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Abstract Title: Concept for Integrated Ecological and Economical Evaluation of
Textile Industry Supply Chains

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The recently emerging Lifestyle of Health and Sustainability (LOHAS) among customers uncovers new differentiation opportunities for the fashion industry. Regarding this, a combined evaluation of ecological and economical performance occurs to be a key challenge. Since cost pressure in the textile industry resulted in complex and global supply chains, the selection of economically and ecologically well performing suppliers is of major importance. However, neither the necessary criteria for an economical and ecological oriented supplier evaluation nor the related methods supporting an efficient supplier evaluation process are clearly defined. With the aim to approach this gap, this paper discusses, based on the specific characteristics of textile supply chains, major requirements on evaluation methods for an economical and ecological supplier evaluation process. Moreover, this paper proposes a concept for an integrated approach of economical and ecological oriented supplier operations in textile industries.

Key Words: Supplier evaluation methods, eco efficiency, textile industries

1 INTRODUCTION

Since manufacturing companies have significantly reduced their range of vertical integration in the last years, value-adding stages upstream the supply chain are becoming more and more important. In the recent decades globalization and the internationalization of supply chains enlarged the amount of potential suppliers by far. This development emphasizes the importance of robust supplier selection methods.

The process of supplier selection comprises 1) the search for potential suppliers, 2) the evaluation of potential suppliers by means of defined selection criteria, and finally 3) the selection of one or more suppliers for cooperation (Schoensleben, 2007).

In terms of selection criteria, research and practice have provided a composition of various factors within the last years (Weber et al., 1991). Whereas economical related factors like the purchasing

price, the delivery time or the product quality have long time been the most important aspects for supplier selection, the last decade lead to a significant change. Due to an increasing environmental awareness in society and politics ecologically designed and produced goods are becoming more and more relevant. Manufacturing companies are therefore increasingly forced to integrate ecologically related evaluation criteria into their supplier selection processes.

Especially in the textile industry the growing trend for the so called lifestyle of health and sustainability (LOHAS) among customers forces textile companies more and more to offer products, which are designed and produced due to ecologically related objectives. Simultaneously, economically related objectives stay in the foreground as textile industry is characterized by high cost pressure. Therefore, the textile industry faces the challenge to develop efficient ways to offer eco efficient products. These products have to satisfy the customers' requirements concerning ecology and still be affordable and competitive. Regarding this, the selection of suppliers by means of both ecological and economical aspects can have a significant impact on the overall eco efficiency performance of a textile supply chain. Thus, high cost pressure in textile industry led to complex and long supply chains in the past (Jones, 2002). Consequently, the brand owners in textile value chains, although selling the textile products, are only partially responsible for the ecological impact. A major part of the impact is caused during the different manufacturing steps upstream in the value chain (Seuring, 2004).

In order to conduct a supplier selection process supporting the eco efficiency of products, aspects of economically and ecologically related objectives need to be integrated into a joint supplier evaluation. However, neither the necessary criteria for a robust supplier evaluation in textile industries nor the related methods supporting an efficient supplier evaluation process are clearly defined.

With the aim to approach this gap, this paper discusses the major requirements for economical and ecological oriented supplier evaluation methods in textile industries and proposes a concept for

an integrated approach of economically and ecologically oriented supplier selection. First, the results of a literature research on supplier evaluation methods concerning either economical or ecological evaluation aspects are presented. Then, typical characteristics of textile industries are discussed and specific requirements for supplier evaluation methods in this sector are derived. Based on these requirements, the available methods for measuring economical and ecological supplier performance are evaluated. Using the evaluation results, a concept for an integrated eco efficient supplier evaluation is discussed. The paper closes with a conclusion and an outlook for further research.

2 METHODS FOR AN ECONOMICAL AND ECOLOGICAL SUPPLIER EVALUATION

This chapter provides the results of a literature research on methods for supplier evaluation processes with regard to economical or ecological aspects. The methods introduced are later evaluated with regard to their suitability in textile industries. This contributes to the development of an integrated supplier evaluation process for textile companies concerning both, economical and ecological aspects.

