APPLYING SUSTAINABILITY BY MULTIDISCIPLINARY TARGETS

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ABSTRACT: *During the years human economic activities, as industrial, agricultural, and commercial ones have been developed in different areas in order to support an increase of humanity quality of life. Nevertheless various experiences have pointed out that human activities have not only positive direct impacts on society but also negative, unwanted and sometimes unthought impacts on environment and society. As a consequence, humanity is nowadays confronting itself with several challenges on local, regional, national, and even on global level. In this regard debates started for finding best solutions for created situations and from these debates the concept of sustainable development arisen, being defined 1987 in the Brundtland-Report. Considering sustainability, chances and challenges of different technological applications have to be carefully analyzed and assessed, what is feasible to be done by Technology Assessment. With regard to Sustainable Development Goals, SDGs, for assessing multidisciplinary impacts of industrial activities, as technological, environmental and social impacts, physical, technological, environmental an social targets are to be considered. Applying sustainability actually means simultaneously considering different aspects from different fields, what implies taking into account multidisciplinary approaches. Considering multidisciplinarity, the role of physics, and engineering in this regard is pointed out in order to meet the growing demand on natural resources, especially connected to energy supply for covering the constantly growing energy demand. This is representing a challenge also for social and political field, and it follows that in order to comprehensively assess multidisciplinary impacts of technological applications with regard to assuring sustainability and humanity quality of life several multidisciplinary approaches are to be considered.*

Keywords: *sustainability; multidisciplinarity; operationalization; sustainable development goals; technology assessment; life cycle assessment.*

1. Introduction

Currently several global problems are facing humanity, as emphasised in Figure 1, which can be grouped in three classes: growth of world population, increase of energy and natural resources consumption and environmental pollution [4]. These so-called "old" global problems have been completed in the last years by other evolving issues, called "new" global problems, as for instance issues related to the use of ICTs, and the new information society [9]. Starting with the '70 years, in the time of huge technological development the world began to realize not only its chances but also its challenges in the form of undesired effects of human activities, especially industrial ones.

After the Conference for Environment in Stockholm in 1972 and the release of the first report to the Club of Rome „Limits to Growth“ in 1972 “ [4] was at the latest understood that besides positive effects of technological advance, also negative effects can appear. As a result in that time the environmental awareness in Western countries began changing by considering potential negative impacts on environment. At that time started to be clear that born regional and global environmental challenges are pretty serious and they should be solved.

2. About Sustainable Development

On global level discussions began on scientific, social, and political level for finding best solutions for arisen problems, which could be applicable with respect to regional differences to the developed as well as to the developing countries. In this context the Brundtland Report of the World Council on Environment and Development, released 1987, represented a result of these worldwide debates, defining for the first time the much discussed concept of sustainable develop-ment, as a potential solution for the global complex ecological, economic, and social problems, as shown in fig.1: *"Sustainable development means the ability of humanity to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs"* [2].

The concept of sustainable development together with its applying forms and understanding patterns was very large discussed on the *United Nations Conference on Environment and Development* in Rio de Janeiro 1992 as well as approached in the closing document *„Agenda 21“* [2]. The vision of shaping a sustainable world was deeply approached during the Global Conference in Johannesburg, known as “Rio + 10” Conference in 2002 [9]. After this time a multitude of activities and initiatives have followed, and these have unambiguously pointed out that evolutions of physical, technological, economic, environmental, as well as of social systems have to be taken into account in synergetic relation. As it is well known, the general Brundtland definition for sustainable development has worldwide been accepted as representing a viable solution for recognised pretty complex challenges. Nevertheless it is to be mentioned that registered experiences since that time have emphasised that the Brundtland definition alone cannot enable gaining a methodological concept, which could be successfully used and applied to different real concrete situations. This fact has been remarked on all considered levels, starting with local and regional levels until national and global levels. As a result manifold debates regarding the necessity to organize a next event have followed, this one being the so-called “Rio + 20” Conference, which took place in 2012 again in Rio de Janeiro [12].

