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Towards A Digital Workflow Solution For Cradle-To-Gate Sustainability Information In Textile Value Chains

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Abstract

Sustainability aspects and their verification are becoming indispensable for companies in the textile industry from both an economic and a legal perspective. The reason for this is that there is a large number of different certificates, specifications, and labels, such as Global Organic Textile Standard, Fairtrade, or OekoTex, as well as legislation, such as the German Act on Corporate Due Diligence Obligations in Supply Chains issued in 2021.

Hence, the requirements for keeping the proof, e.g. for the batch-accurate world-wide tracing of organic cotton for clothing, or for the necessary transparency to determine the carbon footprint or the recycling percentage, are becoming more and more associated with considerable effort, especially for small and medium-sized enterprises (SMEs). Depending on the certificate or specification, SMEs need not only to determine their own sustainability information (gate-to-gate), but also that of the upstream stages of the value chain (cradle-to-gate). The multi-stage value chains of the SME-dominated textile industry, together with the vast and fast-changing variety of materials and products, lead to high complexity in processes and communication. In addition, when confronted with batch-related sustainability criteria and a variety of sustainability and labelling requests from different customers, SMEs have to spend an increasing amount of time and effort on the reliable provision and communication of the respective information.

The paper describes the challenges and existing approaches, e.g. the use of blockchain technology, associated with the provision of cradle-to-gate sustainability information in textile SMEs and proposes a holistic framework enabling SMEs along the value chain to configure and implement an infrastructure for efficient, fully digital cloud-ready workflow, based on process models and textile product master trees, in order to address these challenges.

Keywords

Cradle-to-Gate Sustainability; Textile Industry; SME; Blockchain

1. Challenges of sustainability information in textile value chains

Sustainability in social, economic and ecological terms is one of the megatrends of recent years [1]. In the textile industry sustainability is also becoming increasingly important for purchasing decisions [2] in the B2B and B2C sectors, as shown in the following examples:

- Large quantities of textiles end up in residual waste and thus pollute the environment. Closed material cycles and recycling have not been established to a larger extent so far. One reason for this is the lack of information on which materials have been processed in the product and how they can be separated, reprocessed and recycled. The provision of such information along the entire value chain is possible [3, 4], but still a challenge.

- The working conditions of the textile industry in low wage countries often do not meet the standards demanded by consumers and NGOs. In addition to legislation, there are standards, certificates and labels to prove social sustainability, but these require a reliable and transparent data basis across the entire value chain. Providing this data is time-consuming, especially when it comes to specific batches and products.

Today, (end) customers expect or demand access to comprehensive data, e.g. via an identifier (QR code, RFID or similar), on environmental impacts (such as carbon footprint), on social standards during production or on the material composition of textile products including all preliminary products [5, 6]. Expectations vary widely across customers, which is reflected in the large number of sustainability requirements and challenges that have to be met by a single company within the textile value chain [7]. Additionally, legislation puts more and more focus on sustainability aspects, e.g. in Germany [8].

Sustainability cannot be measured with a single indicator. Rather, there is a multitude of criteria of different types and structures and thus many types of certificates, labels and standards with different requirements, criteria and system boundaries. SMEs in the textile industry therefore have to provide their data in ever new forms. For example, the producer and all suppliers need a Scope certificate [9] for each delivery of a certified product according to the Global Organic Textile Standard (GOTS) [10]. Transaction certificates for the corresponding batches must also be submitted for the product and all pre-stage products. This process is time-consuming, cost-intensive and limited to specific statements. This form of cross-company communication can only be implemented for a limited number of sustainability criteria by an SME without a supporting organisational and information technology infrastructure.

Traceability for sustainability purposes is the focus of such an infrastructure. Traceability includes the objectives of transparency, identification, authenticity and quantification [11], and corresponding information on: (a) origin of the relevant materials back to the source, (b) material composition (especially with regard to bio-materials and recycling), (c) ecological life cycle assessment parameters (carbon footprint, blue water consumption) with differentiation according to Scope 1 (direct emissions), Scope 2 (indirect emissions through energy used, especially electricity) and Scope 3. 1 (emissions from input products, services) [12] and (d) ecological and ethical verification (certificates such as GOTS [9] or IVN BEST [13]).

