Classification of traceability information in textile and clothing supply chain: A Delphi-based approach

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Abstract

The study explores empirically the need and requirement of traceability system in Textile and Clothing (T&C) supply chain. A Delphi based survey was conducted with 28 supply chain experts (industry professionals and academicians) to collect qualitative and quantitative data in order to identify and prioritize various factors that influence traceability adoption in T&C supply chains. Based on these factors the study further explores, classifies and suggests information that can be recorded and shared for a complete traceability among T&C supply chain actors, both business-to-business and business-to-customers.

Keywords: Traceability, Delphi Study, Supply Chain

Introduction

Information asymmetry and lack of transparency have made the textile and clothing (T&C) supply chain almost untraceable. Although connected to each other through a complex and diverse network, supply chain actors finds it difficult to identify and access information about all the involved suppliers and sub-suppliers (Grimm et al., 2016). Ignorance and lack of proper information-sharing mechanism have resulted in unfortunate events in past that has raised serious concern among governments and consumers (Kumar et al., 2017).

On the other hand, such opaque supply chains facilitates easy intrusion of counterfeits and industry suffers huge loss every year due to these products (Corbellini et al., 2006). Counterfeit products not only damage the fashion brand image and economies, but are also harmful for the consumer due to the inferior quality (Ekwall, 2009). As per the report of the European Union Intellectual Property Office Observatory, due to counterfeit products, the T&C industry loses 9.7% of sales, 26.3 billion euro of revenue per year in the sector, 36300 direct jobs and 8.1 billion euro of revenue by government (Wajsman et al., 2015).

According to *OECD report* (2017), traceability is one of the mechanisms that can be adopted to counter above-mentioned issues in T&C supply chain. However, despite of numerous benefits, it is still an emerging and less implemented concept. Some of the major reason being, *lack of dedicated and inexpensive technology* developed taking into account the complex T&C supply chain structure and product features, *lack of awareness and consensus* about the potential benefits of adaptation of single traceability system, and *absence of universal traceability rules and regulations* for the T&C supply chain (Richero and Ferrigno, 2017). Thus, traceability is still a voluntary measure and partially adopted by brands to share information related to their sustainability aspects, which is also not uniform among different brands. (Kumar et al., 2017). Therefore, steps must be taken to promote traceability and develop consensus among the supply chain actors for adaptation of a single and complete traceability system that can record and share information related to all supply chain stages. For this as a first step, understanding and classification of traceability information is required, with extent they must be shared among various stakeholders.

In this direction, the study formulates and empirically explores the answers for the two research questions stated below.

RQ 1: *What are the key factors influencing traceability implementation in T&C supply chain?*

RQ 2: *What essential information a traceability system needs to record and share among various stakeholders in the T&C supply chain?*

To answer above questions an extensive literature review was conducted to explore key traceability Factors in T&C supply chain and different sets of information that can to be recoded, shared and secured by a traceability system. To reach a consensus through a collaborative approach, the study further conducts a Delphi based (Dalkey and Helmer, 1963) survey with 28 T&C supply chain experts to collect qualitative and quantitative data based on question developed from literature analysis. The list of traceability factors and information sets were modified and added through the subsequent survey rounds and finally analysed, ranked and clustered.

Related Literature

Traceability –Factors

Traceability as defined by the International Organization for Standardization (ISO 9001:2015) "*the ability to identify and trace the history, distribution, location, and application of products, parts, materials, and services. A traceability system records and follows the trail as products, parts, materials, and services come from suppliers and are processed and ultimately distributed as final products and services*"**.** Table 1 reviews supply chain management literature that explains different factors that influences traceability implementation.

Table 1- Factors that influence traceability implementation in T&C supply chain

	Factors	***Description***	***Ref. (Textile)***	***Ref. (Others)***
1	***a)Transparency b)Visibility***	*Transparency* is the extent to which information is shared among the supply chain actors (including customers) and *Visibility* implies to the extent to which a buyer can trace back the details about the suppliers and sub-suppliers involved in construction of the final product.	Egels-Zandén et al., (2015)**,** Kumar et al., (2017a)**,** Doorey, (2011)**,** Strähle and Merz, (2017)	Kraisintu and Zhang, (2011)**,** (Nel) Wognum et al.,(2011)

