



<sup>1</sup>. Magdalena GABRIEL, <sup>2</sup>. Martin TSCHANDL, <sup>3</sup>. Alfred POSCH

## SUSTAINABILITY-ORIENTED LIFECYCLE COSTING

<sup>1-2</sup>University of Applied Sciences, Faculty of Industrial Management  
Werk-VI-Straße 46, Kapfenberg, AUSTRIA

<sup>3</sup>. University of Graz, Faculty of Environmental, Regional and Educational Sciences  
Merangasse 18, Graz, AUSTRIA

**Abstract:** Against the background of increasing importance of sustainability-oriented goals, it is also necessary that the controlling of the company adapts its planning, control and reporting systems. Thus decision-relevant information for the management is available. This requires that the ecological and social impact of a product, system or process must be quantified. For this quantification different models are available in literature: on the one hand environmental and social cost accounting systems, on the other hand rating systems. All these methods quantify sustainability and express it in monetary terms. But they are isolated and independently of the others. To fill this gap the paper aims to create a holistic approach in which the different methods in connection with the concept of lifecycle are combined. So a "cradle to cradle"-consideration of the sustainability cost is possible. Because of this the main objective of this paper is to show how the lifecycle concept can be used for a sustainable cost accounting approach (sustainability-oriented lifecycle costing). Additional to this recommendations for practical use are derived. To achieve these objectives the three dimensions for holistic management of the triple bottom line are described theoretically by the different instruments. All of these methods subsequently are connected in the final concept of sustainability-oriented lifecycle costing. Based on this conclusions for practical use are made.

**Keywords:** sustainability-oriented lifecycle costing, lifecycle, holistic approach

### 1. WHY IS SUSTAINABILITY-ORIENTED LIFECYCLE COSTING RELEVANT?

By the global integration of finance, production and consumption, globalization turns out to be a driver of economic growth. At the same time it leads to an overload of our social systems and the regenerative capacity of nature.[25] If the negative consequences of this trend are more noticeable, sustainable management also becomes increasingly important. Development is considered sustainable if "*it meets the needs of the present without compromising the ability of future generations to meet their own need*".[5]

This definition gives insufficient evidence for the management and must be concretized by objectives:[24]

- Compliance with the triple bottom line (the company's success is sustainable if it meets economic, environmental and social criteria)[6]
- Striving for effectiveness (achievement of all areas of the triple bottom line) and efficiency (especially in terms of material/substances/energy)
- Long-term orientation (long-term investments for future profits versus short-term investments, often forced by financial optimization)
- Opportunities/fairness for generations (especially concerning raw materials)
- Methodological integration of social and environmental management systems in the company
- Observance of cultural and ethical relativity (due to different social, moral and economic developments in the region, country, markets).

### **1.1 Motives of sustainable management**

What are the reasons for a company to strive for sustainability without compromising their competitiveness? Possible motives are the legitimacy and (social) adoption due to reputation and trust, minimization and management of risks, the use of potentials due to differentiation and innovation, increasing productivity by eco-efficiency and socio-efficiency or the receipt of values of the decider.[23] Sustainability is an interdisciplinary, cross-divisional and cross-departmental issue and, therefore, an increasing strategic topic for the company. For these reasons, sustainability is getting into the focus of (top)-management and, consequently, in the area of controlling.[15]

### **1.2 Development of new tools of cost management**

Important indicators for controlling of sustainability in business are costs and revenues. In the 1980s and 1990s it became a reorientation of the priorities of cost accounting. Reasons for this trend were a high number of product or process innovations, an increasing complexity of the business environment, shortening market phases while extending the develop- and decline phases, an increasing variety or an increasing of cost and lower revenue decreased within earlier stages of the product.[22] Subsequently, the development of numerous reorganization proposals came into theory and practice with target costing, benchmark costing, process cost accounting or lifecycle-oriented models.[19] The special feature of lifecycle models are the early provision of information for decision making. Especially in the early stages of a lifecycle, with a low level of information, basic decisions are made that affect the entire lifecycle and are often difficult to revise.

To guide sustainability along a "sustainable path" it makes sense for companies to know identification of the sustainability costs of the lifecycle of their processes, materials and products. This allows identifying those processes, materials and product mix which are preferred to make their defined sustainability goals attainable. This paper shows how the lifecycle concept can be used for the approach of sustainability-oriented lifecycle costing. The description of the three dimensions of sustainability in such a lifecycle costing should provide evidence for a practical implementation as part of a sustainability controlling.