In the context of the preparation of internal company data [14], textile companies are faced with some challenges. The type of information collected from suppliers must be selected and for communication the form, granularity and participants must be determined. Also, practical issues like aggregation and allocation of sustainability data on production processes and products arise. Finally, the textile companies have to protect and secure their data. There are numerous individual systems, e.g. Blockchain [15], for this, but no holistic solution. The reason for this is that textiles comprise a variety of products or product types, from clothing to home textiles to technical textiles, with different requirements for sustainability information. Production is usually multi-stage and distributed across many different companies along the value chains with a wide range of semi-finished and raw materials being used. This results in complex material flow with a diversity of textile traceability targets and certificates. The highest complexity in the requirements arises in the case of cross-stage traceability at batch level. Here, the material interrelationships and the associated sustainability information must be mapped across the entire value chain. For one product, the product family tree (see Figure 1) illustrates the basic problem with traceability. Materials from numerous preliminary stages in different quantities and of different natures go into a finished product, such as a garment. For complete traceability, this situation must be mapped in terms of information technology and supported across companies.

However, a reliable provision of information across all levels with the required granularity and the dynamic of the textile value chains with changing network structures from batch to batch (see example in Figure 1 with different yarn networks) is time-consuming. Corresponding data preparation and allocation are today often performed manually and using individually created, complicated and therefore error-prone spreadsheet models. As a result, the quality and integrity of the information also suffer.

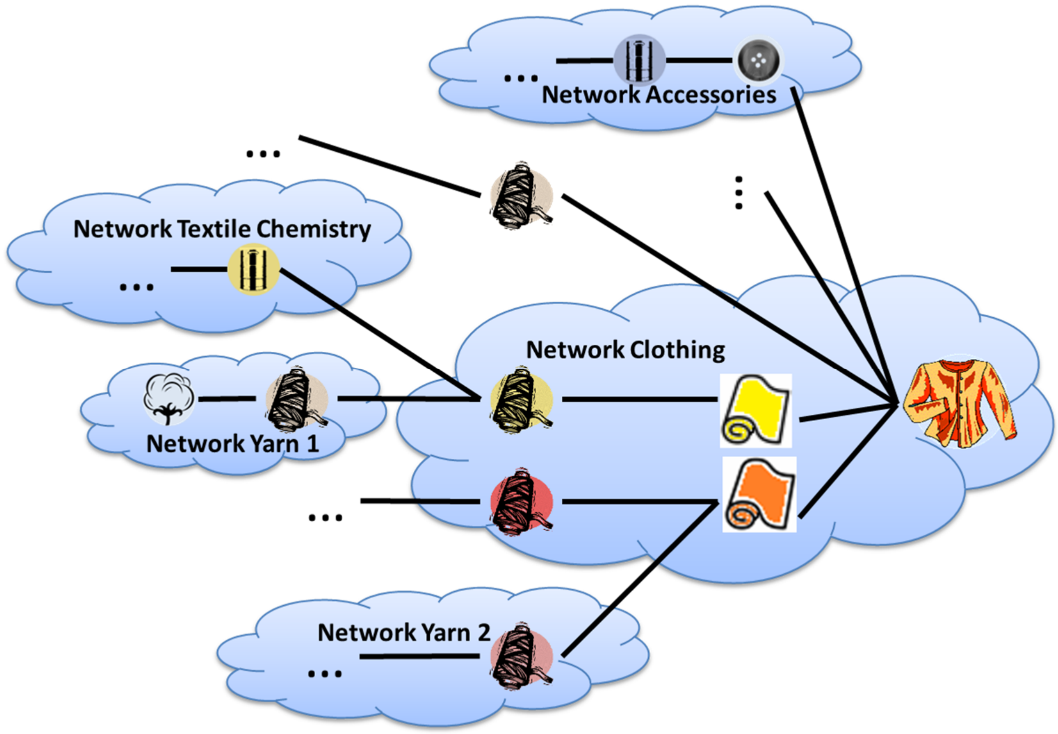

Figure 1: Example of a textile product master tree

2. Solutions for sustainability information and open issues

To cope with the complexity of tracking and tracing of products and materials as well as communicating sustainability information along the value chain a large variety of solutions have been proposed. These solutions often include one or more of the following aspects:

- Closed value networks
- Cross-level communication of sustainability information
- Provision of sustainability information
- Conformity of sustainability information

However, the specific demand of textile value chains is often only partially covered by these solutions like explained in the following sections.