2	***Product Maintenance***	Textile product maintenance in its use-phase, especially during washing and drying, is one of the key concern influencing the durability and recyclability of textile product. Thus, product maintenance information is crucial for customer and recycling agent.	Kumar, (2017)	(Tao et al., 2016)
3	***Market surveillance***	Market surveillance by public authorities that closely observe products in market and ensure that the products are in conformity with the applicable law, require crucial information about the history, origin and composition of product/raw material and intermediate product. . Examples of such authorities are: Administrative Cooperation Group (AdCos), Rapid Alert System (RAPEX) etc.	Kumar, (2017)	Alemanno, (2010)**,** Alemanno, (2009)
4	***a)Reverse logistics b)Textile renting, sharing and reuse***	Reverse logistics management, involves collection, sorting and segregating of used product during recycling and inventory management during remanufacturing and return. An automated reverse logistic system using traceability tag and information can save cost, time, enable effective recycling, reuse and renting of products.	Palm et al., (2014)**,** Pigni et al., (2007)**,** Nayak et al., (2015)**,** (Legnani et al., 2011a)**,** Azevedo et al., (2014)	Wyld, (2010)**,** Nativi and Lee, (2012)**,** Henrik Ringsberg, (2014)**,** Bechini et al., (2008)
5	***a) Quality Monitoring b) Recall Mechanism***	Recording and sharing of quality related information enables effect control and monitoring of product quality and recall management, to identify origin of defect.	Kumar, (2017)**,** Cheng et al., (2013)**,** Pigni et al., (2007)	J. Oehlenschläger et al., (2006)**,** Meuwissen et al., (2003)
6	***a) Sales forecasting b)Production data management***	Real-time tracking and tracing of product and product data management, enables effective and more precise sales forecast, production planning and control.	Siu Keung Kwok and Kenny K.W. Wu, (2009)**,** (Legnani et al., 2011b)	Henrik Ringsberg, (2014)**,** Bechini et al., (2008)**,** Jansen-Vullers et al., (2003)
7	***a)Product authentication b) IPR Protection***	Product and information security is one of the key concerns of T&C supply chain that requires secure technologies and system for counterfeit deduction and data protection.	Corbellini et al., (2006)**,** Kumar, (2017)	Sun et al., (2014)**,** Bechini et al., (2008)**,** Turcu et al., (2013)**,**
8	***Marketing***	In this era of fast fashion consumer, need more information about the product to make an ethical buying decision.	Kumar, (2017)**,** Guercini and Runfola, (2009)	Bechini et al., (2008)**,** Roosen, (2003)

Traceability- Information sets
Although there are different types of information that are recorded at different stages of product lifecycle, starting from raw material production to reverse logistics, not all the information are essential to be recorded and shared with other supply chain actors (Thakur and Donnelly, 2010). However, there should be a clear segregation of essential traceability information and non-traceability information for optimum information sharing and effective functioning of traceability system. Information especially concerning product traceability, can be broadly classified as product, process and quality (Thakur and Donnelly, 2010). A fourth type of information concerning the social and environmental impact of a product forms a distinct category for T&C brands, specially to convey the ethical and ecological information related to product (Kumar et al., 2017).

a) *Product/Material Information*: Information related to a product which includes the name, origin, composition, inbound material specification, outbound product specification, cost data, sales data, manufacture suppliers ID and details of the intermediate and final products or raw materials used in formulating the final product.
b) *Process Information*: Information related to process name, time stamps, machinery ID and processor/operator ID for all processes involved in manufacturing of the product.
c) *Quality Information*: Information related to material quality (test performed, test results, contents), quality checker ID, certifications and tracking data of surplus materials referred to intermediate and final product and related processes.
d) *Information related to social/environmental impact of the product*: Social audit reports/ certifications, environmental audit report/certification and carbon foot print data of product.

Methodology
Considering the research questions which aims to explore and identify the key factors of traceability in T&C supply chain and essential traceability information sets, Delphi based survey approach is deemed to be appropriate.

Developed at Rand Corporation by Dalkey and Helmer, (1963), Delphi is a widely used and accepted technique to achieve consensus on a complex and multidisciplinary problem. Based on the rationale that "two heads are better than one, or …n heads are better than one", it is a systematic group communication process, allowing for anonymous interaction among dispersed panel experts. These selected panel experts are questioned by a sequence of questionnaires in multiple rounds, where the responses from each round are used as input for the next rounds. After evaluations by the survey moderators, questions on which agreement or consensus can be identified are filtered out, whereas questions with low or no agreement are explored further in the following rounds. This anonymous and controlled feedback method is helpful to avoid noise and negative effects of dominant personalities, interpersonal biases, defensive attitude and unproductive disagreements. Moreover, panel experts are able to modify or refine their response based on the feedback anonymously without the risk of embarrassment (Hsu and Sandford, 2007). Delphi has been adapted to numerous research fields, such as needs assessment, resource utilization, policy determination, forecasting and program planning (Kembro et al., 2017).