## **2 APPROACHES FOR DETERMINING SUSTAINABILITY COSTS - AN OVERVIEW**

When companies follow strategic and ethical reasons as well as economic, ecological and social objectives, it becomes practice to question how sustainability affects their triple bottom line. What added value can be achieved for the company through holistic consideration of economic, environmental and social aspects? To answer these questions it is necessary to quantify the ecological and social impacts of a product, a system or a process. There are different models available in literature for the evaluation of sustainability: One is environmental and social cost accounting systems. These models offer transparency about ecological and social costs and potentials to reduce them. There are also rating systems to evaluate ecological and social impacts. These models assess the impacts, quantify and finally express them in monetary terms.

### **2.1 Existing approaches to environmental cost accounting**

Each activity of a company, in which natural resources are used, is also a burden on the environment. In past, a large part of the costs, the company has created in connection with the consumption of the natural resources, not taken into account. Due to the increasing requirements of relevant stakeholders, companies often have to internalize their external ecological costs.

Many companies realize that the reduction of environmental pollution not only lead to costs but also often accompanies positive financial aspects. For example, by reducing the use of material a reduction of waste can be achieved simultaneously. This leads on the one hand to declining purchasing costs and on the other hand to a reduction of disposal fees. Consequently, the main task of environmental accounting is to identify such ecological cost reductions. In table one it is shown a literature review of existing models of environmental cost accounting.[8,17]

Table 1 – Summary of the objectives of environmental cost accounting

Approaches for environmental cost accounting	Consideration of internal environmental costs	Consideration of external environmental costs	Allocation of costs to those who generate	Disclosure of cost reduction potentials	Special accounting	Representation of material flows
Environmental costs on full cost basis	●		●	●		
Activity based costing	●		●			
Residue costing	●			●		●
Flow cost accounting	●		●	●	●	●
Ecology oriented costing	●	●	●	●		
Costs of environmental effects	●	●			●	
Full Cost Accounting	●	●			●	
VDI-Guideline 3800	●				●	
Environmental budgeting	●				●	

The following conclusions can be drawn from table 1. The main task of environmental cost accounting is, as already discussed, the disclosure of interdependencies between economic and environmental objectives within the company. Therefore it's possible on the one hand to identify the indeed ecological costs while on the other hand identified cost reduction potentials can be identified. Based on these objectives of the environmental cost accounting, the analyses of the existing literature shows that none of the above stated approaches fulfill the defined objectives completely. This is due to the lack of cause-appropriate allocation of costs of a particular product in which cost reductions cannot be identified. Additionally, external effects are not completely considered so the total costs are unknown.[8,17]

## 2.2 Existing approaches to social accounting

In addition to the environmental aspects also social and community issues are gaining importance. At the same time, however, studies show that those specific instruments to get into account the financial impact of increased social orientation, in terms of a social cost accounting, are hardly implemented and put into operation.

Analogously, it can be, as related to the current application state, of what seen in the literature that many authors deal with the financial impact of increased ecological orientation of a company. In contrast to this, studies that deal with a stronger social orientation are not widespread. The main reason for this trend is that most companies focus their efforts on qualitative social aspects which usually are difficult to express quantitatively. Concerning this issue table 2 shows methods which represent social aspects in an alternative way.

Table 2 – Summary of methods for determining social costs

Approaches for social cost accounting	Qualitative statement about social aspects	Quantitative statement about social aspects	Consideration of internal effects	Consideration of external effects	Discussion in the literature	Practical application
Social cost accounting		●	●	●		
Social reporting		●	●	●	●	●
Global Reporting Initiative	●		●	●		●
ISO 26000	●		●	●		●

It turns out that the companies try to pursue the social component of sustainability inside and outside of the company boundaries. However, the financial impacts are considered less. This is due to the lack of consistent methods of social cost accounting. Instead, the companies try to show their social commitment with welfare reports. This gives the stakeholder an overview of social activities of the company, but cannot be directly related with the improvement costs and the raising revenues to be recognized.[14]

## 3 THE LIFE CYCLE MODEL

The analyses in the previous chapter show that the existing approaches for environmental and social cost accounting have limited impact areas. In a sustainability controlling system it's

necessary to include all three dimensions of sustainability. For this the lifecycle model is a possible evaluation system.