Made experiences since that time have emphasized, that although the general Brundtland definition for sustainable development was worldwide approved, this definition alone is not enough to deliver a pragmatic concept to be successfully handled and applied to many different real concrete situations [3, 7]. This remarked task has been consequently recognized not only on regional or national level, but on global level too. This fact has had as a result more attention brought to sustainable development meaning, following challenging debates on various levels during different events and conferences on a worldwide level. In this context it is to be pointed out that already there are some debates concerning next World Summit for Sustainability, being stated for the year 2022. An event in this year would also represent the celebration of a half of a century since UNEP founding and the 50th Anniversary of United Nations Conference on Human Environment, held in Stockholm in 1972.

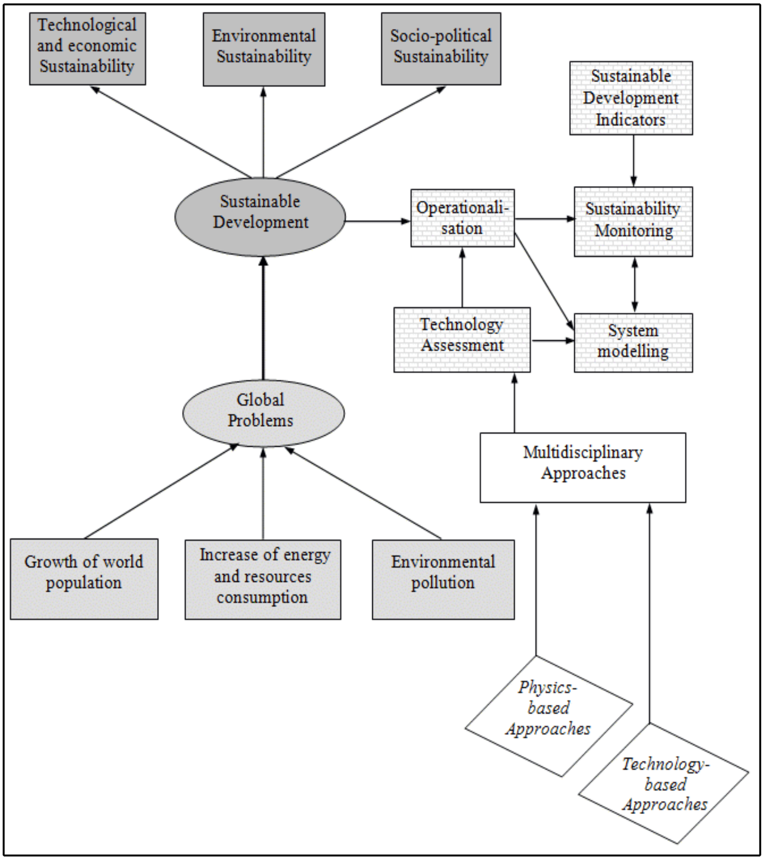

Fig.1. Multidisciplinarity in Sustainable Development Operationalisation

Taking into account mentioned developments, the goal of this article is to point out the need of multidisciplinary targets in order to support assuring human sustainability on various levels [5].

3. Sustainable Development Goals

Sustainable development has in the meantime become a widely used term. Checking specific literature dealing with sustainability topics, the opinion can for sure arise, that there are as many definitions of sustainable development as there are users of this notion [3]. Anyway with the desire of making this concept more understandable, several rules, strategies and principles of sustainable development have been during the time defined and implemented [8]. The same remark can anyway be made, that the general Brundtland definition of sustainable development, together with delivered rules, strategies and principles, still does not deliver a concrete methodology regarding its applying ways to real concrete situations, especially on local or regional level [9].

