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Application of Life Cycle Sustainability Assessment and Socio-Eco-Efficiency Analysis in Comprehensive Evaluation of Sustainable Development

Zastosowanie zrównoważonej oceny cyklu życia i analizy socjoekoefektywności w kompleksowej ocenie rozwoju zrównoważonego

Abstract:
The article presents an overview of a comprehensive evaluation methods for sustainable development. This paper summarizes the state-of-the art with regard to analysis of the environmental dimension, the economic dimension and the social dimension. It was presented two ways of comprehensive assessment of sustainability – Life Cycle Sustainability Assessment (LCSA) and Socio-Eco-Efficiency Analysis. These methods integrate sustainability criteria. Comprehensive assessment of these three components enable the realization of the principles of sustainability.

Streszczenie:
W artykule przedstawiono przegląd metod kompleksowej oceny w zakresie zrównoważonego rozwoju. W pracy przedstawiono stan wiedzy w zakresie analizy trzech wymiarów zrównoważonego rozwoju: wymiaru środowiskowego, ekonomicznego i społecznego. Przedstawiono dwa sposoby kompleksowej oceny zrównoważonego rozwoju: zrównoważonej oceny cyklu życia (Life Cycle Assessment Sustainability – LCSA) i socjoekoefektywności (Socio-Eco-Efficiency Analysis). Metody te integrują kryteria zrównoważonego rozwoju. Tylko kompleksowa analiza wszystkich trzech elementów umożliwi realizację zasad zrównoważonego rozwoju.

Keywords*: Sustainability, Life Cycle Sustainability Assessment (LCSA), Socio-Eco-Efficiency Analysis (SEEbalance), Life Cycle Assessment (LCA), Life Cycle Costing (LCC), Social Life Cycle Assessment (SLCA)*

Słowa kluczowe*: rozwój zrównoważony, zrównoważona ocena cyklu życia LSCA, analiza socjo-eko-efektywności (SEE balance), środowiskowa ocena cyklu życia LCA, koszty cyklu życia (LCC), społeczna analiza cyklu życia (SLCA)*

Sustainability means that manufacturing processes are considered from the perspective of all the sustainable development factors – environmental, economic and social aspects – in whole life cycle (fig.1). One of the methods to comprehensive assessment processes, products or technologies at every stage of life is Life Cycle Sustainable Assessment (LCSA). The second method of the effectiveness assessing of taking into account all three components of sustainable development is Socio-Eco--Efficiency Analysis (SEEbalance).

Sustainability was adopted by UNEP in Rio de Janeiro (1992) as the main political goal for the future development of humankind. It should also be the ultimate aim of product development. Sustainability comprises three components: environment, economy and social aspects. These components of sustainability have to be properly assessed and balanced if a new product or technology is to be designed or an existing one is to be improved [1,2].

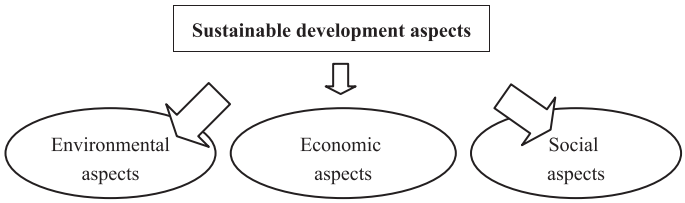

Fig. 1. Sustainability components

Integration of sustainable development aspects into Life Sustainability Cycle Assessment

Sustainability consists of the three dimensions for which society needs to find a balance or even an optimum [3,4]. The concept of sustainable development was first described in 1987 by the World Commission on Environment and Development under the leadership of the former Norwegian Prime Minister Brundtland [4]. It describes a development that is capable to cover today's

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needs for an intact environment, social justice and economic prosperity, without limiting the ability of future generations to meet their needs. The preservation of the natural environment is a prerequisite for a well-functioning economy and social justice. Thus it is necessary to bring the three pillars of sustainability – environment, economy, social well-being in harmony in all areas of life, both nationally and internationally.

Finkbeiner et. al. [5] explore the current status of Life Cycle Sustainability Assessment (LCSA) for products and processes. For the environmental dimension well established tools like Life Cycle Assessment are available. For the economic and social dimension, there is still need for consistent and robust indicators and methods. In addition to measuring the individual sustainability dimensions, another challenge is a comprehensive, yet understandable presentation of the results.