The Delphi technique reported in this study was conducted in five steps each continuing until a consensus or agreement is met on each question. A brief overview of each step is discussed below.

Step 1: Subject Selection

Selecting appropriate panel experts is the most important step in a Delphi-based study as it directly influences the result quality. Since the aim is to collect and refine experts' opinions (that are limited in number) over a considerable amount of time and multiple survey rounds, Delphi subjects must possess appropriate knowledge and experience related to the specific issue being discussed and should represent a variety of views. Top management decision-makers or individuals whose judgments are being sought are mostly preferred as panel members as they can use the results of the Delphi study. Nomination based selection process and professional staff members along with their teams are recommended. To ensure validity of results, all these Delphi guidelines were followed during subject selection.

Initially, company and organization members of Sustainable Apparel Coalition (SAC) were approached to nominate traceability and supply chain-related experts from their respective enterprises for the study. The nominated individuals further recommended 50 potential panelists. Finally, an invitation letter explaining the subject, aim and duration of the study was sent to these nominated panel experts. These experts were various multi-national companies from Europe, United States and Asia and possessed extensive experience of T&C supply chain. Most of them held major positions, either as CEO, COO and Global Heads responsible for Sustainable Development. To get an outside perspective, 15 well-known academics, senior consultants and investigating journalists researching on T&C supply chain traceability and transparency related topics were also included.

To determine the appropriate size of the panel, a method adapted by Kembro et al., (2017) was followed. As per their recommendation, the panel should not consist of more than 30 or less than 20 experts. More than 30 experts can decrease the response rate, delay the results as well as limit the exploration of the insights whereas a small number might not represent the variety of viewpoints and might lead to potential bias. Moreover, the subgroup (in this case the industry professionals and the outside perspective holders or researchers) should be in-between 10 to 18 experts. So, for this study 14 industry professional and 13 academics and consultants were finally selected in the final panel.

Step 2: Design of survey

Traditionally, Delphi study starts with an open-ended questionnaire to collect an extensive list of information related to a specific area. However, as a common and well-accepted modification in the Delphi format, a structured or semi-structured questionnaire can be designed based on extensive literature review (Hsu and Sandford, 2007). Therefore, as an initial step, different traceability factors and information sets identified through the literature review were compiled in a semi-structured questionnaire. The importance (in terms of level of influence each factor have on traceability implementation) of these factors was evaluated using a five-point Likert scale, where 'strongly agree' represents '5' and 'strongly disagree' represents '1'. To identify traceability information related to each factor and classify it, matrix scale questions were created. In these questions, rows list all the sets and sub-sets of information acquired from the literature and different columns enlists the factors. The respondents were asked to select the information corresponding to each factor that must be recorded and shared at the business-to-business (B-to-B) and business-to-customer (B-to-C) levels. Further, open-ended questions were included to add the possibility to provide feedback and input on the factors or information. A pilot run of the developed survey was conducted with four supply chain experts (who were not part of the final panel) to: (a) test the relevancy and clarity of the formulated questions and avoid ambiguity, (b) evaluate the ease of using the survey tool, (c) validate the content and enhance the quality of communication and survey structure (*survey questions, format and responses can be obtained from authors on request*).

Step 3: Survey round one

The first round of the survey was distributed to the selected expert's panel through *Survey monkey* platform. It consisted of three parts inquiring about: (1) traceability in general, (2) product use-phase and (3) in reverse logistic application. All the terminologies and factors were explained and defined at the location they appeared in the survey. The respondents were given around three weeks to respond. During this time, they were contacted on regular basis to enquire and solve any technical problems.

Step 4: Evaluation (round one) and Survey round two

After the first round, mean and standard deviation (of the Likert scale value) for each factors was calculated and one to one comparison was made in order to obtain a difference matrix and eventually the responses with low agreement. Responses from the matrix scale questions related to the traceability information were ranked using average Euclidian distance between each information type and clustered using hierarchical clustering tool. In the second round, experts were given an opportunity to reconsider the factors with low agreement and the information corresponding to the low response in the matrix scale question. As suggested in commentary response by the experts during the first round, more factors and information types were added for the second round of survey to further investigate the impact.