2.1 Methods for supplier evaluation with regard to economical aspects

Although the criteria for supplier selection have changed over time, the economical evaluation of suppliers has always been important. Typical criteria to consider for an economical evaluation are the purchasing price, the delivery time, the delivery reliability, the product quality and so on (Weber et.al., 1991). As a consequence of the multiplicity of these criteria, different evaluation methods were established over time. Differences between these methods can be found especially in the level of detail as well as the area of observation. In order to provide an overview, available methods focusing on economical aspects of single supplier relationships are introduced in the following. In detail, 1) traditional managerial accounting (TMA), 2) activity-based costing (ABC), and 3) total cost of ownership (TCO) are discussed.

In TMA, the economical evaluation of a supplier bases on an evaluation of the variable purchasing costs supplemented by shared fixed costs. Fixed costs consist of expenses by means of supplier and component qualification, purchasing costs, carrying costs as well as costs of receiving and inspecting purchased goods. Fixed costs can be allocated to a product by a percentage of the variable purchasing costs. The percentage is calculated by dividing the total fixed costs by the total variable costs (Schoensleben, 2007). Advantages of TMA are simplicity, low calculation efforts and assured availability of data. Disadvantages are the focus on the purchase price and the imprecision of allocating fixed costs of purchasing.

ABC has been introduced to overcome the shortcomings of TMA (cf. Cooper and Kaplan, 1988). The basic premise of this cost accounting system is a fair and realistic allocation of fixed costs to business processes and activities (Schoensleben, 2007). ABC is applied following several steps. At first, indirect cost resources related to cost relevant value-adding processes are accumulated (e. g. purchasing, receiving, assembly, etc.). Subsequently, cost drivers are identified for each process to allocate the accumulated process costs to products. Examples of cost drivers are number of orders, number of products and time. The process cost rate for each process is calculated by dividing the accumulated process costs by the overall process quantities in units of the corresponding cost driver. Finally, the share of fixed costs of each process allocated to a specific product is calculated by multiplying the process cost rate and process quantity. The advantages of ABC are the high accuracy and the transparency supporting decision making. Disadvantages are the complexity and high effort of determining essential data about processes and cost drivers.

TCO is “a purchasing tool and philosophy which is aimed at understanding the true cost of buying a particular good or service from a particular supplier“ (Ellram, 1993). Beyond the purchase price of a good, costs for transportation and logistics, transaction costs, capital lockup, depreciations and risk costs (e.g. cost related to the delivery reliability of suppliers) are considered. Moreover, TCO compares costs of several periods. In TCO, cost elements associated to the phases of pre-transaction,

transaction and post-transaction are measured (Ellram, 1993). The advantage of TCO is the holistic character of the approach improving decision making in purchasing. Disadvantages are the availability of data and high calculation efforts.

Summarizing the results on all introduced methods, Figure 1 illustrates the main characteristics for the evaluation methods of economical supplier performance introduced above. The main characteristics support the assessment of TMA, ABC and TCO with regard to their suitability for an application in textile supply chains.

Traditional managerial accounting (TMA)	<ul style="list-style-type: none"> ▪ Consideration of variable costs ▪ Allocation of fixed costs with cost keys ▪ Single period consideration ▪ Low efforts for application
Activity-based costing (ABC)	<ul style="list-style-type: none"> ▪ Consideration of variable costs ▪ Calculated allocation of fixed costs ▪ Single period consideration ▪ Medium efforts for application
Total cost of ownership (TCO)	<ul style="list-style-type: none"> ▪ Consideration of variable and fixed costs ▪ Consideration of costs related to transaction, capital lockup, depreciations and risk ▪ Multi period consideration ▪ High efforts for application

Figure 1: Methods for supplier evaluation with regard to economical aspects

2.2 Methods for supplier evaluation with regard to ecological aspects

After introducing available methods for an economical evaluation of supply chain relationships the following part of this paper presents major methods for an ecological evaluation of supply chains. In the literature various methods for assessing ecological performance in supply chain can be distinguished (Srivastava, 2007). Besides a different level of detail, the methods vary by different procedures and different application focuses. In order to provide an overview, this paper discusses the methods of 1) Life Cycle Assessment (LCA), 2) Best Available Techniques (BAT), and 3) Eco Efficiency Indicators.