The first conceptual ideas leading to the LCSA approaches of today can be attributed to the German Oeko-Institut with their method called "Product Line Analysis" (German: Produktlinienanalyse) in 1987 [6] and later O'Brian et al. [7]. Kloepffer put the LCSA (Life Cycle Sustainability Assessment) framework into the conceptual formula (1) in 2007 [8] which was improved into its current form (1) including editorial hints of Renner and Finkbeiner [9,10].

$$LCSA = LCA + LCC + SLCA \quad (1)$$

where LCA is the SETAC/ISO Environmental Life Cycle Assessment, LCC is an LCA-type Life Cycle Costing assessment and SLCA stands for societal or social Life Cycle Assessment.

Environmental Aspects

LCA represents application relating to the environmental dimension of sustainability. The international standards ISO 14040 and 14044 are now the main reference system in performing LCA [11,12]. Structure of LCA consists of goal definition and scoping, inventory analysis, impact assessment and interpretation. LCA is a holistic, system analytic tool and is now an established and integral part of the environment management tools. LCA is distinguished from other environmental assessment tools by two main features [13]:

- Life cycle perspective: all phases (from the cradle to the grave) of the life cycle of a product (good or service) – from the extraction and processing of the resources, over production and further processing, distribution and transport, use and consumption to recycling and disposal – have to be assessed with regard to all relevant material and energy flows.
- Cross-media environmental approach: all relevant environmental impacts are taken into account, i.e., both on the input side (use of resources) and on the output side (emissions to air, water and soil, including waste).

According to ISO 14040 LCA is defined as "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle". Life cycle assessment and application of LCA in the analysis of industrial processes have been described by Burchart-Korol [14,15].

Economic Aspects

For the economic dimension of sustainability, there are a variety of approaches for the calculation of cost and performance. The economic evaluation is usually done by considering manufacturing costs (from a business perspective) and life cycle costs (from the customer's perspective) [16]. The life cycle costs are the total costs of a system or product, produced over a defined life time [17,18]. The synonyms 'total costs' or 'total life cycle costs' indicate the coverage of all costs; without assigning them to a cost unit. Including further performance parameters can be addressed by life cycle costing in a broader sense. A key challenge for life cycle costing is the different possible perspectives when considering the life cycle costs [19]. The term life cycle costing is used for total-cost-of--ownership assessments as well as external or social cost assessments.

Life Cycle Costing (LCC) summarizes all costs associated with the life cycle of a product that are directly covered by one or more of the actors in that life cycle (e.g., supplier, producer, user/consumer and those involved at the End-of--Life); these costs must relate to real money flows in order to avoid overlap between environmental LCA and LCC. Environmental LCC is performed on a basis analogous to LCA, with both being steady-state in nature. This includes the definition of a functional unit and similar system boundaries in both LCA and LCC. Ideally, an LCA or LCI should be available for the same product system(s), but a LCC can also be performed as a stand alone assessment [10]. This environmental LCC is shaped according to the structure of LCA, as defined in ISO 14040. It includes the whole physical life cycle of a product with the use- and end-of-life phases and avoids any monetization of external costs, which may occur in the future due to environmental damages in order to avoid double counting. In contrast to LCA, LCC has no component Impact Assessment. The aggregated result is a calculated cost per functional unit expressed in one of the well known currencies.

Social Aspects

The social dimension of sustainability captures the impact of an organization, product or process on society. The social benefits can be estimated by analyzing the effects of

the organization on stakeholders at local, national and global levels [20]. The majority of social indicators measure the degree to which societal values and goals in the particular areas of life or politics can be achieved. However, many social issues on which a performance measurement takes place are not easy to quantify. Therefore a number of social indicators contain qualitative standards of systems and activities of the organization, including operating principles, procedures and management practices. These indicators address needs specific to social issues such as forced labour, working hours or existence of trade unions.