Step 5: Final evaluation

A general agreement was identified for all the factors. Kendall's rank coefficient (Kendall, 1948) was calculated to test the rank correlation among the ranking data of information categories from round one and two. In the final stage, obtained quantitative and qualitative data were systematically structured, categorized and analyzed using factors analysis and hierarchical clustering tools *(It can be noted that due to limitation of space not all the results and quantitative data has been added in this paper).*

Results

Out of 27 experts who agreed to participate in the study, 23 finally attended the survey in both the rounds (85% response rate).

a) Traceability-Factors

Table 2 Mean and standard deviation (SD) (latter in bracket) values corresponding to each factor shows a general agreement in response among the panelists. Three factors with low agreement (high SD value), obtained through pairwise comparison were subjected to further validation in the round 2 and a general agreement can be observed. A new factor (*) was added based on the input from the experts.

b) Traceability-Information

Based on experts' aggregate response on choice of information related to each factors for both B-to-B and B-to-C levels, each information was ranked in both rounds. The Kendall's tau and rank in each round is shown in Table 3, that show a strong rank correlation among the B-to-C information ($\tau = 0.84$) and moderate relation among the B-to-B information ($\tau = 0.53$). Therefore, using the data from second round, information that can be recorded and shared between B-to-B and B-to-C were ranked and clustered into three sets as shown in Figures 1 and 2. Cluster-1 contains the most important information that should be recorded and shared followed by Cluster-2 and Cluster-3.

Table 2 - Results (Likert scale), Round 1 and 2

Factors		Mean (SD)		Final Rank
		Total N=23	Total N=23	
		Round 1	Round 2	
1(a)	Transparency	4.22(0.66)	-	8
1(b)	Visibility	4.43(0.50)	-	3
2(a)	Quality Monitoring and control	4.43(0.58)	-	4
2(b)	Recall mechanism	4.13(0.74)	-	9
3	Marketing Tool	4.30(0.68)	-	7
4	Market Surveillance	4.36(0.64)	-	5
5(a)	Product authentication	4.5(0.75)	-	2
5(b)	IPR protection	4.31(0.79)	-	6
6(a)	Product Data Management	4.04(0.79)	-	10
6(b)	Sales Forecasting	3.72(0.91)	3.61(0.72)	13
7	Product use/ maintenance	3.5(1.08)	3.35(0.74)	14
8(a)	Reverse logistics activities	4.0(0.95)	4.00(0.77)	11
8(b)	Textile renting, sharing and reuse	3.86(0.76)	-	12
9	*Risk Management	-	4.60(0.57)	1

Table3 – Results (ranking), Round 1 and 2

	Information		Rank			
			Round 1		Round 2	
			B-to-C	B-to-B	B-to-C	B-to-B
1	Product Information	Origin	2	1	2	2
2		Composition	1	2	1	1
3		Manufacturer/ supplier details	6	3	6	3
4		Inbound material specifications	9	6	12	11
5		Outbound product specifications	8	7	11	12
6		Costing data	16	16	18	15
7		Lot numbers	14	8	14	10
8		Sales data	15	18	15	16
9	Quality Information	Audit reports	10	4	7	6
10		Test procedures and reports	11	14	9	5
11		Quality Certification Data	7	5	8	7
12		Tracking data of surplus or damaged# material/product	12	12	13	8
13	Process Information	Process names/ details	13	13	10	4
14		Machines Ids	18	17	16	17
15		Time stamps	17	15	17	18
16	Social-Environmental Information	Social audit-report / certification	4	10	5	14
17		Environmental audit-report / certification	5	9	4	13
18		Carbon footprint data of products	3	11	3	9
19		*Recycling Data			-	-
			Rank Coefficient (Kendall's tau)			
			τ = 0.84 (B-to-C) , τ = 0.53 (B-to-B)			