2.1 Closed value networks

There are solutions for closed value networks in which all partners work exclusively according to a common procedure or even standard. 'bioRe® Sustainable Textiles' [16], for example, allows each product to be traced back up to the cotton field via a code in the garment. Authenticity is guaranteed by completely organising and controlling the value chain and making the information available to consumers on proprietary platforms. These approaches are also suitable for multi- or fully integrated companies that can manage sustainability information internally within their own information architecture. Furthermore, there are software solutions that enable traceability. However, these often only cover individual aspects of the above requirements. One example is the software of the start-up ‘sustainabill’ with a cloud platform for uncovering and analysing transparency along supply chains [17].

Since most companies in the textile industry do not operate in closed value networks and available software systems only cover partial aspects of traceability (e.g. transparency and authenticity at [16]), there is a gap here. There is no systematic and flexible support for the cross-stage provision and communication of sustainability information for the textile industry. Companies cannot meet the obligations and expectations due to a lack of knowledge about their supply chains and poor information quality [18].

2.2 Cross-level communication of sustainability information

There are several quasi-standards from the GS1 organisation for communication. The ‘Global GS1 Traceability Standard’ is a very comprehensive framework document for the design of interoperable traceability systems in supply chains [19]. Based on globally unique product numbers GTIN and location numbers GLN [20], end products can first be identified and tracked, typically between end manufacturer and retailer. Pre-products back to the first raw material source are also considered. Building on this, Global Textile Scheme has developed [21]. This initiative aims to simplify and standardise the exchange of data, especially sustainability data, in the textile value chain.

For the communication of master data, there is the Global Data Synchronisation Network (GDSN). However, this does not allow traceability at batch level. A comprehensive implementation guide complements the formal GS1 standards of the GDSN with advice on their implementation and operation [22]. With the GDSN, product content is automatically uploaded to data pools, maintained and shared. Only implicit communication is used, i.e. the partners independently retrieve the data they need from the master data provided. The largest data pool provider for this is the company Atrify [23] in Germany. For the textile flooring sector, there is the European Product Information System [24]. For the communication of batch-based information for the traceability of textile products, there are some basics but no concept analogous to master data or as in other sectors, such as the food industry [25].

2.3 Provision of sustainability information

Today, the internal processing of data for traceability at batch level is usually carried out in textile-specific ERP solutions. However, these cannot provide the functionalities required for the cross-stage provision of sustainability information, such as (1) uniform identifiers for batches, (2) their unambiguous mutual assignability with (3) a high degree of security and integrity. Within the company, individual identifiers are usually used for this purpose, which are also communicated to customers. For external communication, there are, for example, independent formats such as the "Universally Unique Identifier" from the Open Software Foundation as part of the "Distributed Computing Environment" [26] in addition to the proprietary GS1 quasi-standard GTIN for the unique identification of objects.

For companies, the security and integrity of their externally communicated information is particularly important. One promising approach to this is blockchain technology [27]. In addition to the first blockchain approaches for cryptocurrencies [28, 29], there are currently open-source alternatives for private company networks (Quorum [30], Corda [31], Hyperledger Fabric [32]). The storage of sustainability data was also investigated [33, 34]. In several scientific publications, the potentials of blockchain in logistics, the food industry and healthcare were presented [25, 35]. Furthermore, Amazon Web Services offers solutions based on Hyperledger Fabric for the textile industry, among others [36]. There are also efforts to store information of the global standard GS1 in blockchains [37, 38]. The potential of blockchain for traceability for the textile industry has already been recognised [27, 39]; numerous companies can show pilot projects in this regard (IBM [40], Provenance [41], Lenzing [42]), also by means of the blockchain alternative IOTA [43] for textiles [44].

2.4 Conformity of sustainability information

Conformity with customer requirements or certificates is another aspect that poses major challenges for SMEs in the textile industry. For example, if a company wants to be part of a "CO2-neutral supply chain", you have to manage your Scope3.1 CO2 emissions [12, 45]. The necessary Scope2 information from the own company is only correctly available for a few companies today, whereas the necessary Scope3.1 data of the purchased raw materials [12,45] are, as of today, not available in most cases. The conclusion of the practical recommendations for data collection and calculation of greenhouse gas emissions in the supply chain clearly shows this: 'Even among the German companies on the CDP A-List, hardly any are able to determine their Scope3.1 emissions on the basis of primary data. Estimates based on average industry data and EEIO databases or tools predominate' [46]. A correct batch-related reporting of the CO2 quantity on Scope3.1 level, supplemented by various sustainability information of certificates by means of transaction certificates, is not possible for textile companies with the communication content and structures available today.

