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Traceability in Textile and Clothing Supply Chains: Classifying Implementation Factors and Information Sets via Delphi Study

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Abstract: The purpose of this study is twofold. First, to explore and classify factors influencing traceability implementation, and second, to cluster essential traceability-related information that demands recording and sharing with businesses and customers, in the context of the textile and clothing supply chain. A Delphi study is conducted with 23 experts (including research practitioners and industry experts) to explore, validate, and classify traceability factors and related information using distribution analyses and hierarchal clustering. As a result, 14 factors and 19 information sets are identified and classified with a moderately high agreement among the experts. Among these, risk management, product authentication, and visibility are the highest ranked and the most important factors influencing traceability implementation in the textile and clothing supply chain. While origin, composition, and sustainability-related information are crucial for sharing with customers, the information vital to businesses includes manufacturer/supplier details, product specifications, and composition. It is noteworthy that this research is among the few that classifies traceability factors and information through expert perspectives, and it creates decisive knowledge of traceability for the textile and clothing supply chain. It further provides insights on the extent to which this information can be shared among supply chain actors. Outcomes of this study can be helpful for the development of an information traceability framework. Policymakers can use the results to draft traceability guidelines/regulations, whilst top management can develop traceability-related strategies.

Keywords: traceability; Delphi study; supply chain; textile and clothing

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1. Introduction

Information asymmetry and lack of transparency have made the textile and clothing (TC) supply chain almost untraceable [1–3]. Although connected through a complex network, supply chain partners find it difficult to identify and access information related to all involved suppliers [4]. Ignorance and lack of proper information sharing systems have resulted in unfortunate events in the past and have raised serious concern among governments and consumers [3,5]. These incidences have exposed the unethical and unsafe practices widely followed in the TC supply chain, and have questioned the accountability and auditing methods [6].

Besides, such untraceable or opaque supply chains facilitate easy intrusion of counterfeits, which has always been an important concern for the TC industry. Because of these products, the TC supply chain suffers huge losses every year [7]. As per the European Union Intellectual Property Office Observatory report, due to counterfeit products, on an average (from the year 2007–2012) the TC industry has lost around 9.7% of sales, EUR 26.3 billion of revenue per year in the sector (EUR 8.1 billion of revenue by the government), and 36,300 direct jobs [8].

To address these challenges, the Organization for Economic Co-operation and Development [9] suggests (in their guidelines) traceability system as one of the mechanisms that can be adopted to achieve information symmetry, security, and accountability in the TC supply chain. Traceability, as defined by ISO (9001:2015), is "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". In general, a traceability system can be used to access information related to all involved actors, activities, and products including raw material components, processing conditions, logistics movements, carbon footprints, etc. As explained by [10], traceability systems facilitate information flow in a way similar to freights carried by railway. In this analogy, the carriages contain traceability information instead of freights, whereas systems related to product identification and transformation can be related to the railway track that ensures the safety and integrity of these carriages (containing traceability information). Thus, the outputs or the benefits of a traceability system are in the forms of transparency, visibility, quality control, etc., depending on the type and extent of information one records and shares in the system (or load on the carriages). Besides, the application and features of traceability systems are largely influenced by the type of supply chain. As a result, researchers and practitioners are working towards the development of a customized traceability system that can cater to the specific needs and requirements of the related supply chains [11]. For instance, traceability is a significantly researched and adopted system in food and pharmaceutical supply chains [12–15].

Regardless of its numerous benefits, traceability is still an emerging and less implemented concept in TC supply chains. Some of the primary reasons, as highlighted in [6,16], are: lack of dedicated and inexpensive technologies that can be developed taking into account the complexities of TC supply chain structure and product features, lack of awareness and consensus among stakeholders regarding the potential benefits of a single traceability system, and absence of traceability rules and regulations. Thus, traceability is still a voluntary measure in the TC supply chain, and it is partially adopted by brands to share information related to their sustainability aspects in the form of green certifications, eco-cotton labels, carbon footprint data, or supplier details [3,17]. Steps are required to promote traceability and develop consensus among the TC supply chain partners for the implementation of a single and complete traceability system that can record and share information related to each supply chain stage in a standardized format [6,16].

One of the steps in this direction could be exploring and prioritizing important factors influencing traceability in the TC supply chain. These factors can induce the perception of the practitioners and motivate traceability implementation. Further, based on these key factors, traceability information can be ranked and classified to determine the extent to which it can be shared among the businesses and with end customers. This requires sector-specific study [11], which is currently missing for the TC supply chain.

In this direction, the study formulates and empirically explores two specific research questions (RQs):

RQ 1: What are the key factors influencing traceability implementation in the TC supply chain?

RQ 2: What essential traceability information needs to be recorded and shared among various TC supply chain stakeholders?

The two RQs are correlated, and to answer them, this paper follows a Delphi methodology with TC supply chain experts. Various key factors influencing traceability implementation in the TC supply chain and related traceability information are explored, prioritized, and classified by reaching consensus through a multi-round survey analysis. To support the findings, the study examines the results in light of arguments from literature and commentary inputs from the experts.

The following sections describe the Delphi-based survey methodology followed in this study, which was conducted in six steps (shown in Figure 1) until a consensus was reached.

Methodology (Delphi based approach)	
Step 1	***Exploring key factors and essential traceability information from literature***
Step 2	***Subject selection*** based on Delphi guidelines
Step 3	**Design of semi-structured questionnaire** based on results from step 1
Step 4	***Survey round 1*** with the selected subjects (Researchers and Industry experts)
Step 5	***Evaluation*** (survey round 1) to find degree of consensus and response with low-agreement, followed by ***survey round 2*** (opportunity to reconsider the responses)
Step 6	***Final evaluation*** (survey round 2) using '*Distribution analysis*', '*Hierarchical clustering*' and '*Optimal leaf ordering*' methods.

Figure 1. Steps of Delphi-based methodology followed in the study.

2. Methodology

Developed at Rand Corporation, Delphi is a well-acknowledged methodology to attain consensus on a complex and multidisciplinary problem. It is a systematic group communication process, allowing anonymous interaction among dispersed panel experts, in multiple rounds. (See detailed explanation in [18]). Delphi has been adapted in numerous research studies designed for needs assessments, policy determinations, and forecasting and program planning [19–21]. In the area of supply chain management, studies highlighting applications of the Delphi technique for investigating factors influencing decision making can be found in [22–25].

2.1. Exploring Key Factors and Essential Traceability Information from the Literature (Step 1)

Traditionally, a Delphi study starts with an open-ended questionnaire; however, as a common and well-accepted modification in format, a structured or semi-structured questionnaire can be designed based on literature analysis (mentioned in [18]; practiced in [25]). Therefore, different factors influencing traceability implementation and related information sets were identified through a narrative review of literature. The explored articles were further segregated into those specific to TC vs. other supply chains. To eliminate potential bias related to narrative review methods, during the first round of survey the experts were asked to validate and add missing factors and information that can be considered for the study.