Situations in different countries have no rarely had as a result serious difficulties in applying the concept of Sustainable Development on a local or regional level, actually not depending on development levels in technological field, in economic or in environmental fields, connected to the socio-political one in various countries [5, 9]. Rating for instance environmental impacts of technological applications could nevertheless enable defining some stringent goals of assuring sustainability on a local or regional level. For sstainability operationalisation there is a need for a general and flexible methodology by a systematic approach, which has to enable defining multidisciplinary targets and by this making possible applying Sustainable Development to each concrete case in specific conditions of the observed system [5].

In this context defined Sustainable Development Goals are very relevant and useful, as being usable for each considered region with various weightings. As mentioned by the UN, Sustainable Development Goals are the blueprint to get a better and more sustainable future for all. They address the global challenges we face, including poverty, inequality, climate change, environmental degradation, peace and justice. The 17 Goals of Sustainable Development, as defined by United Nations, are presented in Figure 2 and mentioned in the following [14]:

Goal 1: End poverty in all its forms;
Goal 2: Zero Hunger;
Goal 3: Health;
Goal 4: Education;
Goal 5: ender equality and women's empowerment;
Goal 6: Water and Sanitation;
Goal 7: Energy;
Goal 8: Economic Growth;
Goal 9: Infrastructure, industrialization;
Goal 10: Inequality;
Goal 11: Cities;
Goal 12: Sustainable consumption and production;
Goal 13: Climate Change;
Goal 14: Oceans;
Goal 15: Biodiversity, forests, desertification;
Goal 16: Peace, justice and strong institutions;
Goal 17: Partnerships.

In order to achieve these goals several specific targets have been defined, which can be regionally followed to be fulfilled, depending on the concrete situation in each considered region.

4. Operationalising Sustainable Development by Considering Multidisciplinary Targets

Operationalising sustainable development actually means translating its goals into measures of various kinds, as especially coming from technical, economic, environmental, socio-political and educational fields. For exact knowing got situation related to sustainable development operationalisation in a certain region there is a need for monitoring and controlling instruments. These should give information with regard to shaping most relevant sustainability targets in order to get mentioned goals, including by this without any doubt multidisciplinary approaches [5]. In this context sustainability operationalization actually means establishing multidisciplinary targets not at least by applying physics - and technology - based approaches on different levels and for various given situations [8]. As it can be recognised in Figure 2, mentioned Sustainable Development Goals are considering multidisciplinary targets [14].

Taking these goals into consideration a general methodology for operationalising sustainability by multidisciplinary targets can be materialized on different levels by emphasising following steps [3, 8]:

- Cstating sustainability target for considered region;
- Cestablishing specific space and time scales;
- Capproaching considered region in a systemic way by modeling existing interactions;
- Csetting up concrete multidisciplinary aims for considered case;
- Celaborating concepts and measures for getting stated sustainability target by establishing priorities;

Fig. 2. Sustainable Development Goals.
(Source: https://en.unesco.org/sustainabledevelopmentgoals)

Cdeveloping monitoring, assessing and controlling instruments in form of indicators;

Cverifying potential results, which could be got after introducing proposed measures by running simulations and by comparing various potential developing scenarios;

Capplying into practical situation most suitable developed concept for the considered case.

In order to succeed a successful sustainability operationalization, made experiences in this field have pointed out that there is necessary to establish concrete aims for an individual problem-case and from these aims concepts to achieve them have to be prepared. In this context sustainability is to be newly defined and approached for each different case. On the other side space and time scales are to be separately established for each case [8]. Such a complex multidisciplinary approach is only possible to be handled if several physical, technological, economic, environmental and social criteria are taken into account as playing main roles [2]. Followed wish is in fact to raise the quality of life of human beings without registering lot of unwanted environmental and social impacts [9].

In order to succeed enabling a multidisciplinary analysis in this regard, methods and instruments of Technology Assessment are to be used and applied for assessing industrial processes by a comprehensive approach with regard to potential economic, environmental as well as social impacts [5, 9, 11].

5. Multidisciplinary Goals by Technology Assessment

After delivering the concept of Technology Assessment, TA around the sixties several publications have appeared, which are dealing with general notions, goals, methods and instruments with regard to this concept. This is the reason why in the following a description of Technology Assessment is not made, only some remarks concerning this concept will be delivered, that are also relevant in the context of operationalising Sustainable Development.