3. A framework for sustainability information in the textile industry

As shown above, there is a wide range of solutions for traceability and communication of sustainability information. However, they don't fully match the requirements of companies of the textile industry, especially of SMEs. The restriction to certain types of sustainability information, e.g. only support of specific labels, the lack of support for open value networks, or limited support of tracking and tracing on batch level limit the suitability of the solutions.

For a systematic and flexible support of SMEs in the textile industry, the authors propose a holistic framework for cradle-to-gate sustainability information. The framework consists of three layers (see Figure 2) and is based on a cloud approach. The top layer supports the breakdown of specific sustainability enquiries into basic enquiry types. This makes it very easy to integrate new types of enquiries and does not limit the framework to specific certificates or labels.

The next layer provides the methodological support to answer the basic enquiries. The textile industry domain workflow, based on the product master tree of textiles, implements the necessary query steps that are required for the respective basic enquiry types. Thus, the framework supports open value networks. This is supplemented by transformation rules that provide the necessary functions, e.g. conversion of units or breakdown of data to batch level, for the preparation of the raw data. Conformity rules ensure that all requirements of certificates and labels are met. Intermediate and final enquiry results but no raw data are stored using a generic, type specific information structure. This also fulfils the requirement for non-disclosure of company confidential data.

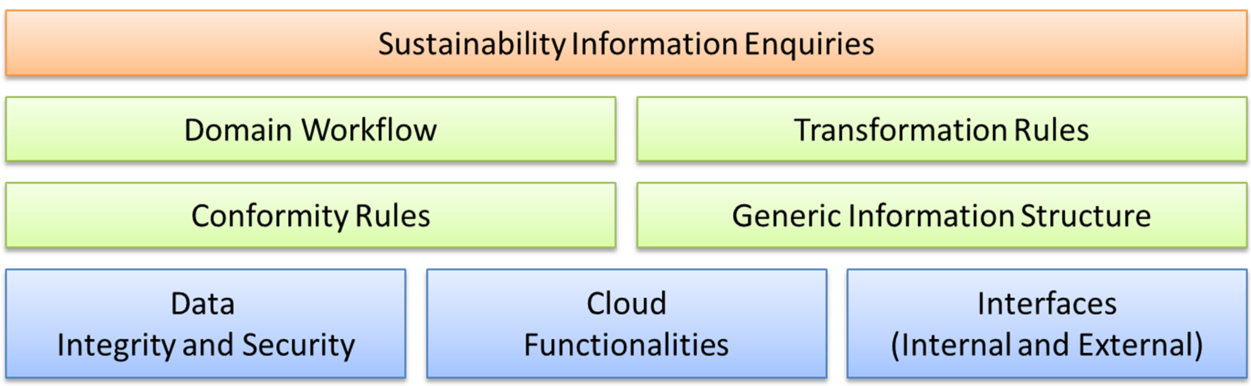

Figure 2: Architecture of the sustainability information framework for the textile industry

The bottom layer provides the technological support required for answering sustainability enquiries. Data integrity and security technologies ensure the safety and validity of company data. Cloud functionalities enable the required communication and transformation activities. Finally interfaces to cloud-internal companies and to other sustainability information networks complement the framework.

Sustainability Information Enquiries: In order to support a wide range of labels and certificates, each specific enquiry must be traced back to basic types. For this mapping, a classification system is necessary that describes the requirements of each enquiry and thus clearly assigns them to a basic type. One example is the system boundary of the enquiry with possible characteristics such as gate-to-gate and cradle-to-gate. However, the classification is not only used to identify a basic enquiry type, it is also used to configure it, i.e. to adapt the workflow, the transformation rules and the conformity rules to the specific request belonging to the basic enquiry type.

Domain Workflow: The textile domain-specific workflows describe the necessary process steps for each basic enquiry type. These can still be adapted to the certificates and labels based on the classification of the previous layer. The basis for the final workflow is the product master data of the product for which the enquiry requests sustainability information. The product master data together with the batch numbers clearly identify the network to which the request refers. This means that not only static networks are supported but also dynamic ones, which are the norm in the textile industry.

Transformation Rules: In addition to the pure collection of data, which is organised by the domain workflow, the raw data must also be processed. The way in which raw data is processed is determined by the transformation rules. As with the domain workflow, the classification from the top level determines the required transformations and can also be used to configure individual transformations. For example, the transformation rules determine how values are to be recorded (industrial mean, annual mean, mean value in the production period, exact values).

Conformity Rules: Finally, the conformity rules comprise framework conditions of certificates and labels that cannot be mapped to the domain workflow and the transformation rules. These rules ensure that requirements such as the existence of transaction certificates in GOTS are fulfilled. Thus, they implement special features of certificates and labels that are not covered by the standardised procedure of the basic enquiry types.