2.1.1. Traceability—Factors

It is evident from previous studies that traceability implementation in supply chains has numerous advantages, as it leads to better visibility, authentication, quality assurance, and product data management [26–28]. For instance, in [27] the author took the example of the horsemeat scandal in European markets and highlighted the importance of complete traceability in the form of product authentication and quality assurance. As an initial step towards traceability system development, the study summed up all the key factors (in Table 1) influencing its implementation in the TC supply chain from extant literature. It can be noted that the detailed discussion on how these benefits are achieved through traceability is not congruent with the purpose of the paper, and it has been opted-out from the review. It is evident that traceability in TC supply chains, even though a pressing issue for practitioners, has gained limited attention in the literature.

Table 1. Factors that influence traceability implementation in TC supply chain.

Influencing Factors	Supporting Authors		How It Influences
	Textile	Others	
Transparency Visibility	[2,29–31]	[32–34]	Transparency is the extent to which information is shared among the supply chain partners, and visibility implies the extent to which a buyer can trace back the details about the suppliers and sub-suppliers. Both are high in demand and crucial elements for a sustainable TC supply chain. To achieve these, an effective traceability mechanism is required that can connect and integrate all the involved supply chain partners.
Product Maintenance	[30,35]	[36]	Textile product maintenance in its use-phase, especially during washing and drying, is one of the key concerns influencing the durability and recyclability of the textile product. Traceability mechanisms are essential to share product maintenance aspects with end users, and at the same time an active traceability mechanism can be programmed to record product use-phase data (e.g., number of washes) that is crucial in recycling stages
Market surveillance	[30,37]	[38–40]	Market surveillance by public authorities that closely observes products in the market and ensures that the products conform to the applicable law, require crucial information about the history, origin, and composition of product/raw material and intermediate product. Examples of such authorities are the Administrative Cooperation Group (AdCos), Rapid Alert System (RAPEX), etc. Traceability mechanisms connect the supply chain partners and enables tracking and tracing of product at each stage of the supply chain.
Reverse logistics Renting, sharing and reuse	[41,42]	[26,43–45]	Reverse logistics management, involves collection, sorting and segregating of the used product during recycling and inventory management during re-manufacturing and return. An automated reverse logistic system using traceability mechanisms and information can save cost, time, and enable effective recycling, reuse, and renting of products.
Quality Monitoring Recall Mechanism	[16,42,46]	[47,48]	Recording and sharing quality-related information enables effect control, monitoring of product quality, and recall management to identify the origin of defects. In the case of recalls, traceability mechanisms can trace the origin of the defect and locate the responsible partner.
Sales forecasting Production data management	[41,49]	[26,43,50]	Real-time tracking and tracing of product and product data management enables effective and more precise sales forecasts, production planning, and control. This can be ensured by a traceability mechanism that integrates the supply chain and records real-time product data.
Product authentication Intellectual Property Rights (IPR) Protection	[7,30]	[38,43,51]	Product and information security are one of the key concerns of the TC supply chain that requires secure technologies and systems for counterfeit detection and data protection. In this direction, a traceability system with secured mechanisms can ensure product authentication and prevent data leakages.
Marketing	[30,52]	[43,53]	In this era of fast fashion consumers, more information is needed about the product to make an ethical buying decision. Enabling the customer to trace the history of textile products through a traceability mechanism can create a positive brand image and boost sales.

Note: Factors with overlapping literature are discussed together.

2.1.2. Traceability—Information Sets

Supply chain traceability requires recording various types of information at different stages of the product transformation, starting from raw material production to reverse logistics. For instance, traceability implementation has long been reported to restore consumer confidence in product quality and safety by providing more information related to product origin, composition, quality, etc. [28]. In [11], the authors highlighted that traceability information, especially concerning product traceability, can be broadly classified as product-, process-, and quality-related. Product information includes name, origin, composition, specifications, and details related to all the raw materials, intermediates, and final product that is delivered to the end consumer [30,50]. Process information includes all the details related to all the processes involved in the manufacturing of the product [16,31]. Finally, quality information is mainly concerned with product quality and the details associated with it [11,16]. A fourth type of information, concerning the social and environmental impact of a product throughout its transformation stages, forms a separate category, especially to convey ethical and ecological concerns. Furthermore, in [11] the authors suggested that not all traceability information is essential to record and share with other actors, including customers. This may act contrary to the functioning of a traceability system. Actually, little is known or explored in past studies about views and opinions associated with traceability, nor consumers' or businesses' preferences for traceability information provisions, especially in the case of the TC supply chain [54]. In this context, there should be segregation of essential and non-essential traceability information for optimum information sharing and efficient functioning of a traceability system [30]. In light of this, as an important step for initiating the investigation in this study, Table 2 presents a comprehensive list of all the information related to traceability that should be recorded and shared, as obtained from the literature. It can be noted that this traceability information is not limited to the final product, but also contains details of intermediate production and reverse supply chain stages.

Table 2. Essential traceability information sets.

Information Sets	Supporting Authors	Sub-Category	Description
Product Information	[11,16,31,49,50,55]	Origin	Origin of the final product, component, sub-component, and raw materials utilized in the production of the final product.
		Composition	Composition of the final product, component, sub-component, and raw materials utilized in the production of the final product.
		Manufacturer/ supplier details	Information about all the manufacturers, suppliers and sub-suppliers involved throughout the lifecycle of the product.
		Inbound material specifications	A detailed description of design and product/material specifications that are procured from the supplier/upstream actor.
		Outbound product specifications	A detailed description of design and product/material specifications of finished product that is transferred to the next downstream actor
		Costing data	Information related to the cost of the final product, raw material, and the entire intermediate product.
		Lot numbers	Unique series of the number provided to a bundle or lot of product to facilitate batch traceability
		Sales data	Real-time data related to product sales in different retail channels.
Quality Information	[11,16,31]	Audit reports	Various audit-quality audit reports done throughout the lifecycle of the product
		Test procedures and reports	Various audit-quality test procedures and test reports done throughout the lifecycle of the product
		Quality Certification Data	Various quality certifications related to raw material, intermediate product, and final product throughout the lifecycle of the product
		Tracking data of surplus or damaged material/product	Tracking data of each product, the damaged or discarded product/intermediate, and raw material in the supply chain.
Process Information	[11,16,31]	Process names/details	Information and details about all the involved manufacturing processes throughout the lifecycle of the product.
		Machines Ids	Machine Ids of the machines involved in product processing throughout its lifecycle.
		Timestamps	Time stamps of all the important events and processes throughout the lifecycle of a product.
Social-Environmental Information	[16,17,31,56]	Social audit-report/ certification	Various social audit reports and certifications associated directly or indirectly with the product
		Environmental audit-report/certification	Various environmental audit reports and certifications associated directly or indirectly with the product
		Carbon footprint data of products	Complete carbon footprint data of the final product throughout its lifecycle

Figure 2 presents the deductive model of factors and information sets. Factor 14 'Risk Management' in Level 1 and 'Recycling data' in Level 2 were added through commentary inputs from experts after survey Round 1 (in Step 5).