Going into details regarding given methodology for operationalising Sustainable Development one can state that many steps of this methodology can be identified also in the single phases of Technology Assessment [1, 9]. The situation has been identified that often a concrete sustainability task is to be approached by carrying out a study of Technology Assessment. Or such a study has the goal to find out if a technology has negative impacts on different domains, which actually is meaning to find out if the impacts of a technology application do not conflict with the goals of Sustainable Development, as presented in Figure 2 [14].

Concerning the application of the concept of sustainable development there are several levels to do it, starting with the global level until the local or even the sectoral one [2]. On a global level applying sustainable development means to define general aims for the whole world, what actually have more or less happenned with the occasion of the Rio-Conferences [12] as well as with the definition by United Nations of the 17 Goals of Sustainable Development [14], as shown in Figure 2. Applying sustainable development on national level implies to define goals by paying attention to specific conditions of considered countries. On regional or local level concrete measures for applying sustainable development are generally stated in the Local Agendas 21 [3, 8, 9]. On the level of an industrial process or of a product applying sustainable development means to actually use instruments of Technology Assessment [1, 3]. Many methods, which are used in Technology Assessment are also used for applying sustainable development by considering multidisciplinary tasks. In Figure 1 Technology Assessment is mentioned in accordance with the methodology for sustainable development operationalisation [3, 9]. In order to assess potential impacts of proposed measures, control and evaluation instruments are needed, with the goal of shaping sustainable development on a local level.

Technologies evaluations made by engineers have up to now been focused almost without exception on technical aspects, like functionality and safety, and on economic aspects, following legal and financial boundary conditions. Considering sustainability more criteria have to be considered like: environmental quality, social and human values, quality of life. This kind of evaluations need multidisciplinary approaches and interdisciplinary cooperations [2, 9]. Applying Technology Assessment for sustainability operationalisation means analysing the stability of complex dynamic environmental, economic and social systems, in order to find out developments which could demonstrate instabilities. Many fields in this context are to be further researched, as for instance [3]:

- State description using Sustainable Development Indicators (SDI);
- Dealing with uncertain or unclear knowledge;
- Improving methods and instruments;
- Orientation with values and dealing with value conflicts;
- Developing specific assessing criteria;
- Modelling and simulating dynamic systems

Technology Assessment independently how it is called, if Technology Evaluation, Innovation Research, System Analysis or others, brings together almost all of the scientific disciplines in a multidisciplinary task, with the question of how is sustainability to be operationalised by using so-called instruments of Technology Assessment. Actually part of what engineers do is to evaluate developments in technology by applying for instance tools for assessing multidisciplinary impacts of technological applications, as presented in Figure 3, as environmental, technological, social or political ones.

6. Assessing Multidisciplinary Impacts

In order to assess multidisciplinary impacts of different technological applications for rating potential effects of human activities, especially industrial ones on environment, several tools can be used [9]. As presented in Figure 2 the commonly applied ones for usual situations are the Multidisciplinary Impact Assessment, the Eco-Audit and the Life Cycle Assessment, LCA [1, 3, 9].

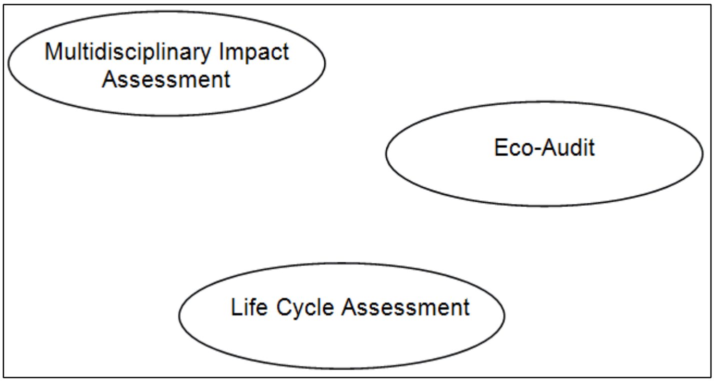

Fig. 3. Tools for assessing multidisciplinary impacts of technological applications