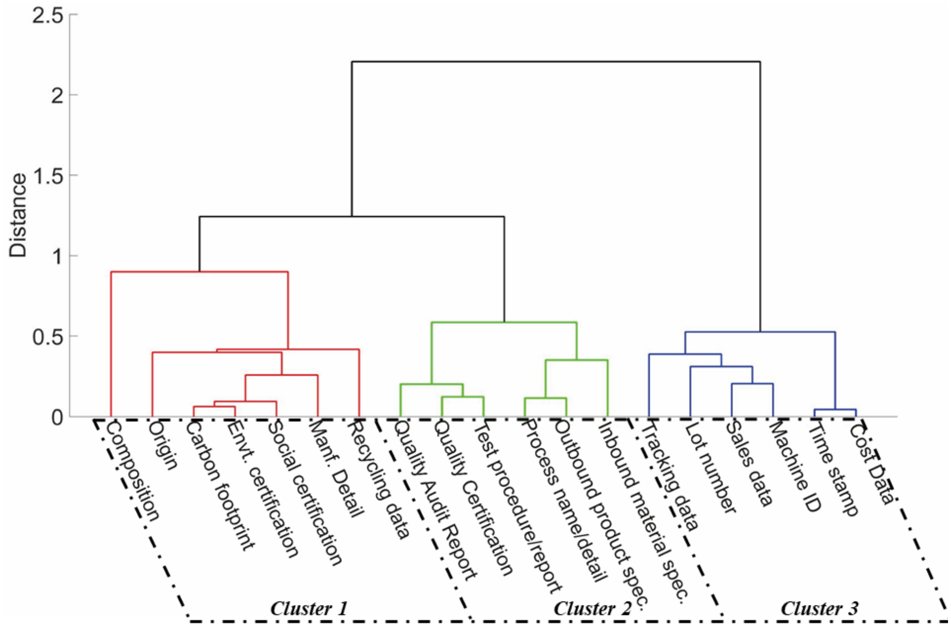

Figure 1 - Information that can be recorded and shared between business-to-customer

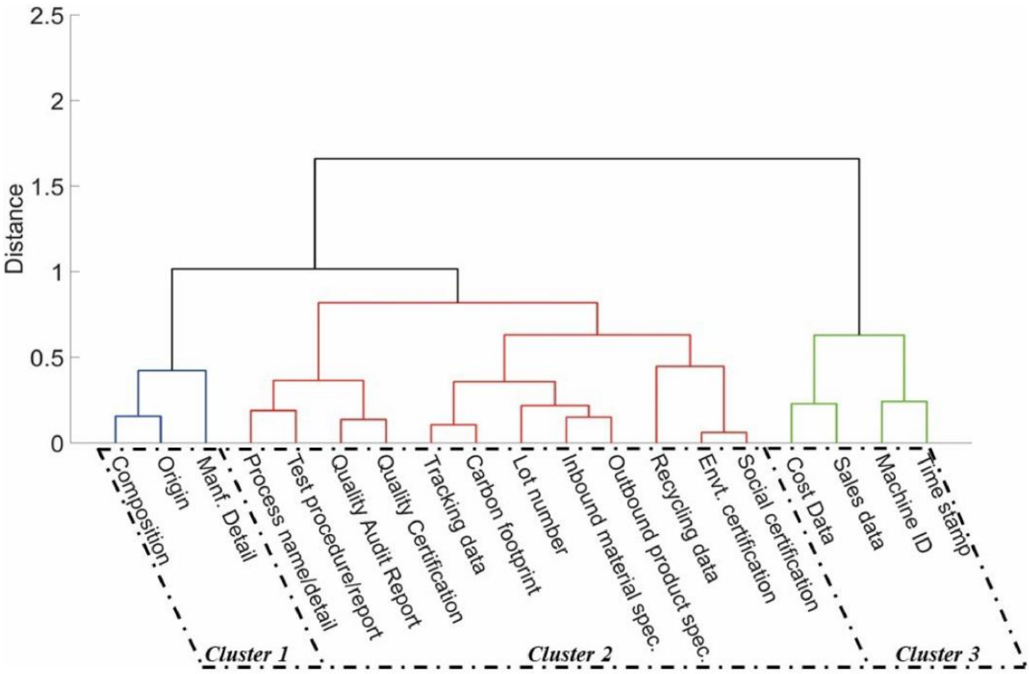

Figure 2 - Information that can be recorded and shared between business-to-business

Concluding discussion

This research is one of the first that empirically investigate key factors and their level of influence in implementing traceability in T&C supply chain. It is also unique in classifying essential information a traceability system needs to record and share among various stakeholders in the T&C supply chain. Following are the main contributions and findings. First, a list of wide range of factors (influencing traceability) and traceability information were explored from literature. Second, following a Delphi based survey approach, these outcomes were validated and each respondent provided a quantitative assessment. Finally data thus obtained was analysed using pairwise comparison and rank

correlation (to find the consensus) followed by average Euclidian distance and hierarchical clustering to rank and classify the information. It can be observed that factors related to supply chain security (risk management, product authentication and IPR protection) followed by transparency (visibility), quality (quality monitoring, market surveillance and recall management) and marketing have highest impact and major influencer for traceability implementation in T&C supply chain. Among the information, 'product information' (related to composition, origin (raw material and intermediate product), manufacturer details), and 'social/environmental information' (related carbon footprint, environmental/social certification and recycling data) are the one that must be shared with customers. Product information (related to composition, origin (raw material and intermediate product), manufacturer details), Quality information (related to audit reports, test reports) and Process information (related to process details, tracking and specifications) are the one that must be shared among businesses in supply chain.
In future, an interview round would be conducted to collect qualitative inputs from expert and a comparative analysis among the group of experts (industry professionals and academicians) would be done to further validate the results.

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