LCA is widely acknowledged in research and practice as a suitable tool for assessing the ecological impact a product causes during its life cycle. It is standardized within ISO 14040 (DIN, 2009) and has become increasingly accepted in companies for the assessment of environmental performance. The scope of a LCA involves tracking all material and energy flows of a product from the extraction of its raw materials to the disposal of the product back into the environment (Arena et al., 2003). The LCA is divided into four phases: 1) The goal and scope definition phase, 2) the inventory analysis phase, 3) the impact assessment phase, and 4) the interpretation phase. Whereas the goal and scope definition phase defines the depth and breadth of a LCA by determining reasonable system boundaries, the LCI phase conducts an input-output-analysis for quantifying all relevant environmental aspects of a system (like the amount of energy input, the amount of raw material input, the amount of emission to air, the amount of discharges to water and soil etc.). The impact assessment phase evaluates the significance of potential environmental impacts by associating the calculated inventory data with specific environmental impact categories and category indicators. Finally, during the interpretation phase the findings from the inventory analysis and the impact assessment are interpreted, closing with a final evaluation result. Although the LCA was developed for evaluating the whole life cycle of a product, this method can also be applied for specific sections in the life cycle (like the evaluation of the environmental impact of a purchased good of a specific supplier). This was shown within a few applications of the LCA for supplier evaluation (Frankl and Rubik 1999; Walker et al. 2008). Summarizing the general characteristics of a LCA, this method represents 1) a quantitative approach, 2) which allows for an assessment and interpretation of various environmental impacts, 3) referring to the ecological performance of products, and 4) providing a high level of evaluation detail.

BAT, published and continuously revised by the Environmental Protection Agency (EPA), represent a collection of recommendations on best practice techniques, which lead to a minimized impact on the environment. BAT recommendations are available for various industries including the

textile sector. For the latter BAT recommends the use of technologies, which in particular lead to a minimization of emissions to air and water as well as the minimization of energy consumption, since these impacts represents the highest environmental burdens in textile value chains in general (European Commission, 2003). Although the BAT is not directly intended to evaluate the environmental performance of suppliers in value chains, it is possible to use this framework for a qualitative assessment of suppliers by reflecting the suppliers' use of best available techniques. Consequently, the BAT is considered to enable the evaluation of the ecological performance of suppliers. Summarizing, the main characteristics of BAT, this method represents 1) a qualitative approach with a low level of detail, 2) assessing either the ecological performance of a product or a whole company, 3) involving less efforts when applying it, and 4) resulting in incomplete evaluation results because of not considered observation areas (e.g. transport).

A further evaluation method for assessing the ecological performance of supplier relationships bases on the concept of Eco Efficiency Indicators (Schmidt and Schwelger, 2008). The concept of Eco Efficiency Indicators was proposed by the United Nations Conference on Trade And Development (UNCTAD) in 2004 (UNCTAD, 2004). The core idea of this concept lies in an evaluation of specific ecological expenditures caused by companies. The concept refers to five major environmental impacts, namely 1) waste water, 2) energy use, 3) global warming, 4) ozone depleting substances, and 5) treatment of waste. Each dimension is evaluated in a quantitative way separately form each other. Therefore, an integrated evaluation of all impacts is not possible. Concerning the major characteristics of the Eco Efficiency Indicator concept, this concept represents 1) a quantitative approach, 2) which evaluates major ecological influences separately from each other 3) on a company-wide level.

Summarizing the results on all introduced methods, Figure 2 illustrates the main characteristics for the evaluation methods of ecological supplier performance introduced above. The main

characteristics support the assessment of LCA, BAT and the Eco Efficiency Indicator concept with regard to their suitability for an application in textile supply chains.

Life Cycle Assessment (LCA)	<ul style="list-style-type: none"> ▪ Quantitative approach ▪ Multi dimensional impact assessment ▪ Product related approach ▪ High level of detail ▪ High efforts for application
Best available technology (BAT)	<ul style="list-style-type: none"> ▪ Collection of best practice techniques ▪ Qualitative approach ▪ Incomplete mapping of supplier relationship ▪ Low efforts for application
Eco Efficiency Indicators	<ul style="list-style-type: none"> ▪ Consideration of main ecological influences ▪ Quantitative approach ▪ One dimensional impact assessment ▪ Company related approach

Figure 2: Methods for supplier evaluation with regard to ecological aspects

3 SUPPLY CHAINS IN TEXTILE INDUSTRY

In order to determine reasonable evaluation methods for supplier selection operations in textile industries, the particular characteristics of textile value chains need to be considered. For this purpose, this chapter gives an overview about major characteristics of textile value chains, including aspects of textile markets, textile products, and textile technologies. Based on these characteristics specific requirements for economical and ecological evaluation methods for supplier selection are derived. These requirements serve as criteria to evaluate the above discussed supplier evaluation methods with regard to their suitability for the textile sector.