6.1. Multidisciplinary Impact Assessment

Regarding Multidisciplinary Impact Assessment it is to be mentioned that since 1985 there is a legislative framework in the European countries. In Germany for example the law concerning the examination of different public or private projects was promulgated 1990. In Romania there is since 1994 a legislative reglementation through the Ordinance of the Minister for Water, Forests and Environmental Protection regarding the examination of potential impacts on the environment of economic and social activities [6]. From the multitude of multidisciplinary impacts, the analysis of environmental effects has as a goal that activities are planed to be carried out in a way that their environmental impacts are as small as possible [4]. Going into details it should be considered that potential consequences of a project have to be searched, described and assessed and that the analysis results have to be delivered to the authorities which have to decide basing on these results. In order to carry out such an analysis, the project, which has to be certified, must contain information about the project itself, about proposed measures to diminish potential negative impacts, as well as about other possible alternatives. The application domain for such studies is generally represented by public projects. The requirements of a project with respect to such a Multidisciplinary Impact Assessment are the following: assessments have to be transparent and public, methods used are to be unified, and results have to be comparable [9].

6.2. Eco-Audit

In the standard family DIN-ISO 14000 is stated that the environmental management in a company is actually representing all of measures directed to organise and lead the activities in a company related to environmental protection, also including installations and plants for environmental monitoring and protection [13]. Taking this into account the Eco-Audit is representing a management tool for a documented, periodic, objective and systematic assessment of the processes regarding the environmental management in a certain company. With respect to environmental protection the Eco-Audit is working in a preventive way. Carrying out an Eco-Audit in a certain institution is actually meaning to monitor the present existing situation in the respective company. Results are stating the potential impact of production processes or other activities in the considered company or institution with respect to the environmental quality. On the other side an Eco-Audit carried out for a company informs about the interest to respect legislative measures and decrees in the field of environmental protection as well as about the goal of the company related to decrease potential environmental impacts [3, 9]. Taking into account the results of an Eco-Audit, it is possible for a company to improve its environmental protection program by reorganising certain production processes or production related activities in the company with considerable environmental impact. The general aim is represented by the fact that companies are actually voluntarily taking part in this process with the conviction of gaining in the end economic advantages. It is to be mentioned that for successfully carrying out an Eco-Audit also a lot of environmental data should be available, which means that an appropriate database should be available. With this goal the steps of collecting, processing and evaluating data and information from companies are relevant, especially regarding production and environment related data [3].

6.3. Life Cycle Assessment, LCA

As a result of the wish to raise humanity quality of life, several activities have been carried out during the years directed to this aim, especially concerning lot of production processes, but also related to non-productive industries, meaning by this especially the services sector as well as tourism industry. All these mentioned activities have had and still do have also in current times as side effect smaller or bigger, anyway not insignificant environmental impacts [2]. One of the most used tools in order o succeed approaching and evaluating potential environmental impacts of different technological applications is represented by the Life Cycle Assessment, LCA [9]. Delivering Life Cycle Assessments of products means taking into account several steps [9, 13]:

- Definition of goal and scope of the analysis;
- Inventory analysis;
- Impact assessment;
- Interpretation of results.

The first step regarding the *Definition of goal and scope* has to clearly state the followed goal, as well as the motivation for carrying out the study, specifying intended audienced. Stating the scope of the Life Cycle Assessment is including several items [13], such as:

- functions of the product;
- functional unit;
- system boundaries;
- used methodology for the impact assessment;
- needs for data requirements;
- made assumptions;
- necessarily considered limitations.