The SLCA captures the impact of an organization, product or process on society. The area of research for SLCA is currently still in its infancy but an increasing number of scholars does it. Social Life Cycle Assessment (SLCA) explores social aspects throughout the product life cycle, generally with the aim of improvement or in comparison to an alternative. The methodological framework, proposed by the UNEP-SETAC Life Cycle Initiative, is based on the ISO-LCA structure. The methodology is object of an increasing number of published papers [21-25]. SLCA is a social impact assessment technique that aims to assess the social aspects of products and their potential positive and negative impacts along their life cycle encompassing extraction and processing of raw materials, manufacturing, distribution, use, re-use, maintenance, recycling and final disposal. SLCA complements LCA with social aspects. A review and current challenges of SLCA have been published by Jørgensen et al. [24,26,27]. Recently, UNEP published Guidelines for Social Life Cycle Assessment of Products [28] which address the overall concepts and methods of SLCA. The Guidelines for Social Life Cycle Assessment of Products provides a map, a skeleton and a flash light for stakeholders engaging in the assessment of social and socio-economic impacts of products life cycle. SLCA is at an early stage of development and a standard and a Code of Practice for SLCA is under preparation. However, the selection of social criteria and their quantification is still one of the major challenges when implementing the concept of sustainability. There are still research needs and consensus needs of the involved stakeholders. There is currently no uniform usage of a standardized set of indicators, but operationally applicable indicators are available [29].

Evaluation of Sustainability in Life Cycle Sustainability Assessment

Apart from the components presented in this paper, LCSA requires an appropriate multi-criteria evaluation scheme. A general evaluation scheme of LCSA is presented in Fig. 2.

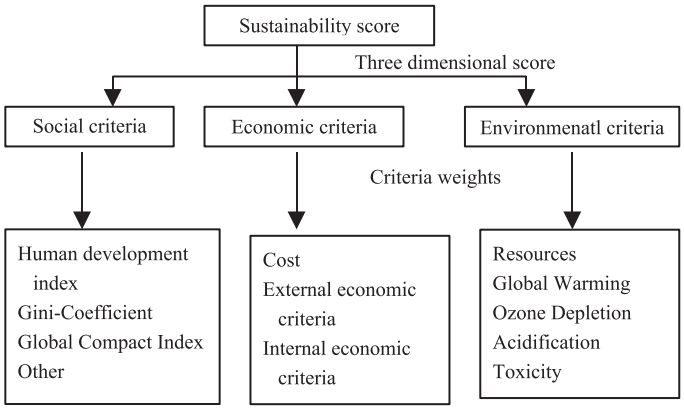

Fig. 2. Three sustainability dimensions in LCSA [5]

Such an evaluation scheme has to address the scales and target levels of the indicators as well as the weighting between them. For LCSA the weighting problem exists on at least two levels:

- weighting of individual indicators within each of the three sustainability dimensions, i.e., weighting between e.g., different environmental indicators,
- weighting among the three dimensions of sustainability

Assessment of Sustainability in Socio-Eco-Efficiency Analysis

Eco-efficiency is a new concept in environmental management which integrates environmental considerations with economic analysis to improve products and technologies. Eco-efficiency is a strategic tool and is one of the key factors of sustainable development. Eco-efficiency analysis allows to find the most effective solution taking into account economic aspects and environmental compatibility of products or technologies [30,31]. According to the concept of Corporate Social Responsibility (CSR) companies operating in accordance with sustainable development should take into account three components – economic, environmental and social, therefore the analysis of eco-efficiency should also include a social element. Extension of eco-efficiency analysis is to analyze the socio-eco- efficiency (SEEbalance®), which refers to the Socio-Eco-Efficiency Analysis developed by BASF. The analysis considers the three dimensions of sustainability: economy, environment and society [32,33].

Socio-Eco-Efficiency Analysis is an innovative tool which not only provides an assessment of the environmental impact and costs of products and processes, but also of the societal impact of products and processes. The aim is to unify and quantify performance of all three pillars of sustainability with one integrated tool in order to direct – and measure – sustainable development in companies. Since the method depends on weighing factors it should be used for internal purposes only. The societal impact is

indicators such as the number of jobs and the number of working accidents occurring during production. Special advantages or risks during the application of the products are also taken into account. The societal indicators are summarized in a societal fingerprint, similar to the ecological indicators. To the social criteria of the eco-efficiency as defined in particular: accidents at work, training, expenditure on research and development. In 2009, the methodology has been extended for a further economic parameters, such as taxes and subsidies [34].

Conclusion

Sustainable development is associated with comprehensive assessment of three components: environmental, social and economic. There are many techniques to assess each dimension separately, but the aim is to assess together the three components of sustainability. Integration of these components enable the methods described in the article – LSCA and Socio-Eco-Efficiency Analysis. LCSA integrates sustainability criteria: LCA for assess the environmental aspects, LCC for assess the economic aspects and SLCA is used to assess the social aspects. Socio-Eco--Efficiency Analysis also takes into account the three dimensions of sustainability: economy, environment and society. Only comprehensive assessment of these three components enable the realization of the principles of sustainable development.

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