A typical textile supply chain can be divided into seven main stages (see figure 3):

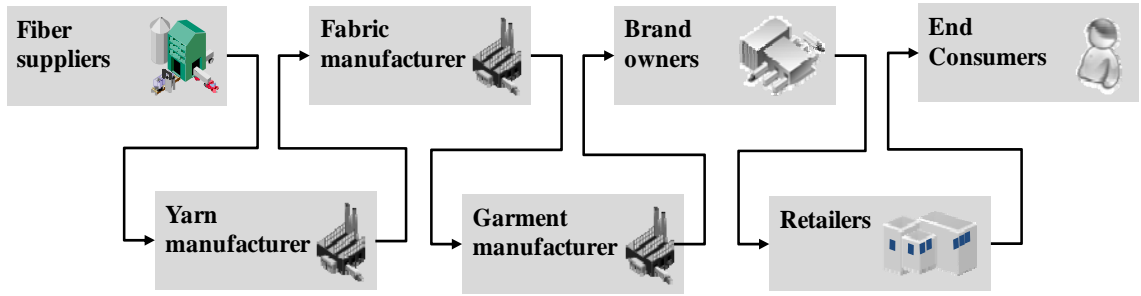


Figure 3: Typical structure of textile supply chains (according to Cao et. al., 2008)

The fiber supplier, either a farmer who produces natural fibers like cotton or wool or a company which produces man-made fibers like polyester or polyamide, provides the raw material. With latter the yarn manufacturer creates yarn. Here, he uses different manufacturing technologies depending on the material machined (Seuring, 2004). Then, the fabric manufacturer converts the one dimensional yarn into two dimensional fabrics, which are being dyed at this stage regularly. Afterwards, the dyed fabrics are used to produce garments. For this purpose, the fabrics are combined with other materials such as zippers or buttons. The manufactured garments are then distributed by the brand owner, who regularly represents the orchestrator in the whole supply chain. For this purpose, the brand owner supplies various independent retailers, which finally sell the textile products to the end customer.

Since centuries of cost pressure in textile industries forces textile companies to exploit regional cost advantages, one typical characteristic of the introduced textile supply chain is its global complexity (Jones, 2002). Normally, fiber suppliers are located in climatic advantageous areas like South Africa, Australia or South America. In contrast, yarn manufactures, fabric manufactures and garment manufactures operate to a considerable extent in low cost countries, especially in Asia. Then again, the brand owners and retailers are located in European and North American countries predominantly. Moreover, the typical market and product characteristics in the textile sector like a short product life cycle, a high volatility of demand, a low predictability of demand, and high impulse purchasing (Fernie and Sparks, 1998), forces the textile supply chain to archive high levels of agility and robustness (Christopher et. al., 2004). Especially the long lead times related to batch production and long transportation times in textile supply chains intensify this characteristic. Another

supply chain characteristic, which has its roots in the requirement for agility and robustness, are limited and long-term supplier relationships on each level of the supply chain. Thus, each supply chain partner tries to minimize its supplier base to a minimum of high qualified suppliers (Christopher et. al., 2004). This supports agile and robust processes and lead to a high level of reliability. Moreover, with regard to the introduced situation of cost pressure in textile industries, strategies for differentiation are very important in the textile sector. Since especially the textile industry has significant environmental impacts along its supply chain (Seuring, 2004), supply chains in textile industries are increasingly forced to optimize their ecological performance.

Summarizing the main characteristics, textile supply chains are globally located, include long-term supplier relationships, cause various environmental impacts and are cost efficient, agile and robust. These characteristics lead to specific requirements on the functionality and scope of economical and ecological supplier evaluation methods (see figure 4).