2.2. Subject Selection (Step 2)

Being limited in number, Delphi subjects (experts) must have appropriate knowledge and experience related to the particular issue being discussed so as to represent an assortment of perspectives [25]. For this reason, companies initially affiliated with the Sustainable Apparel Coalition (SAC) [57] were approached to nominate traceability and supply chain-related experts from their respective enterprises for the study. SAC was deemed appropriate to initiate the expert search because of its global outreach to textile and clothing industry players, including advocacy groups and academicians, with the objective to create a sustainable industry. The nominated individuals further recommended around 50 potential panelists. Finally, an invitation letter explaining the topic, aim, and duration of the study was sent to these nominated experts. These experts, associated with various multi-national TC companies all over the globe, held major positions, as CEO, COO, or Global Heads, responsible for sustainable development with extensive experience in the TC supply chain. Additionally, fifteen well-known academics, senior consultants, and investigation journalists researching TC supply chain traceability and related topics were conjointly invited. To determine the suitable size of the panel, a method prescribed by [21,24] was followed.

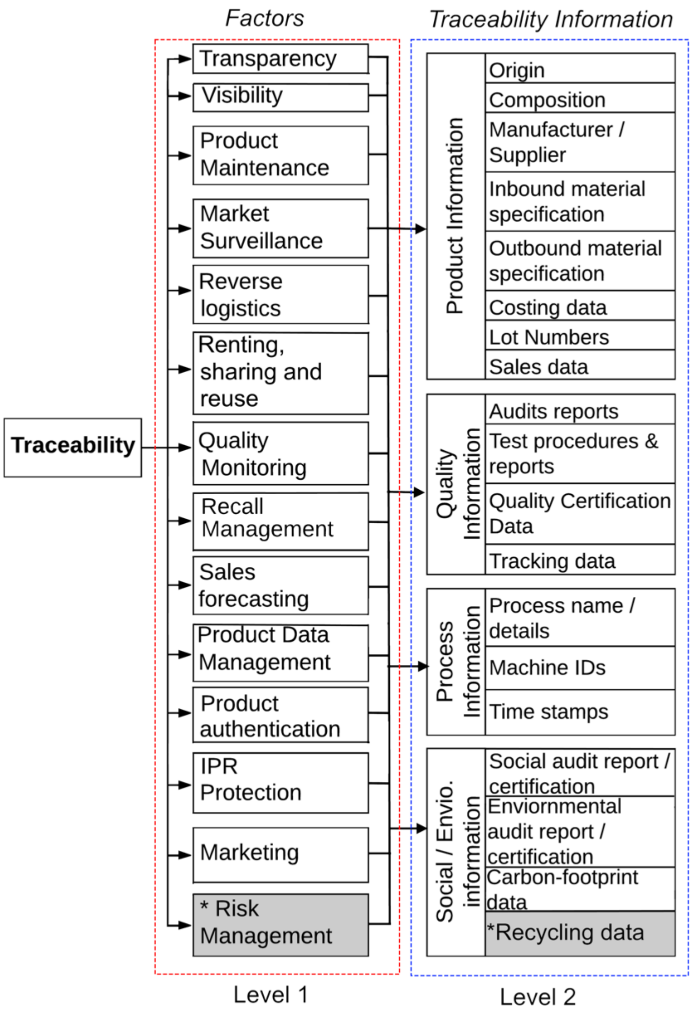

Figure 2. Summary of different traceability factors and information. Marked with (*) are the factors and information type added through commentary inputs.

2.3. Design of the Semi-Structured Questionnaire (Step 3)

Based on outputs from Step 1, factors and information were compiled in a semi-structured questionnaire. For questions related to traceability factors (Level 1), the experts were asked to rate each factor based on their importance for traceability implementation along a five-point Likert scale, where 5 was 'most important' and 1 was 'least important'.

To identify traceability information related to each factor (Level 2), matrix questions were created with the rows containing the sets and subsets of information (Table 2) and the columns containing the traceability factors. The experts selected the information corresponding to each factor that must be recorded and shared at the business-to-business (B2B) level and with the end customer, i.e., at the business-to-customer (B2C) level. Additionally, open-ended questions were included to receive feedback and comments (if any).

A pilot run of the survey was conducted with four supply chain experts to: (a) test the relevance and clarity of the formulated questions and avoid ambiguity, (b) evaluate the usability of the survey tool, and (c) validate the content and enhance the quality of the survey structure. However, no significant changes were prescribed. The survey form can be obtained from authors on request.

2.4. Survey Round 1 (Step 4)

The survey was distributed to the selected panel of experts through the Survey Monkey e-platform. All the terminologies, factors, and information types were explained and defined in the survey. The experts were contacted individually in case further clarification was required or if they encountered any technical difficulties. A time limit of three weeks was decided to collect the responses.

2.5. Evaluation (Round 1) and Survey Round 2 (Step 5)

Level 1 questions were assessed using pairwise comparison and a distribution analysis to select responses with relatively higher standard deviations (meaning lower agreement among experts). Therefore, in the survey Round 2, experts re-evaluated these factors only. The Level 2 questions were evaluated through a weighted mean formula as shown in Equation (1).

$$\overline{m} = \frac{\sum_{i=1}^{n}(m_i * w_i)}{\sum_{i=1}^{n}(m_i)}, \quad (1)$$

where, n is the number of experts in the panel, w_i is the Likert scale value provided by expert 'i' to the wth factor (from Level 1), and x is 'Yes, record and share' (m = 1) or 'No response' (m = 0) for the traceability information corresponding to the factors. Information with response rates ≤ 75% or ≥ 25% was re-considered in Round 2.

2.6. Final Evaluation (Step 6)

To test consensus, a Pearson correlation coefficient (ϱ) was calculated between the survey responses from different rounds and between the different group of respondents within the same round, using Equations (2)–(4):

$$\overline{X}_a = \sum\nolimits_{i=1}^{n}(X_{a,i})/n, \quad (2)$$

$$\overline{Y}_b = \sum\nolimits_{j=1}^{n}\left(X_{b,j}\right)/n, \quad (3)$$

$$rho(a,b) = \frac{\sum_{i=1}^{n}(X_{a,i} - \overline{X}_a)(Y_{b,i} - \overline{Y}_b)}{\sqrt{\left\{\sum_{i=1}^{n}(X_{a,i} - \overline{X}_a)^2 \sum_{j=1}^{n}(Y_{b,i} - \overline{Y}_b)^2\right\}}}, \quad (4)$$

where n is column length or a number of questions, X_a is the responses by group 'a' and X_b by group 'b', and $\overline{X}_a$ and $\overline{Y}_b$ are the means of responses. The value of rho ranges from −1 to 1, where −1, 1, and 0 indicates a perfect negative, a perfect positive, and no correlation, respectively.

