INSTRUMENTS FOR ENVIRONMENTAL IMPACT ASSESSMENT OF INDUSTRIAL ACTIVITIES

Ildiko TULBURE

UNIVERSITY of Petroşani & TECHNICAL UNIVERSITY of Clausthal, Germany

Rezumat. *Pe lângă efecte dorite pozitive ale aplicaţiilor tehnologice menite să crească nivelul de trai al populaţiei, de cele mai multe ori acestea au şi efecte nedorite negative asupra mediului ambiant şi asupra societăţii. Din acest motiv, activităţile şi procesele industriale trebuie evaluate nu numai din punct de vedere tehnologic şi economic, dar şi al efectelor asupra mediului şi social. Din multitudinea metodelor şi instrumentelor utilizate în noua disciplină denumită „Technology Assessment", unele dintre ele se folosesc cu succes pentru evaluarea efectelor asupra mediului. Cea mai discutată metodă la ora actuală este analiza ciclului de viaţă al produselor (Life Cycle Assessment LCA). În lucrarea de faţă se prezintă noţiuni de bază legate de „technology assessment" şi LCA cât şi un exemplu practic.*

1. INTRODUCTION

After the Conference for Environment in Stockholm in 1972 and the first report of the Club of Rome „The Limits of the Growth" in 1972 was understood that besides wanted effects of technological progress, undesired and negative effects can appear. Nowadays we confront us with a series of global problems, which can be grouped in three categories: world population growth, growth of the 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. Very much discussed has been sustainable development on the Conference for Environment and Development in Rio de Janeiro 1992, in the closing document „Agenda 21" as well as during the Johannesburg Conference in 2002.

Part of what engineers do is to evaluate developments in technology. Their evaluation has up to now almost without exception been focused on technical aspects and on economic aspects following legal and financial boundary conditions. With respect to sustainability more criteria have to be considered like: environmental quality, social and human values, quality of life. The activities of engineers when evaluating technologies can be sustained by the new discipline called technology assessment (TA).

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 USA, Japan, Germany and other European countries, there is still need in developing integrative methods for technology assessment.

2. TOOLS FOR ENVIRONMENTAL IMPACT ASSESSMENT

Technology Assessment means after [9] 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.

In order to assess the possible effects of human activities, especially industrial processes on environment, several tools, so-called instruments of technology asessement can be applied with respect to the question which has to be answered (Figure 1). Here are listed the most used and important ones:

- Environmental impact assessment
- Life-cycle-assessment
- Eco-Audit
- Ecobalances

The most important one is the Life-Cycle-Analysis, to which I will refer in the following.

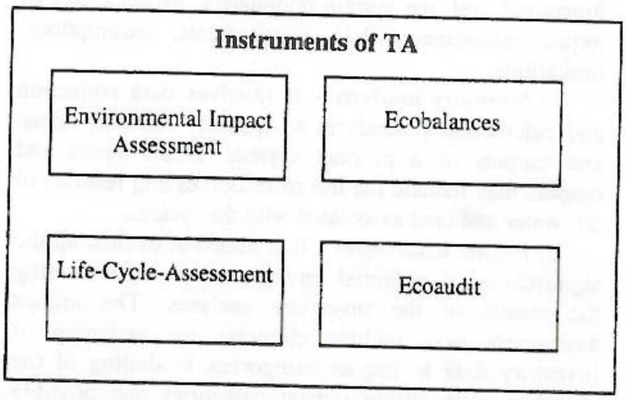

Fig. 1. Instruments of technology assessment.

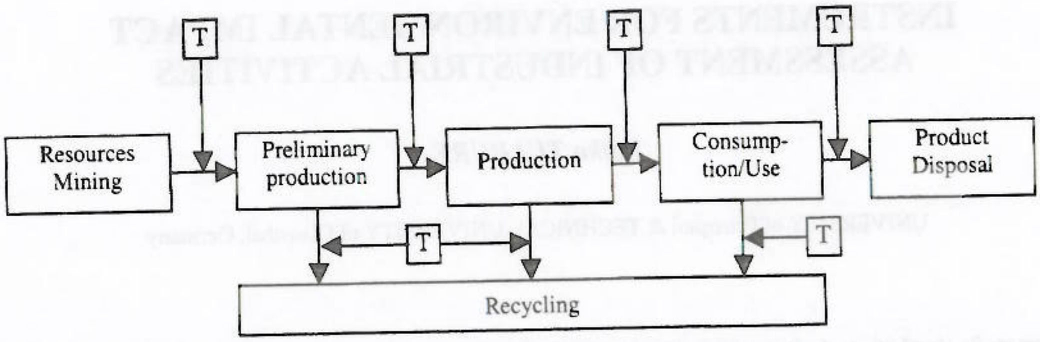

Fig. 2. General life-cycle of products.