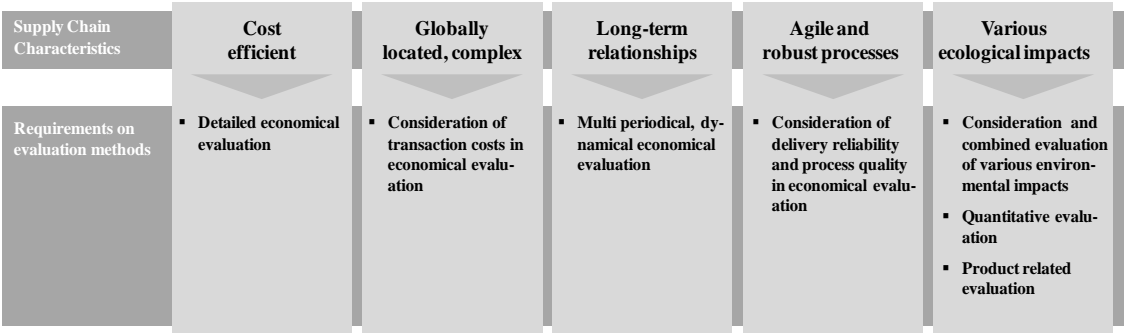


Figure 4: Characteristics of textile supply chains

Thus, the importance of cost efficiency in textile supply chain for example requires a high level of detail for economical evaluations. Since e. g. transactions costs can be considerable high within globally conducted value creation processes (Seuring, 2004), they should be integrated into the economical evaluation of suppliers. Moreover, delivery reliability in general has a significant importance for the overall performance of a textile supply chain (Christopher, 2004). Consequently, also this factor should be integrated into the economical evaluation of textile supply chains.

Furthermore, long-term supplier relationships in textile supply chains argue for a dynamical cost evaluation including multi periodical cash flows.

With regard to ecological supplier evaluation methods, the generation of various environmental impacts within textile supply chains requires for an evaluation method, which can compare different ecological impacts. Moreover, the high importance of customer clarification concerning environmental impacts argues for an application of methods, which are conceivable, comprehensive and result in striking findings. Therefore, especially quantitative methods are suitable. Moreover, detailed product related findings can influence best the customers buying behavior. For this purpose, evaluation methods should refer rather to detail product assessments than to non striking company related assessments.

4 CONCEPT FOR AN INTEGRATED ECONOMICAL AND ECOLOGICAL EVALUATION OF TEXTILE SUPPLY CHAINS

After introducing different methods for either economical or ecological evaluation of supplier relationships (chapter 2) and after determining the specific requirements regarding the functionality of economical and ecological supplier evaluation methods in textile industries (chapter 3), this chapter discusses both findings in a joint context. For this purpose, each method introduced is evaluated with regard to each requirement derived. This assessment provides recommendations on the suitability of each method considered for an application in textile industries and therefore gives insights on how an integrated evaluation of eco efficiency in textile supply chains may look like.

Figure 5 illustrates the results of the assessment of each introduced evaluation method for supplier selection with regard to the specific requirements of an economical and ecological supplier evaluation in textile supply chains. Since the fulfillment of the derived requirements only considers the benefits related to the application of each method, the assessment was complemented with an evaluation of efforts, which occur with implementing and applying the evaluated methods. This

should provide more balanced and comprehensive results. In order to distinguish the level of suitability which each method achieves three different evaluation levels (not suited, partly suited, suited) were applied.

		Methods and Tools for economical and ecological evaluation					
		Traditional managerial accounting (TMA)	Activity-based costing (ABC)	Total Cost of Ownership (TCO)	Life Cycle Assessment (LCA)	Best available technology (BAT)	Eco Efficiency Indicator Concept
Requirements of textile supply chains (Benefit)	Evaluation of variable and fixed costs	◐	●	●	Not relevant for ecological evaluation		
	Evaluation of transaction costs	○	○	●			
	Muti periodical economical evaluation	○	○	●			
	Evaluation of delivery reliability	○	○	●			
Requirements of textile supply chains (Benefit)	Mapping of all relevant processes	Not relevant for economical evaluation			●	○	◐
	Consideration and comparison of multiple impacts				●	○	◐
	Quantitative ecological evaluation				●	○	●
	Product related ecological evaluation				●	◐	○
Effort	Efforts for application	●	◐	○	○	●	◐

○ not suited

◐ partly suited

● suited

Figure 5: Assessment of different evaluation methods with regard to their suitability in textile supply chains