Level 1 questions were analyzed using a distribution analysis. The final data matrix (Z) of weighted mean responses of Level 2 questions was clustered, classified, and logically arranged using hierarchical clustering with optimal leaf ordering. For this, the pairwise Euclidean distance (d) was first calculated between two data points (e.g., 's' and 't') in the form of different row vectors (each with dimension 'n' equal to the number of factors) using Equation (5):

$$d_{st}^2 = \sum_{i=1}^{n} (z_{si} - z_{ti})^2. \quad (5)$$

A similarity matrix of the obtained distances was computed (d) using Ward's linkage algorithm. This method creates a dendrogram with a multilevel hierarchy. Additionally, to generate an optimal relationship among the clusters, the optimal leaf ordering algorithm was followed. This arranges all the elements in a logical order, typically with the most weighted element towards the origin and the least weighted element towards the end of the dendrogram. For further details related to the algorithm, refer to [58].

3. Results

Out of 27 experts who agreed to participate in the study, 23 finally attended the survey in both the rounds (85% response rate). Out of these, 12 were research practitioners, and the rest were industry experts. After Round 2 of the Delphi study, a moderately high consensus was observed firstly between research practitioners and industry experts, and secondly, between aggregate responses from Round 1 and Round 2.

3.1. Traceability Implementation Factors in Textile and Clothing (TC) Supply Chains

The means and standard deviations (SD), obtained through the Likert scale corresponding to each factor in both survey rounds, are shown in Table 3. Three factors with low agreement (high SD value), obtained through pairwise comparison and distribution analysis, were further validated in the next round. After Round 2, a general consensus among the experts' responses was observed with a low SD (value corresponding to each factor) and a Pearson correlation coefficient ϱ (rho) = 0.66 (p-value < 0.01). Figure 3 is the graphical representation of aggregate results (mean value on a Likert scale) corresponding to each factor obtained after Round 2, arranged in descending order (ranking).

Table 3. Results (Likert scale) after each round.

	Implementation Factors	Mean (SD) -					
		Round 1 (R1)			Round 2 (R2)		
		Rec (N = 12)	Ind. (N = 11)	Aggregate	Rec (N = 12)	Ind. (N = 11)	Aggregate
1	Transparency	4.17(0.69)	4.27(0.61)	**4.22(0.66)**	-	-	-
2	Visibility	4.33(0.47)	4.54(0.50)	**4.43(0.49)**	-	-	-
3	Quality Monitoring and control	4.58(0.64)	4.27(0.45)	**4.43(0.58)**	-	-	-
4	Recall mechanism	4.42(0.76)	3.82(0.57)	**4.13(0.74)**	-	-	-
5	Marketing Tool	4.16(0.69)	4.45(0.66)	**4.30(0.68)**	-	-	-
6	Market Surveillance	4.58(0.49)	4.10(0.70)	**4.36(0.64)**	-	-	-
7	Product authentication	4.58(0.64)	4.50(0.67)	**4.54(0.65)**	-	-	-
8	IPR protection	4.33(0.74)	4.40(0.66)	**4.36(0.71)**	-	-	-
9	Product Data Management	4.33(0.74)	3.70(0.85)	**4.04(0.79)**	-	-	-
10	Sales Forecasting	3.92(0.95)	3.50(0.81)	3.72(0.91)	3.75(0.60)	3,55(0.78)	**3.65(0.70)**
11	Product use/maintenance	3.66(1.10)	3.30(1.00)	3.50(1.08)	3.41(0.75)	3.27(0.75)	**3.35(0.75)**
12	Reverse logistics activities	4.25(0.82)	3.70(1.01)	4.00(0.95)	4.08(0.85)	3.90(0.67)	**4.00(0.77)**
13	Renting, sharing and reuse	3.67(0.62)	4.10(0.85)	**3.86(0.76)**	-	-	-
14	* Risk Management	-	-	-	4.75(0.43)	4.45(0.65)	**4.60(0.57)**

Note: Total N = 23; Rec = research practitioner; Ind. = industry experts; * = added after R1. Marked in bold are the final mean (SD) values corresponding to each factor after survey R2.

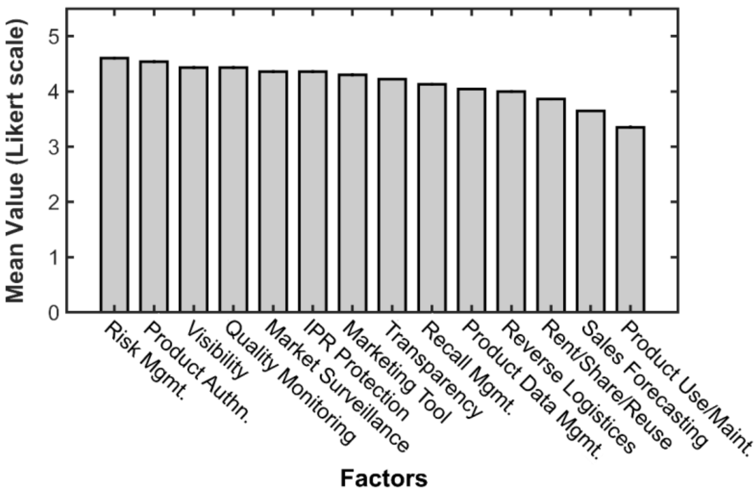

Figure 3. Bar plot of aggregate results corresponding to traceability factors after R2, in descending order of importance.

3.2. Traceability Information in TC Supply Chains

The study prioritized and classified two sets of traceability information. The first set consisted of information that can be shared with customers/end-users, i.e., at the business-to-customer (B2C) level, while the second set consisted of the information that supply chain actors could consider sharing among themselves, i.e., at the business-to-business (B2B) level. After the two rounds of Delphi, a moderately high degree of agreement and stability in responses—related to the B2C set of information—was observed between the group of research practitioners and industry experts, with $\varrho = 0.77$ and 0.74 for Rounds 1 and 2, respectively. In addition, a substantial degree of correlation ($\varrho = 0.92$) was observed in the mean responses from the two rounds.

Similarly, for responses related to the B2B set of information, the agreement between the two groups was moderate ($\varrho = 0.6$ for both the rounds), hence, showing stability in the responses. Furthermore, the consensus between the rounds was also high ($\varrho = 0.84$), indicating a strong correlation.

After ensuring a consensus and stability in the responses, mean values from Round 2 were clustered through hierarchical clustering, and the obtained dendrogram was optimized through an optimal leaf ordering algorithm. The obtained dendrogram, as shown in Figure 4; Figure 5, represents clustering of traceability information at the B2C and B2B levels such that the elements in cluster one have the highest rank (C-1: most important information), followed by cluster two (C-2: important information) and cluster three (C-3: less important information).