The term cycle describes a circulation of periodically recurring things or events. In analogy to biology the lifecycle process can be interpreted from the emergence until the downfall of an object or subject. Transferred to companies, the life cycle concept can be applied to products, technologies, projects or systems as well as companies or whole industries. It is effective to subdivide the whole lifecycle in phases. Number and type of these phases are dependent by the underlying object. The phase-oriented structure has the advantage of a holistic and dynamic view. In the following section we first discuss the life cycle of a product type and afterwards the life cycle of a single product or a product system.

### 3.1 The lifecycle of a product type

The product lifecycle concept was originally designed as a marketing tool in the 1950s. With this model it was possible to determine the current position of the product within its lifecycle. The aim was to predict on future expected sales and profit trends. Based on these trends, strategies and actions were defined according to the current phase.[22,7]

Originally, the product lifecycle model described only the market phase of a product type which means the time from the launch of the product until its exit from the market. However, the lifecycle of a product type already starts before the market entry which is usually with the first idea in the research. In addition, the lifecycle isn't completed until the disappearance from the market in which the subsequent disposal must also be considered. Therefore it can be seen that the consideration of the market phase alone is not sufficient. *Pfeiffer/Bischof* recognized this problem and developed the concept of an integrated product lifecycle. This model divides the cycle into three main phases: in addition to the known market phase it has an upstream development phase and downstream disposal/recycling phase.[18,7,22] By this extension it is, therefore, possible to consider planning and preparatory activities of production as well as waste management and service tasks. This can ultimately have a significant effect on the company's success.[22] Each phase is further divided into sub-phases in which different activities are performed. (Figure 1) [7]

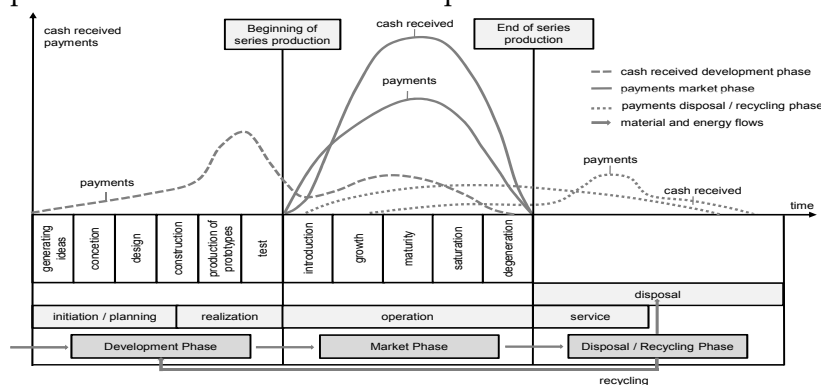


Figure 1 – Integrated product lifecycle

The **development phase** is very important in the integrated product lifecycle because the decisions at this stage always have a major impact on the subsequent phases. In the development phase, not only the costs of the subsequent stages are defined but also environmental impacts and social impacts for the entire production process are

predestined. With increasing specification of the product and its associated production steps it becomes more difficult to reduce the influence possibilities for further phases.

While the product is in the **market phase**, the production takes place which is based on the previously described development phase. Parallel to the production of the product, actions for maintenance and for services are considered. The market phase can, for example, be divided in the five sub-phases of introduction, growth, maturity, saturation and degeneration. It can be observed, that the development phase is extended while the market phase becomes shorter. This development has to be justified on the one hand by the fact that consumers change their desires faster and tend to be of higher quality and individuality while on the other hand companies pursue the effort to meet these changed customer requirements by differentiating products and thereby protect and expand market share.



The main focus of the last phase of the integrated product lifecycle, the **disposal/recycling phase**, is the implementation of actions to eliminate or recycle wastes that arise during the production. In addition to this service tasks such as repair and maintenance services, as well as customer service and training are also perceived in this phase. As the costs in this area are rising, especially through legislative measures, this phase becomes increasingly important for companies. Governmental regulations and laws encourage companies to design their products in a way that the subsequent disposal may take place easily. Therefore, long-lasting, maintenance-friendly and recyclable products should be developed.[7,22]

### 3.2 The lifecycle of a single product or a product system

Previously the options were examined to determine costs and revenues of a product type throughout its entire lifecycle. Next to this there is also the possibility to make a material and energy flow analysis along the phases of the lifecycle of a single product or product system. From there, opportunities can be derived of how the ecological characteristics of a single product, a process or a company can be optimized within a defined period.[2]