Generic Information Structure: In order to answer sustainability requests a variety of sustainability information must be captured and processed in the production network and the result has to be provided to the requester. Therefore, corresponding generic information structures are required for the different basic enquiry types. These then serve to store the sustainability information captured by the workflow and processed by the transformation rules. Information required by conformity rules must also be stored there. No raw data of the participating companies is stored in the generic information structure.

Data Integrity and Security: The focus is on securing and maintaining the integrity of the data when communicating sustainability information across companies and networks. This protection is of central importance for SMEs of the textile industry, since on the one hand access to raw data would allow conclusions to be drawn about production processes and thus affects the company's business secrets, and on the other hand the integrity of the communicated data must be ensured. Established concepts such as encryption or blockchain are used to secure the data.

Cloud Functionalities: In addition to the standard functions of a cloud, further functionalities must be provided. This refers in particular to the necessary functions that realise the concepts and methods of the higher layers of the framework. These functions are conceptually combined in topic-specific libraries.

Interfaces (Internal and External): For identification of sustainability information, concepts and methods for communication across organisational boundaries are needed. Concepts and methods, currently discussed in international standardisation committees, for both technical (e.g. interfaces, protocols) and organisational (e.g. responsibilities, request and response process) aspects of cross-organisational communication will be used. The textile value chain is sometimes very extensive. Therefore, it cannot be assumed that all actors work together in a common cloud. In this case, different data sources can only be integrated into the workflow to a limited extent. To ensure that the entire value chain can still be covered, established concepts for the integration of sustainability information from external data sources (e.g. companies that are not members of the cloud but are part of the production network) are used.

4. Summary and outlook

Summarising, the proposed framework can enable organisations of the textile industry, in particular SMEs, to create an infrastructure for flexible and efficient generation and communication of sustainability information of textile materials and products on batch-level along the value chain.

The proposed framework can serve all relevant aspects of sustainability information for the vast variety of textile materials, products, processes, as well the huge number of different labels and sustainability certificates. It enables companies of the textile industry to react quickly to new sustainability information demands by a reliable provision and communication of the respective information, and thus reduces related time and effort. This is in particular achieved by the holistic structure of the framework and the decomposition of the problem area into eight well defined framework elements.

For further refinement, focus will be put on elaborating and refining the framework concepts and methods and creating an applicable reference framework solution. This includes for example the further specifications of the textile industry domain towards the domain workflow, the identification and generalisation to basic enquiries types, or initial transformation rules. This will be part of upcoming activities in research projects at the German Institutes of Textile and Fiber Research.

Transparency is necessary to improve sustainability. In particular for the transformation of today’s linear textile value chains into new circular economy structures [47, 48], transparency is one of the key enablers. If transparency is not available, the existing and emerging recycling technologies [49] or re-purposing of textiles is impossible without knowing what is in the textile and from which origin, for example. Thus, the proposed framework can significantly support the textile industry in their transformation process towards a circular economy and increased sustainability.

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Biography

Dieter Stellmach (*1958) has been working at the Center of Management Research of the German Institutes of Textile and Fiber Research in Denkendorf (DITF) since 1986 as senior project manager and EU contact point co-responsible for research in organisation and management of sustainable textile value creation and in textile digitisation. He is active member of networks about fibres and textiles on regional, national and European level.

Michael Weiß (*1973) has been working at the Center of Management Research of the German Institutes of Textile and Fiber Research in Denkendorf (DITF) since 2001. Dr.-Ing. Michael Weiß completed his doctorate in 2019 on model-based design of knowledge-intensive value-adding networks in the textile industry. His research includes modelling of textile value chains and information processing.

Jürgen Seibold (*1965) has been working at the Center of Management Research of the German Institutes of Textile and Fiber Research in Denkendorf (DITF) since 1990. He received his Dr.-Ing. on modelling of textile expertise in expert systems in 1995. He has coordinated many regional, national and European research projects. His research includes the development of methods and models for evaluating the material and energy efficiency of textile production processes as a basis for sustainable production.

Meike Tilebein (*1966) has been the Director of the Institute for Diversity Studies in Engineering at the University of Stuttgart since its establishment in 2009. Prof. Dr. rer. pol. Dipl.-Ing. Meike Tilebein also heads the Center of Management Research of the German Institutes of Textile and Fiber Research Denkendorf (DITF) that supports the textile industry’s digital transformation.