At the B2C level, information related to the origin, composition, manufacturer/supplier details, and product sustainability were in C-1, and they were the most important. While at the B2B level, manufacturer/supplier details, product specifications, and quality certification data along with composition and origin-related information were in C-1 and were among the crucial elements. Moreover, the overall ranking, composition, origin, and manufacturer/supplier information were among the most crucial elements for both B2B and B2C levels, while process-related information, such as machine ID, time stamps, and sales and costing data, were among the least important elements for both B2B and B2C levels.

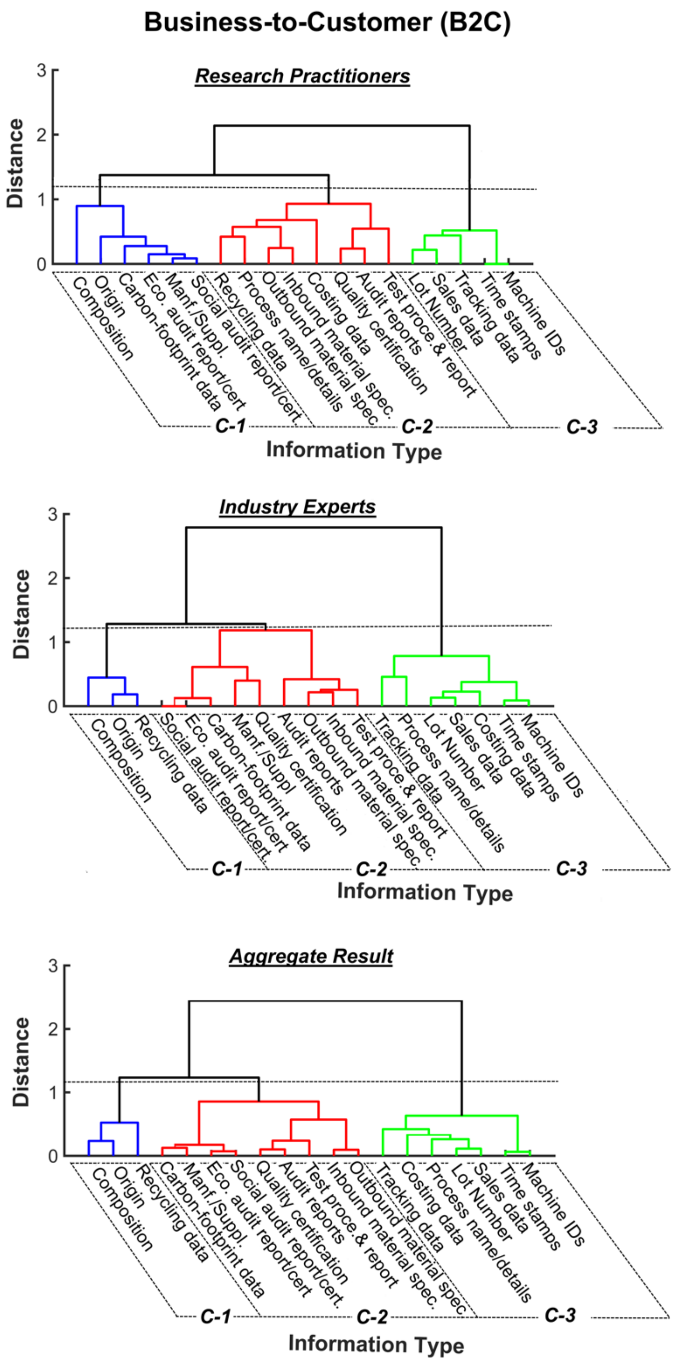

Figure 4. Information that can be recorded and shared at the business-to-consumer (B2C) level.

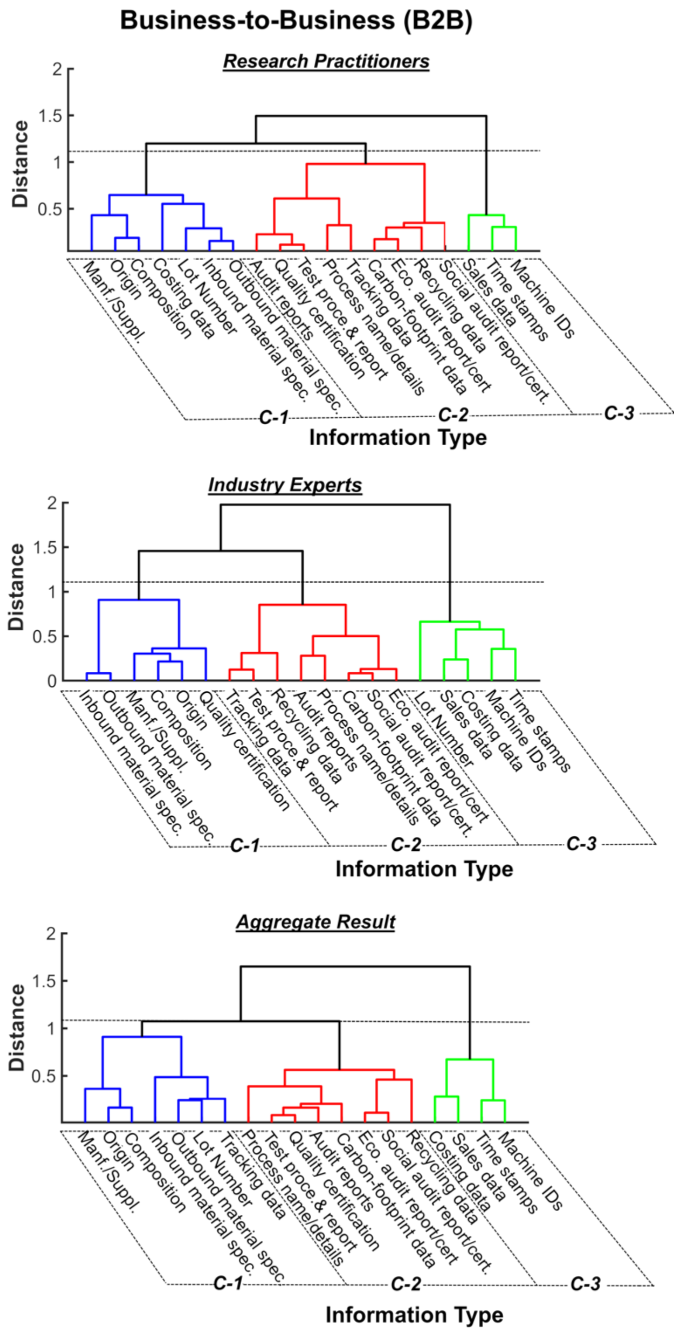

Figure 5. Information that can be recorded and shared at the business-to-business (B2B) level.

4. Analytical Discussion

This section presents an analysis of the obtained results using commentary inputs from the experts, along with inputs from literature, as sources of validation.