Analysing the result, the assessment indicates that for the economical supplier evaluation in textile supply chains the TCO concept is most suitable. Thus, the TCO concept in-depth considers variable and fixed costs of purchasing, transaction costs as well as costs related to the delivery reliability. Therefore, TCO comprehensively displays the main cost drivers of supplier relationships in textile supply chains. However, the assessment also indicates that the efforts related to the implementation and use of a TCO concept, even in long-term textile supplier relationships, are considerably high. Consequently, companies need to evaluate carefully, whether the benefits of using a TCO concept in textile supply chains justify the efforts related to its use. Since TMA and ABC however completely disregard delivery reliability related costs, transaction costs as well as multi

periodically cash flows, a long-term implementation of TCO for economical supplier selection in textile industries is advisable.

With regard to evaluation methods focusing on the ecological performance of a supplier relation, the assessment indicates that LCA fulfills the determined requirements of textile supply chains best. Thus, LCA provides possibilities to compare the degree of different environmental impacts. Moreover, LCA enables product related, quantitative evaluation studies which are of major importance especially in the textile industry with its aim to establish a high level of traceability and authenticity towards customers. However, the LCA also indicates high efforts regarding time and resources. As an alternative, the Eco Efficiency Indicator concept might be a probable measure. Here the assessment indicates in comparison to the LCA a lower performance with regard to the completeness of all relevant ecological impacts as well as a lower performance with regard to the comparison of multiple impacts. Moreover, this concept is not product related and does therefore not fulfill one of the main objectives of LOHAS. However, since the Eco Efficiency Indicator concept causes in comparison to an application of LCA lower efforts of time and resources, companies might use this concept as a compromise. With regard to the results of the BAT concept, the assessment indicates an overall low level of suitability in textile supply chains. Therefore, the BAT may not be used for the purpose of evaluating comprehensively the ecological performance of suppliers.

In summary, the assessment indicates that especially TCO and LCA fulfill the requirements of an economical and ecological supplier evaluation in textile supply chains. Consequently, an integrated supplier evaluation method incorporating economical and ecological aspects should consist of a combined application of these both methods. This would result in a two dimensional evaluation solution comparing the Total Cost of specific supplier relationship (TCO) with the Total Environmental Impact of the supplier's value creation (LCA).

5 CONCLUSION AND OUTLOOK

This paper introduced the results of a qualitative assessment of various evaluation methods determining the economical or ecological performance of suppliers with regard to their suitability for an application in textile supply chains. Moreover, based on the assessment results achieved, a concept for an integrated supplier evaluation approach, determining the eco efficiency related performance of suppliers in textile industries, was drafted. For this purpose, first different supplier evaluation methods, assessing either the economical or the ecological performance of a supplier, were introduced. In detail 1) TMA, 2) ABC, and 3) TCO were presented as typical supplier evaluation methods, assessing the economical performance of suppliers. Besides 1) LCA, 2) BAT, and 3) the Eco Efficiency Indicator concept were discussed as typical supplier evaluation methods, assessing the ecological performance of suppliers. Moreover, this paper presented main requirements on supplier evaluation methods, which were derived from the specific characteristics of textile supply chains. Referring to this, it was shown that especially transaction costs, costs related to the delivery reliability and dynamical cost evaluations are important requirements of the economical supplier evaluation in textile industries. Consequently, suitable methods for the economical supplier evaluation should fulfil these requirements. Moreover, quantitative and detailed, product related evaluations of the ecological performance of suppliers were discussed as important requirements on suitable ecologically related supplier evaluation methods. With these results TMA, ABC, TCO, LCA, BAT and the concept of Eco Efficiency Indicators were assessed critically.

The results of this assessment indicated that especially LCA and TCO are suitable methods for an application of an integrated supplier evaluation approach of eco efficiency in textile supply chains. However, since the assessment also indicated high efforts of applying both of these methods, efficient ways for implementing and applying an integrated approach of evaluating eco efficiency in textile supply chains need to be found. This situation represents a comprehensive potential for new research objectives, investigating for example possibilities to simplify both methods.

With regard to possible limitations of this paper, it must be stated that the results introduced in this paper are based on the authors' experience and knowledge about supplier selection methods gained within several national and international projects. Moreover, it must be stated that the presented results aimed at generating a general statement, how an integrated concept for evaluating eco efficiency in textile supply chains may look like.

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