport "Henri Coanda" in Bucuresti, this actually means for the distance of 442 km [11].

When taken into account the four mentioned transport means, it is important to know their specific fossil fuel consumption (here diesel fuel) pro 100 km, data found in the literature, by mentioning also the number of transported passengers:

a. car: Skoda Fabia – 5.09 l/100 km [12], 5 passengers [13]

b. coach: Mercedes Benz Tourismo – 25.1 l/100 km [14], 51 passengers [15]

c. train: considered motor: 060 DA - 230.7 l/100 km [16], 480 passengers (from the assumption of 5 wagons, 96 passengers/wagon)

d. airplane: Boeing 747 - 400 – 1 610 l/100km, 416 passengers [17]

By using these data, in the following it is possible to calculate the diesel consumption for the whole travelled distance between the two cities, results given in Table 1.

In order to calculate the respective CO_2 emissions when travelling by car, coach or train on the considered distance and for a person, it is necessary to know the carbon content of diesel, C_c, which is 87 % [18]. With this information the mass of carbon, m_c, in a volume V=1 m^3 diesel can be calculated when knowing the diesel density, $\rho_{Diesel} = 832\ kg/m^3$:

$$m_C = C_C \times V \times \rho_{Diesel} = 723 \quad kg \tag{1}$$

In order to calculate the CO_2 emissions resulted when burning the volume 1 l diesel, the corresponding known chemical reaction is necessary, $C+O_2 \rightarrow CO_2$.

It follows that the mass of the CO_2 emissions is to be calculated with the formula:

$$m_{CO_2} = m_C \times \frac{M_{CO_2}}{M_C} \qquad (2)$$

where: M_C –molar mass of carbon; M_C = 12 kg/kmol

M_{CO_2} – molar mass of carbon dioxide; M_{CO_2} = 44 kg/kmol

m_C – the mass of carbon entering in the reaction (kg)

m_{CO_2} – CO_2 mass emissions (kg)

This means that when burning 1l diesel, the CO_2 emissions are

$$m_{CO_2} = 0.723 \times \frac{44}{12} = 2.65\ kg\ from\ burning\ 1\ l\ diesel$$

When travelling by airplane between the two cities, from the literature data is known that an airplane is emitting 2.76 kg CO_2 for each liter kerosene [19]

Summing up, the calculations results are presented in Table 1 and in Figure 3.

Table 1. CO_2 emissions for different transport means for the distance from Bucharest to Cluj Napoca

Transport means	Number of passen-gers	Fossil fuel consumption l/100 km	Total fossil fuel consum-ption (l)	CO_2 emissions when burning 1 l fossil fuel (kg)	Total CO_2 emissions (kg)	CO_2 emissions per passenger (kg)
Car	5	5.09	22.49	2.65	59.59	11.91
Coach	51	25.1	110.94	2.65	293.99	5.76
Train	480	230.7	1 019.69	2.65	2 702.17	5.62
Airplane	416	1610	7 116.2	2.76	19 640.71	47.21

The diagrams from Figure 3 are presenting in a concise form the calculation results about the CO_2 emissions for different transport means for the considered distance.

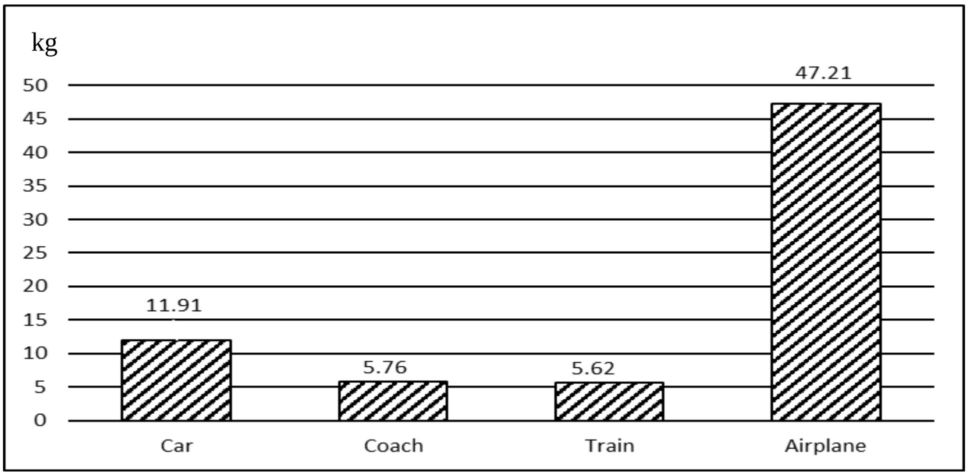

Figure 3. Emissions of CO_2 for different transport means

5. Conclusions

The operationalisation of the concept of sustainable development means to try to find the balance among technical, economic, environmental and social aspects. Giving emphasise to technical and environmental aspects this could mean to lead technology assessment studies especially environmental assessments. The heightened awareness of the importance of environmental protection and the possible impacts associated with products manufactured and consumed has increased the interest in the development of methods to evaluate these impacts. There are several tools in order to evaluate environmental impacts of human activities, one of them having been discussed in this paper. An assessment method based on an emission indicator has been presented and applied for automotive systems. Results emphasise the significance of the presented method, because it is possible to compare environmental impacts of different transport means by calculating the CO_2 emissions in the utilisation phase of each of these. The made calculations are emphasising that the most „friendly" transport mean considering the fossil fuel consumption and the number of passengers is the train and the most „unfriendly" transport mean is the airplane, the other two transport means, car and coach, being between the other two ones. There are several measures to reduce these impacts, especially technical measures for reducing the fossil fuel consumption for airplanes, but also organisational measures and ones acting in the social field.

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