4.1. Traceability Implementation Factors

Risk management emerged as the most significant factor influencing traceability implementation in the TC supply chain. In general, traceability can contribute extensively to risk management in a multi-tier supply chain (e.g., TC) that deals with various risks causing delays and disruptions (also supported by [59] for the food supply chain). According to one of the experts, the "[. . .] main need for traceability is about—risk assessment and enabling brands to assess whether they will get the product on time with expected quality". It is also supported in study by [60], wherein the authors analyzed different supply chain risks (including TC) and mentioned the importance of traceability to identify and eliminate potential sustainability-related risks. Following this, product authentication emerged as the second most influential factor, owing to the issue of counterfeit products. It was mentioned that because of the lack of dedicated traceability technology in the TC supply chain, brands suffer huge economic losses from counterfeit products. One of the experts further added, "[...] most of the [traceability] solutions until now are hard to realize in the production systems [...]. Example [...] RFID, which is very hard to produce in a large quantity [...]. The cost of a durable, washable tag is very high, and the programming is complicated. The label printers that effectively can produce RFID or Barcode tags cannot print and program the durable tags because of their size and thickness. The barcodes and 2D codes that are easy to reproduce are also very easy to counterfeit or copy". In this regard, various studies in the past [7,30] have worked towards the development of product traceability and authentication systems for the TC supply chain.

Closely associated is the supply chain visibility that emerged as the third most influencing factor, and as per an expert, "Traceability implementation can increase visibility also of in-shored/re-shored production. It provides an opportunity to better monitor supply chain actors and their activity". Traceability can also assure the claims of the quality certifications (like green labels and organic cotton certification schemes) and can enable effective quality monitoring. It verifies certification reliability by tracking and recording each step of the product lifecycle and "ensures that certification schemes are independent and applied in an equal manner globally." This is also highlighted by [3,46].

Fifth in rank was market surveillance and, as mentioned by the experts, "due to lack of traceability mechanism, border surveillance authorities and customs find it challenging to verify origin and ingenuity of products when they cross borders". Additionally, in the case of product recalls, since there is no traceability system, market surveillance authorities such as RAPEX (Rapid Alert System) find it difficult to trace the origin of defects or the accountable stakeholder [3].

Following this, the sixth influencing factor was concerns related to IPR Protection. Security and IPR concerns are also essential for the TC industry as per the IBM security report [61]. To highlight its importance, one of the research practitioners working on blockchain technology stated, "[...] traceability ensures that information is controlled at various levels of the supply chain with restricted access to authorized actors only. All information [in the survey] plus even more should be available and accessible. [...] I am a strong believer of the future [...] of blockchain technology-based traceability systems. The [...] spot where traceability and transparency come to a collision".

After risk, accountability, and quality-related factors, the seventh, eighth and ninth positions were factors related to marketing, transparency, and product recall. Sharing traceability information with customers can act as a marketing tool and "can showcase sustainability concern of a brand, create a positive image and act as a competitive advantage," as mentioned by one of the experts. Further, transparency can help "to gather information on the origin of materials, in order to measure social/animal welfare/environmental impact [...]", as mentioned by an expert and supported in the literature by [2,29,30]. Moreover, traceability information can help in tracing the recalls, identifying its early warning signs, following products, and monitoring customer reactions.

Product data management and sales forecasting got the tenth and thirteenth positions, respectively. As per one of the experts, "traceability can help in effective management of product and production data by real-time tracking and tracing of material is in stock exchange—trading the total quantity sales for each product/color, location or the factory address and name, and traceability code for the manufacturing mapping".

Interestingly, factors related to supply chain circularity and share economy, i.e., reverse logistics, rent/share/reuse and product use/maintenance, were ranked at the eleventh, twelfth, and fourteenth positions. Unlike what was expected from the literature, these factors got lower ranks because of the lack of a complete traceability mechanism in the TC supply chain. Supporting experts mentioned, "[Traceability] information are not relevant during the use and maintenance of the product, but during the purchasing decision making. Traceability is more necessary at the post-sales level, for the collection of relevant data and information on consumers' behavior [...] set of elements that could give customers the traceability/transparency of their footprint while using/not using, maintaining/not maintaining, re-cycling, up-cycling/discharging their textile products. In order to apply to the sharing business, the tag [traceability mechanism] should have its recording system that harvests the number of washes, mistreatment, etc., while the garment is being shared. Aftersales traceability information of the kind [...] is crucial for recyclability reasons".

4.2. Traceability Information in TC Supply Chains

It was observed that information related to 'origin' and 'composition' was always in the first cluster and among the most important elements. As a mandatory government regulation (e.g., EU TC legislation), this information is already shared with end customers and surveillance authorities. Albeit, it lacks correspondence to all tiers of the supply chain. Following this is the information related to manufacturer/supplier details and social-environmental sustainability (like 'recycling data', 'social audit report/certifications', 'environmental audit report/certifications', and 'carbon footprint data'). As is evident from Figure 4, research practitioners consider this information very important and among those that should be shared with customers along with origin and composition details. One of them even stated that "[...] traceability relevant information is not only about sourcing locations, but also on the environmental and social footprint of raw material sourcing, an, i.e., agricultural method of production, soil regenerative performances of the plantation. (E.g., best fibers used in agricultural rotation cycles, water consumption in case of organic cotton, pesticides, and fertilizers used in conventional agricultural systems) as well footprint of virgin oil extraction referred to synthetic materials." They believe that these sustainability aspects are often ignored and not communicated properly to the customer. Further, one researcher added, "raw material and production footprints, as well as social and economic footprints of the tiers' "deeper depth" (for example the tier with chemical manufacturers), are too often the blind spots of any social and environmental assessment today. Customers [...] should not only be informed about carbon-emission but on all the relevant factors that represent the negative and/or positive environmental and social footprint. Carbon-emissions during transportation [...] starting from raw material to the consumers purchasing location, all should be part of traceability information shared at B2C level".

On the other hand, as per industry experts, recycling-related information is more important than any other sustainability information. They added, "[...] recycling data related to recyclability and where to send the product at the end of the usage' [...] would be key for both B2C and B2B. [...] closing the loop of the material is the most important objective of being transparent. Moreover, disposal information can be a component of traceability information which can help the consumers at the end of the product's life." Despite differences in opinion, information in the two clusters (C1 and the first half of C2) are close to each other in the aggregate results and among the most important elements.

In the latter half of C2 is information related to product quality and specifications, such as 'quality certification', 'audit reports', 'test procedure/reports', and 'inbound and outbound product specifications', and are among the important information elements. Based on the level of traceability and information storage capacity of the traceability system or tag, brands or retailers can choose to share this information with customers and end users.

Finally, in the last cluster, and among the less important traceability information for customers, are those related to 'costing' and 'tracking', and process-related elements like 'machine ID', 'timestamp', 'sales', and process details. As per one of the experts, "[...] customers do not require timing, tracking and sales data. It can be important for B2B sharing purposes."