3. LIFE-CYCLE-ASSESSMENT (LCA)

The LCA is an analysis which registers all the effects on the environment of a product during its life "from the cradle to the grave", from the production to the consumption and recycling. The general life cycle of a product is presented in Figure 2. We see that besides production and consumption processes also transport processes are taken into consideration. With T are indicated the transport processes within the life cycle of a product.

The life-cycle-analyses is appropriate to improve the production lines of products, to compare different products and to ecologically optimize the life-cycle of products. The LCA is in fact an ecobalance which can be performed as a singular study or as a comparative study. The ecobalance registers material and energetical flows when producing something, or within a process or within a company or a region. Such an analysis needs several steps [1]:

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 releases to air, water and land associated with the system.

c) *Impact assessment* - It is aimed at evaluating the significance of potential environmental impacts using the results of the inventory analyses. The impact assessment may include elements as: assigning of inventory data to impact categories, modelling of the inventory data within impact categories and possibly aggregating the results in very specific cases and only meaningful. It is to be mentioned that the methodological and scientific framework for impact assessment is still being developed. Very often in the step of assessment aggregated indicators are used in order to allow a transparent evaluation (see the 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 takes the form of conclusions and recommendations to decision-makers, consistent with the goal of the study.

With respect to the LCA a difficult step is represented by getting on data and informations about the products and production processes. To compare different life cycle stations of a product from the point of view of pollutants emissions a method has been developed at the Technical University of Clausthal and will be presented in chapter 4.

4. APPLICATION EXAMPLE FOR ENVIRONMENTAL IMPACT ASSESSMENT IN LIFE CYCLE ASSESSMENT

Aggregated indicators are needed in order to provide a comprehensive assessment of environmental impacts of industrial systems [7, 8]. An application for automotive systems bases on an aggregated emission indicator AEI [4] which consists of the weightened sum of single emissions:

$$AEI = \frac{1}{\sum_i w_i} \cdot \sum_i w_i E_i \qquad (1)$$

where: w_i - weighting coefficients and E_i - pollutants emissions.

The weighting coefficients are determined depending on the effects of pollutants on health and on ecosphere and on the emitted quantity using a fuzzy logic based approach, see for details [7]. The values for weighting coefficients of some pollutants are shown in Table 2.

Accordingly to Figure 2 different life cycle stations of a product can be compared from different point of views. From the point of view of pollutants emission in the atmosphere the comparison can be made by a matrix of emissions as proposed in [4] and shown in Table 1.

Table 1. Matrix of emissions for different pollutants S_j in different life cycle stations P_i.

Phase P_i	Pollutants S_1 ... S_j .... S_m					AEI
P_1	E_{11}	...	E_{1j}	...	E_{1m}	AEI_1
...	...		...		...	...
P_i	E_{i1}	...	E_{ij}	...	E_{im}	AEI_i
...	...		...		...	...
P_n	E_{n1}	...	E_{nj}	...	E_{nm}	AEI_n
Σ	$E_1 = \Sigma E_{i1}$	...	$E_j = \Sigma E_{ij}$	...	$E_m = \Sigma E_{im}$	AEI

In this example two life cycle stations of a generic passenger car are compared from the point of view of pollutants emissions. These are the preliminary production and the utilizing phase of a car. Preliminary production means here making basic materials from natural resources or raw materials. The data used are basically from [6]. For a generic car with an average weight of 1000 kg the emissions data have been calculated in the phase of material fabrication and in the phase of use, see for more details [4]. The generic car is a car with an average weight of 1000 kg, an average mileage of 150000 km and with emissions calculated as average between diesel and petrol motors.

The matrix of emissions with the data for this application example is given in Table 2. The indicator AEI has been calculated with formula (1).

Table 2. Matrix of emissions with emissions in [kg] and calculated AEI for two life cycle stations of a generic car

	CO_2	NO_x	SO_2	CO	AEI
w_i	0,67	0,46	0,42	0,33	
...					
Basic materials fabrication	1692,58	2,16	5,16	0,50	**604,98**
...					
Utilization	29308	189	6,8	804	**10633,76**
...					
Σ	**31000,58**	**191,16**	**11,96**	**804,5**	**11238,74**

The results obtained emphasize that in the utilizing phase of a car the most pollutants are emitted compared with the fabrication phase. It is to be mentioned that transport processes have not been taken into account because of lack of data. It is interesting to calculate this indicator in other life cycle stations too and for other products too allowing in this way comparisons and assessments of different products. In this way dangerous and unsafe points in the production lines can be found and measures to improve production can be established. The results may emphasise that this methodology can be successfully applied.

CONCLUSIONS

For industry and engineers the operationalisation of sustainable development 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 better comprehend 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 aggregated emission indicator has been presented and applied for automotive systems. Results emphasise the working way and the advantages of the presented method.

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