The next phase of Inventory analysis is mainly meaning data collection and stating calculation methods for quantifying relevant inputs and outputs of the approached system. Such inputs and outputs may state the use of resources as well as pollutants emissions by the system [13]. The third step regarding Impact assessment has as a goal assessing possible impacts on the environment by using results of inventory analysis. Impact assessment may possibly include aggregating got results [9]. It is to be emphasised at this point that the methodological and scientific framework for impact assessment is still in development. In this step of impact assessment aggregated indicators are often applied with the goal of enabling transparent evaluations [1]. Last phase regarding *Interpretation of results* deals with putting together findings from inventory analysis and impact assessment in form of conclusions and recommendations to decision-makers [1, 9].

7. Applying Life Cycle Assessment in Multidisciplinary Context

For dealing with Life Cycle Assessment especially for improving various products and by this their fabrication lines in order to get minimum environmental impacts, as a result of many debates in scientific circles, already several years before the international family of standards DIN ISO 14000 for environmental management was promulgated [13]. This family of standards contains also one, the specific norm, DIN ISO 14040, for Life Cycle Assessment. Considering this standard, the Life Cycle Assessment is represented by a holistic integrative analysis, which records environmental effects of a product during its life cycle, starting with its fabrication, and ending with its consumption and disposal, by considering as well recycling, as can be remarked in Figure 4 [9]. It is to be observed that transport processes are also considered in the general life cycle of a product, and stated with „T", not only production and consumption processes. Actually each phase

The life cycle of a product considers relevant phases in existence and use of a product, as presented in Figure 4, starting with the extraction of various resources used to manufacture the product and ending with product disposal [9, 13]. When going into details regarding the most important steps in the product life cycle it can be remarked that there are the following ones, as presented in Figure 4 [7. 9, 13]:

- Resources mining;
- Preliminary production;
- Production;
- Consumption or use
- Product disposal.

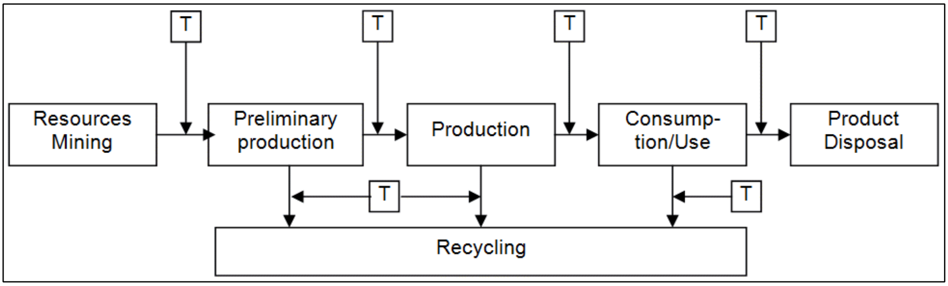

Fig. 4. Phases of the general life cycle of products

in the general life cycle of a product can have relevant environmental impact, but actually not only an environmental impact, but also impacts in economic and social field, considering by this multidisciplinary impact assessment [5].

In the process of carrying out Life Cycle Assessment a difficult step is represented by gaining specific relevant data and information about products and production processes [2, 11]. In order to compare different life cycle stations of a product from the point of view of environmental impacts is generally needed to apply various environmental indicators. Such indicators are applied depending on intended goal of the Life Cycle Assessment of a certain product, meaning by this if the results are assessed on sectoral, local or regional level. [9, 13]. The process of shaping appropriate environmental indicators is currently still in development [1, 5].

Recycling is representing a considerable phase in each product life cycle, actually having a main role in various phases of the life cycle, beginning with the preliminary production, over production and consumption or use of the certain product, as it can be observed in Figure 4.

The step of *resources mining* is including mineral resources extraction, which become raw material used to manufacture the considered product. The step of *preliminary production* is containing the fabrication of components, which will be assembled during production to get the intended final product. In the step of production the components are assembled, resulting the product in its final form.