It is understandable from Figure 5 that at the B2B level, 'inbound and outbound material specification', 'quality certification/audit', 'lot number', and 'tracking data' are considered very important to be recorded and shared, along with traceability information related to 'manufacturer and supplier details', 'origin', and 'composition' (that were also among the most important ones for B2C). Previous studies have also advocated the importance of this information in order to have better visibility, accountability, and control over the supply chain activities [2,30,34]. Traceability information related to all the suppliers across tiers (i.e., tier 2, and even 3) should be recorded and shared with all supply chain partners. Moreover, as stated by one of the experts, "incomplete or improper specification leads to quality issues and problems in production".

Product quality and social-environment sustainability were clustered in C2. As mentioned before, based on the traceability level, supply chain actors can choose to share this information with all supply chain actors. It was observed that information related to social and environmental sustainability fall in the second important cluster, rather than the most important one as in B2C level.

Finally, in the last cluster the least important set of information for businesses is almost the same as that for the B2C level. This consists of information related to 'product costing,' 'sales data' and process related to 'machine ID', 'timestamp', 'sales', and process details. Usually, businesses find it unsafe to share such sensitive data, primarily related to cost and sales, in order to maintain their competitive advantage [32].

5. Conclusions

This research is one of the few that empirically investigates key factors and their level of influence in implementing traceability in TC supply chains. It is also unique in classifying essential information in a traceability system that is needed to record and share among various stakeholders in the TC supply chain. In line with the RQs posed, two specific contributions emanate from this study. First, a list of a wide range of factors and essential traceability information were explored from the literature, which was then validated via a Delphi-based survey with leading experts in the field to attain consensus. Secondly, with the data obtained, the factors were furthered ranked, and traceability information was classified using hierarchal clustering. It can be observed that factors related to supply chain security (risk management and product authentication) followed by visibility, quality (quality monitoring, market surveillance, and recall management), and marketing have the highest impact and major influence in traceability implementation in the TC supply chain. Among the information, 'product information' (related to composition, origin, manufacturer details), and 'social/environmental information' (related carbon footprint, environmental/social certification, and recycling data) are the elements that must be shared with customers. Product information (related to composition, origin, and manufacturer details), quality information (related to audit reports and test reports), and process information (related to process details, tracking, and specifications) are the elements that must be shared among businesses in the supply chain.

5.1. Research Implications

The study contributes to traceability research by exploring and ranking the factors influencing its implementation and the traceability information essential in TC supply chains. It works towards solving some of the major concerns (as stated in [6,62]) related to traceability systems in the TC supply chain for stakeholders and policy makers. The outcome of the study can be useful for a number of reasons. (i) The supply chain actors can determine the information that is needed to be linked with different traceability systems and that can be shared with customers, also indicated in [16]. (ii) The supply chain leaders or fashion brands can refer to the study for traceability-related decision-making and in determining the extent of traceability in their supply chain. (iii) The study can aid the policy makers in setting traceability rules and regulations. Finally, (iv) it can influence the customer to make ethical buying decisions [63,64].

In terms of advancements made in scientific research, the work can support the development of a blockchain-based traceability framework for the TC supply chain, as proposed in [16,65]. The blockchain technology stores the entire database across different nodes of the blockchain system; therefore, storage of minimum essential information is advisable for an effective and energy-efficient system. Essential traceability factors can also be useful for the development of an innovative business model based on blockchain technology. Through interesting qualitative inputs from experts belonging to top-level management, it can be perceived that implementing traceability and sharing sustainability-related information could lead to competitive advantages and can contribute to strategic management literature, e.g., to reduce information asymmetry in supply chains [16]. For instance, in literature related to the food supply chain, it is supported in [32].

5.2. Limitations and Future Research

Commonly in Delphi study, the choice of panelists from a specific industry, as in this paper, can challenge the generalizability of the results in the larger supply chain context. However, as mentioned earlier, such sector-specific research is of significant importance and required in order to answer the RQs [11]. Another limitation is potential biases in the Delphi panel selection. However, following guidelines by [24] and referring to [25], it is unlikely that another panel would reach entirely different agreements.

Additionally, it can be noted that "why" and "how" questions were not addressed. Detailed explanations of the ranking or clustering, and how a factor influences traceability or how recording and sharing of particular information would affect traceability, were not covered. In future research, the findings can be used to (a) do an in-depth qualitative work, e.g., via interviews to address the above-mentioned "why" and "how" questions; (b) look into traceability through various strategic theoretical lenses, e.g., information asymmetry; and (c) incorporate more developmental research related to understanding the design issues and performances of traceability systems [16] with the results of this study.

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References

1. Boström, M.; Micheletti, M. Introducing the Sustainability Challenge of Textiles and Clothing. *J. Consum. Policy* **2016**, *39*, 367–375. [CrossRef]
2. Egels-Zandén, N.; Hulthén, K.; Wulff, G. Trade-offs in supply chain transparency: The case of Nudie Jeans Co. *J. Clean. Prod.* **2015**, *107*, 95–104. [CrossRef]
3. Kumar, V.; Agrawal, T.K.; Wang, L.; Chen, Y. Contribution of traceability towards attaining sustainability in the textile sector. *Text. Cloth. Sustain.* **2017**, *3*, 5. [CrossRef]
4. Grimm, J.H.; Hofstetter, J.S.; Sarkis, J. Exploring sub-suppliers' compliance with corporate sustainability standards. *J. Clean. Prod.* **2016**, *112*, 1971–1984. [CrossRef]
5. Freise, M.; Seuring, S. Social and environmental risk management in supply chains: A survey in the clothing industry. *Logist. Res.* **2015**, *8*, 2. [CrossRef]
6. Richero, R.; Ferrigno, S. *A Background Analysis on Transparency and Traceability in the Garment Value Chain*; Directorate General for International Cooperation and Development, European Commission: Brussels, Belgium, 2016.
7. Corbellini, S.; Ferraris, F.; Parvis, M. A Cryptographic System for Brand Authentication and Material Traceability in the Textile Industry. In Proceedings of the 2006 IEEE Instrumentation and Measurement Technology Conference, Sorrento, Italy, 24–27 April 2006; pp. 1331–1335.
8. Wajsman, N.; Arias Burgos, C.; Davies, C. *The Economic Cost of IPR Infringement in The Clothing, Footwear and Accessories Sector*; European Union Intellectual Property Office: Alicante, Spain, 2015.
9. OECD. *OECD Due Diligence Guidance for Responsible Business Conduct Responsible Supply Chains in the Garment and Footwear Sector*; OECD: Paris, France, 2017.
10. Olsen, P.; Borit, M. The components of a food traceability system. *Trends Food Sci. Technol.* **2018**, *77*, 143–149. [CrossRef]