The system boundaries of this approach can be defined, depending on the company, basically as free. However, within the meaning of the concept of sustainability, the holistic consideration room of cradle to grave fits especially well. This scope offers the possibility to consider environmental aspects and potential environmental impacts of the product throughout its entire lifecycle which include raw material extraction to final disposal. The observation is also not just limited to their own production but also across the upstream and downstream companies.[13] This approach is also used in the course of life cycle assessment which is standardized according ISO 14040. According to the standard it refers to environmental aspects and potential environmental impacts, for example the use of resources and the environmental impact from emissions, over the lifecycle of a product from raw material acquisition through production, use, waste treatment, recycling and final disposal.[2]

### 3.3 Lifecycle and Cost Accounting

An approach for sustainable lifecycle costing should support the comprehensive management of the triple bottom line and also the strategic sustainability controlling. In the literature lifecycle costing approaches have been discussed for some years. A literature analysis shows that the approaches of the early lifecycle cost accounting focus primarily on determining the profitability of an investment or a major project. The methods usually consider only the use phase of an object and the costs of the development phase while the disposal/recycling phase will not be considered. In contrast in most current models of the lifecycle of a product are considered. In addition, the analysis period is extended by a development and disposal/recycling phase.[26,16,7,22]

Within all examined lifecycle approaches thus far the ecological dimension of sustainability is taken into account only once which is in the ecological lifecycle accounting from *Fassbender-Wynands*.[7] The social dimension is never even considered. One approach which links sustainability and lifecycle costing cannot be found yet.

## 4 SUSTAINABILITY-ORIENTED LIFECYCLE COSTING

Sustainability controlling means the management of sustainability along the planned finish line of the company. If sustainability-oriented lifecycle costing wants to make a contribution to this goal, all economic, environmental and social costs are taken into account throughout the lifecycle of a product. For this purpose it is useful to subdivide the cost analysis for the different dimensions of sustainability, economy, environment and social aspects. For each dimension already internalized effects have to be observed. Additionally, even externalities have to be considered. Not all of these

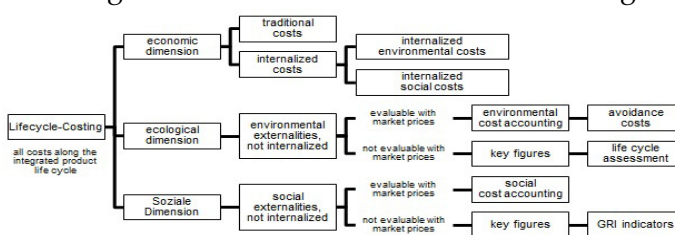


Figure 2 – Dimensions of lifecycle costing

effects can be measured in monetary terms. In this case, non-monetary quantitative values must be used (Figure 2).

#### 4.1 Economic dimension of lifecycle costing

In the economic dimension of lifecycle costing all directly attributable (internal) and internalized (microeconomic relevant external) costs and revenues that are considered have to be considered along the integrated product life cycle. Thus, besides the traditional internal costs for material, staff, transportation or maintenance costs, also those costs to avoid or reduce, protect, substitute or eliminate environmental pressures or social burdens have to be valued at market prices and taken into account.

The ultimate costs in the **development phase** of the integrated lifecycle are relatively low. However, this phase determines 60 to 95% of the cost of the subsequent phases.[16] The classical costs in this phase are costs for basic research or applied research, costs of development of products or processes, costs for preparation of production or costs that may already be assigned for sales and marketing. Additionally already internalized environmental and social effects (e.g. costs of substitution by environmentally friendly material or design under environmental and social aspects, ...) are also taken into account. In addition to these higher costs, however, potential savings can be uncovered in future phases. Revenues in the development phase are resulting from the integration of environmental and social aspects of public subsidies or tax breaks.

The majority of the costs in the **market phase** refers to the purchase of resources such as machinery, the production of goods, and is in line with production carried out within maintenance activities. In addition, costs are also taken into accounts that are incurred for the marketing and distribution of products. Costs for preventing or reducing environmental and social effects (e.g. costs of substitution for purchase, costs of security and control measures or costs of health promotion activities) also have to be considered. The revenues achieved in the market phase relate primarily to the sale of products. Besides, it is possible to obtain more revenues in addition to traditional sales, for example, through its premium service and repair services. If the company considers environmental or social requirements, this may be perceived by customers as being very positive. This can result in additional revenues such as organic food or non-sandblasted jeans.