The phase of *consumption* or use is meaning processes after product sale, because thereafter the respective product is entering in the stage of consumption or use. After the step of product use follows the step of *product disposal*, which is actually the last stage in the product life cycle. In this stage the used product should be directed, if possible, into the phase of *recycling*. Certain product elements, which can not be recycled, finally become waste and enter into the waste processing stage [7, 11].

In order to make possible the use of presented tools for assessing environmental impacts along products life cycle, different steps in the life cycle of a certain product or same step in the life cycles of different products have to be analysed and compared [8, 9, 10]. With this aim aggregated indicators are needed in order to make possbile a comprehensive assessment of environmental impacts of industrial systems [2, 7]. Such an indicator is represented by the Aggregated Emission Indicator, AEI [9], which is defined as the weightened sum of single emissions:

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

where: wi - weighting coefficients and
Ei - pollutants emissions

The use of weighting coefficients is pointing out the fact that pollutants impacts on health and on ecosphere and also the emitted pollutants quantity is not the same for all considered pollutants [8]. By using a Fuzzy Logic based method it is possible to calculate such weighting coefficients, wi for different pollutants, some results for a generic car, having an average weight of 1000 kg, and an average mileage of 150000 km, being given in Tables 1 and 2. According to Figure 4, the environmental impact of different life cycle stations can be compared by presented Aggregated Emission Indicator, AEI [8, 9].

By using the values for pollutants emissions, as given in Table 1, in the fabrication process of basic materials for a generic car as well as in the utilisation phase, the overall matrix of emissions with relevant data for the analysed application example can be got, and is presented in Table 2.

6. Conclusions

Pollutants emissions in the given example, stated in Table 1 are emphasising that most pollutants are emitted in the usage phase of a car. This means that the Aggregated Emission Indicator, AEI is much bigger in this phase compared to the phase of

Table 1: Pollutants emissions in [kg] in the fabrication process of basic materials for a generic car and in the usage phase [9]

Phase of basic materials fabrication (Preliminary production)					
Material	Weight [kg]	CO_2- emissions [kg]	NO_x- emissions [kg]	SO_2- emissions [kg]	CO- emissions [kg]
Steel + iron	654	1007,16	0,78	1,18	0,039
Flush	80	48,88	0,016	0,18	0,0008
Plastics	100	189,3	0,51	1,06	0,072
Alumin.	40	292	0,69	2,44	0,36
Rubber	60	134,59	0,16	0,30	0,027
Glass	35	20,65	0,0046	0,00094	0,007
Σ	969	1692,58	2,16	5,16	0,50
Phase of generic car utilisation (Consumption/Use)					
Generic car		29308	189	6,8	804

basic materials fabrication. It would be of interest to calculate AEI also for other life cycle phases. It is to be expected that in this way problematic points in the production processes can be emphasised with the goal of finding appropriate measures for improving life cycles of considered products by multidiscplinary targets. The growing interest for establishing potential impacts of different products and production processes has pushed forward developing appropriate tools of Tchnology Assessment. Although industrial activities have the aim to support increasing humanity quality of life, nevertheless beside their positive impacts, they often have also negative ones on environment and society.

Several tools of Technology Assessment can be used for evaluating diverse multidisciplinary impacts of human activities. From these ones, the Life Cycle Assessment, LCA is currently world wide used to assess especially environmental impacts of products.

An evaluation method based on the Aggregated Emission Indicator, AEI has been presented and applied for an automotive system.

Got results emphasise working ways of presented methodology and enable assessing different phases of products life cycles. In presented example the phase of geting basic materials needed for a car fabrication is followed by a certain environmental impact regarding air, but the phase of effective car usage produces much more air pollutants than the car production itself. By this a multidisciplinary area is touched, because actually there would be a need of changing human mentalities regarding car using ways, being much more relevant than getting a less pollutant car production process.

From this reason inter- and multidisciplinary cooperation is needed in the future for optimizing products life cycles and by this for minimizing their environmental impacts.

Table 2: Matrix of emissions with emissions in [kg], and calculated AEI for two life cycle stations of a generic car [9]

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

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