Within the final **disposal/recycling phase** there is usually only a very limited ability to generate revenues to cover the existing costs. This shows again the importance of the decisions taken during the development phase, as these have a direct impact on the cost of the disposal/recycling phase. Of particular importance in this phase are costs for disposal and recycling of waste exemplified by costs for measures for recycling or for the environmentally compatible disposal. Moreover, costs for downstream services are mentioned within this phase. Social costs are also identifiable within this phase. Within the disposal/recycling phase is the possibility of achieving revenues which can be classified as rather low. In general, these are by sales of used production facilities, surplus substances and materials or buildings.[7]

#### 4.2 Ecological dimension of lifecycle costing

The ecological dimension of lifecycle costing deals with external environmental costs that are not internalized. *Roth* describes external corporate environmental costs as environmental pressures caused by the company that aren't internalized yet. Consequently, they have not yet been considered in the company's cost accounting and must be paid from other in the form of tangible or intangible damage.[21]

It is possible to compare the potential loss of revenues, due to perceived environmental impacts of production, to those costs which would be spent for an internalizing such as those costs for reduction, substitution, recycling and disposal of ecological effects. Additionally those costs, that would be spent by prophylactic avoidance of external environmental impacts could be determined. These costs would have to be estimated without knowing the exact causal relationships.

Abatement costs are usually assumed for external effects whose effective damage costs cannot be determined or only with great difficulty and/or large uncertainty estimable costs such as external costs because of climate change due to the greenhouse effect.[12,1] Potential abatement costs can also be used as a basis for the monetization of external environmental effects during the environmental cost accounting. Thus, the ecology-oriented cost accounting is based on this approach. It was designed by *Frese/Kloock* in the late 1980s and developed by *Roth* some years later.[9,21] The model is based on the incompleteness of the conventional environmental cost accounting that considers only internalized costs while costs of external environmental impacts are neglected.

The ecology-oriented cost accounting wants to remedy this deficiency. Not internalized environmental impact costs are recorded (based on abatement costs) and charged in a parallel cost accounting. For a sustainability-oriented lifecycle costing, it is necessary that this special accounting is used in all relevant value added stages and that the values are summed up at the end. To collect the relevant data for this special accounting a considerable effort is to be expected. Moreover, not all environmental impacts can be detected in monetary terms. This may lead to a complete overview of the external environmental effects of each product or product system. To identify significant environmental indicators, it is useful to refer to material and energy balances as a base. Therefore it's also possible to consider external effects. Such material and energy flow analysis along the life cycle is referred to as LCA or Life Cycle Assessment.

#### **4.3 Social Dimension of lifecycle costing**

The rising costs of social systems are increasingly forcing "the government" to limit its spending on social tasks. For this reason, relevant stakeholders of the companies increasingly demand an integration of social aspects into the target system. Consequently companies are further integrated in the social development of society.[11]

To make a statement about the monetary added value of paying attention to social aspects of the company, already internalized values are not sufficient. Beyond that it is necessary to expand the analysis by external social costs, which may be a result of damage to human health or arises because of the destruction or diminution of property values.[4] A monetary assessment of social impacts is only within narrow borders possible. To determine social effects and, subsequently, evaluate their impact on society, there have been different approaches developed in recent years in the literature. The focus of the models is the provision of indicators to measure the social aspects. Social indicators are often not monetarily detectable. Therefore, it is not possible to evaluate these quantitatively, so a qualitative review is required. An example is the measurement of employee motivation which is a subjective and individual assessment.[3]

A comprehensive collection of indicators is provided by the Global Reporting Initiative (GRI). The guideline for the design of sustainability reports includes not only economic and ecological indicators but also social indicators. Through these integrated indicators, the impacts of business activities are presented. GRI indicators are divided into the areas of working practices and decent employment, human rights, society and product responsibility. GRI indicators, especially for the representation of social issues, are in practice especially for large companies.[10]

## **5 CONCLUSIONS FOR PRACTICAL USE**

Using the instrument of sustainability-oriented lifecycle costing the corporate environmental controlling is extended twice. First, it extends the system borders from "cradle to gate" to the entire lifecycle of a product. Second, the focus broadened from the protection of nature to on a consideration of all dimensions of sustainability. The following challenges of sustainability controlling can be detected:

- For sustainability-oriented lifecycle costing it is necessary to create an inventory analysis, in which material and energy flows from raw material extraction to disposal of the product (cradle to grave) or its recycling (cradle to cradle) is also included. In practice, a complete and

detailed survey would be very expensive. Therefore, prioritization of material and energy flows is necessary.

- Sustainability-oriented lifecycle costs can be divided into internalized costs and external costs. External costs are paid by third parties or by the general public. For sustainability-oriented lifecycle costing both types of costs must be considered.
- It must be assessed what proportion of external costs should be monetized in an individual way. This means what proportion can be expressed in monetary units, and which proportion must be expressed with non-monetary indicators (systems).
- In many cases, the monetization of external costs is difficult or impossible. In the representation of sustainability-oriented lifecycle costs through a performance measurement system, the most important non-monetary environmental and social impacts are quantified. For the selection and calculation of the key figures a number of different methods are available. The method of the life cycle assessment according ISO 14040 provides a framework. It does not include any social effects. For a holistic approach this would have to be extended.

Sustainability-oriented lifecycle costing is primarily an instrument for strategic sustainability controlling. It helps in making decisions about the selection of future business or on the production program and assortment. The greatest potential for reducing the cost of sustainability lies undoubtedly in the development phase of each product.

However, the theoretical concept of sustainability-oriented lifecycle costing designed in this paper is just a first small step in the right direction. There is still a great potential for future research especially for practical application in companies.

## REFERENCES

- [1] Adensam, H. et al.: *Externe Kosten - Studie*, Vienna 2002.
- [2] Austrian Standards Institute: *ISO 14040 Umweltmanagement – Ökobilanz*, Vienna 2009.
- [3] Bollmann, B.: *Indikatoren zur Bewertung sozialer Auswirkungen abfallwirt. Maßnahmen*, Vienna 2007.
- [4] Bontrup, H.-J.: *Volkswirtschaftslehre – Grundlagen der Mikro- und Makroökonomie*, Munich 2004.
- [5] Brundtland, G. H., *Report of the World Commission on Environment and Development: Our Common Future*, Oslo: United Nations 1987.
- [6] Elkington, J.: *Cannibals with forks: the triple bottom line of 21st century business*, Philadelphia 1998.
- [7] Faßbender-Wynands, E.: *Umweltorientierte Lebenszyklusrechnung*, Wiesbaden 2001.
- [8] Fichter, K. et al.: *Betriebliche Umweltkostenrechnung*, Heidelberg 1997.
- [9] Frese, E. et al.: *Internes Rechnungswesen und Organisation aus der Sicht des Umweltschutzes*, in: PFuP, Journal 2 1989, 1-29.
- [10] Global Reporting Initiative: *Leitfaden zur Nachhaltigkeitsberichterstattung*, Amsterdam 2006.
- [11] Greisberger, H.: *Positionspapier: Wesentliche ökologische, soziale und ökonomische Aspekte zur Beurteilung von Nachhaltigkeitsberichten*, ÖGUT, Vienna 2011.
- [12] Günther, E.: *Ökologieorientiertes Management*, Stuttgart 2008.
- [13] Herrmann, C.: *Ganzheitliches Life Cycle Management*, Berlin/Heidelberg 2010.
- [14] Herzig, S. et al.: *Wie managen deutsche Unternehmen Nachhaltigkeit*, Lüneburg 2009.
- [15] International Group of Controlling : *Controller Wörterbuch*, Berlin 2010.
- [16] Kemminer, J.: *Lebenszyklusorientiertes Kosten- und Erlösmanagement*, Wiesbaden 1999.
- [17] Loew, T. et al.: *Ansätze der Umweltkostenrechnung im Vergleich*, Berlin 2003.
- [18] Pfeiffer, W.: *Produktlebenszyklen* in: Steinmann, H. et al.: *Planung und Kontrolle – Probleme der strategischen Unternehmensführung*, Munich 1981, 133-166.
- [19] Riezler, S.: *Lebenszyklusrechnung – Instrument strategischer Projekte*, Wiesbaden 1996.
- [20] Roth, U.: *Umweltkostenrechnung*, Wiesbaden 1992.
- [21] Schild, U.: *Lebenszyklusrechnung und lebenszyklusbezogenes Zielkostenmanagement*, Wiesbaden 2005.
- [22] Tschandl, M.: *Perspektiven der Integration im Umweltcontrolling*, in: Tschandl, M. et al.: *Integriertes Umweltcontrolling*, Wiesbaden 2012, 11-39.
- [23] Tschandl, M. et al.: *How to Become Sustainable Considering Ethical Aspects*, in: Koubek, A. et al.: *Bene Meritus*, Graz 2007, 305-327.
- [24] Tschandl, M.: *Sustainability, Ethics and Strategic Management*, in: Oehme/Seebacher (Hrsg.), *Corporate Sustainability: Theoretical Perspectives and Practical Approaches*, Wiesbaden 2005, 17-48.
- [25] Zehbold, C.: *Lebenszykluskostenrechnung*, Wiesbaden 1996.