11. Thakur, M.; Donnelly, K.A.-M. Modeling traceability information in soybean value chains. *J. Food Eng.* **2010**, *99*, 98–105. [CrossRef]
12. Chaudhuri, A.; Dukovska-Popovska, I.; Subramanian, N.; Chan, H.K.; Bai, R. Decision-making in cold chain logistics using data analytics: A literature review. *Int. J. Logist. Manag.* **2018**, *29*, 839–861. [CrossRef]
13. Doukidis, G.; Pramatari, K.; Kelepouris, T. RFID-enabled traceability in the food supply chain. *Ind. Manag. Data Syst.* **2007**, *107*, 183–200.
14. Li, Z.; Liu, G.; Liu, L.; Lai, X.; Xu, G. IoT-based tracking and tracing platform for prepackaged food supply chain. *Ind. Manag. Data Syst.* **2017**, *117*, 1906–1916. [CrossRef]
15. Paltriccia, C.; Tiacci, L. Supplying networks in the healthcare sector: A new outsourcing model for materials management. *Ind. Manag. Data Syst.* **2016**, *116*, 1493–1519. [CrossRef]
16. Kumar, V.; Hallqvist, C.; Ekwall, D. Developing a Framework for Traceability Implementation in the Textile Supply Chain. *Systems* **2017**, *5*, 33. [CrossRef]
17. Ritch, E.L. Consumers interpreting sustainability: Moving beyond food to fashion. *Int. J. Retail Distrib. Manag.* **2015**, *43*, 1162–1181. [CrossRef]
18. Hsu, C.-C.; Sandford, B.A. The Delphi Technique; Making Sense of Consensus. *Pract. Assess. Res. Eval.* **2007**, *12*, 1–8.
19. Brinch, M.; Stentoft, J.; Jensen, J.K.; Rajkumar, C. Practitioners understanding of big data and its applications in supply chain management. *Int. J. Logist. Manag.* **2018**, *29*, 555–574. [CrossRef]
20. Darkow, I.-L.; von der Gracht, H.A. Energy-constrained and low-carbon scenarios for the transportation and logistics industry. *Int. J. Logist. Manag.* **2016**, *27*, 142–166.
21. Kembro, J.; Näslund, D.; Olhager, J. Information sharing across multiple supply chain tiers: A Delphi study on antecedents. *Int. J. Prod. Econ.* **2017**, *193*, 77–86. [CrossRef]
22. Förster, B.; Keller, J.; von der Gracht, H.A.; Darkow, I.L. Delphi-based strategic issue management: Crafting consumer goods supply chain strategy. *Int. J. Phys. Distrib. Logist. Manag.* **2014**, *44*, 373–391.
23. Nair, R.; Mason, R. Supply-side strategic flexibility capabilities in container liner shipping. *Int. J. Logist. Manag.* **2013**, *24*, 22–48.
24. Okoli, C.; Pawlowski, S.D. The Delphi method as a research tool: An example, design considerations and applications. *Inf. Manage.* **2004**, *42*, 15–29. [CrossRef]
25. Pal, R.; Harper, S.; Vellesalu, A. Competitive manufacturing for reshoring textile and clothing supply chains to high-cost environment: A Delphi study. *Int. J. Logist. Manag.* **2018**, *29*, 1147–1170. [CrossRef]
26. Ringsberg, H. Perspectives on food traceability: A systematic literature review. *Supply Chain Manag. Int. J.* **2014**, *19*, 558–576. [CrossRef]
27. Sarpong, S. Traceability and supply chain complexity: Confronting the issues and concerns. *Eur. Bus. Rev.* **2014**, *26*, 271–284. [CrossRef]
28. Cheng, M.J.; Simmons, J.E.L. Traceability in Manufacturing Systems. *Int. J. Oper. Prod. Manag.* **1994**, *14*, 4–16. [CrossRef]
29. Doorey, D.J. The Transparent Supply Chain: From Resistance to Implementation at Nike and Levi-Strauss. *J. Bus. Ethics* **2011**, *103*, 587–603. [CrossRef]
30. Kumar, V. *Exploring Fully Integrated Textile Tags and Information Systems for Implementing Traceability in Textile Supply Chains*; University Lille 1 in Collaboration with Högskolan i Borås (Sweden) and Soochow University (Suzhou): Borås, Sweden, 2017.
31. Strähle, J.; Merz, L. Case Study: Total Transparency at Honestby.com. In *Green Fashion Retail*; Strähle, J., Ed.; Springer Series in Fashion Business; Springer: Singapore, 2017; pp. 269–291, ISBN 978-981-10-2439-9.
32. Canavari, M.; Centonze, R.; Hingley, M.; Spadoni, R. Traceability as part of competitive strategy in the fruit supply chain. *Br. Food J.* **2010**, *112*, 171–186. [CrossRef]
33. Morgan, T.R.; Richey, R.G., Jr.; Ellinger, A.E. Supplier transparency: Scale development and validation. *Int. J. Logist. Manag.* **2018**, *29*, 959–984. [CrossRef]
34. (Nel) Wognum, P.M.; Bremmers, H.; Trienekens, J.H.; van der Vorst, J.G.A.J.; Bloemhof, J.M. Systems for sustainability and transparency of food supply chains—Current status and challenges. *Adv. Eng. Inform.* **2011**, *25*, 65–76. [CrossRef]
35. Shin, S. Consumers' Use of Care-label Information in the Laundering of Apparel Products. *J. Text. Inst.* **2000**, *91*, 20–28. [CrossRef]

36. Tao, F.; Wang, Y.; Zuo, Y.; Yang, H.; Zhang, M. Internet of Things in product life-cycle energy management. *J. Ind. Inf. Integr.* **2016**, *1*, 26–39. [CrossRef]
37. Assmuth, T.; Häkkinen, P.; Heiskanen, J.; Kautto, P.; Lindh, P.; Mattila, T.; Mehtonen, J.; Saarinen, K. *Risk Management and Governance of Chemicals in Articles. Case Study Textiles*; Finnish Environment Institute: Helsinki, Finland, 2011; ISBN 978-952-11-3901-7.
38. Machado, S.M.; Paiva, E.L.; da Silva, E.M. Counterfeiting: Addressing mitigation and resilience in supply chains. *Int. J. Phys. Distrib. Logist. Manag.* **2018**, *48*, 139–163. [CrossRef]
39. Alemanno, A. *Solving the Problem of Scale: The European Approach to Import Safety and Security Concerns*; Social Science Research Network: Rochester, NY, USA, 2009.
40. Alemanno, A. European Food Import Safety regime under a Stress Test: The Melamine Contamination of the Global Food Supply Chain. *Erasmus Law Rev.* **2010**, *3*, 203.
41. Legnani, E.; Cavalieri, S.; Pinto, R.; Dotti, S. The Potential of RFID Technology in the Textile and Clothing Industry: Opportunities, Requirements and Challenges. In *Unique Radio Innovation for the 21st Century*; Ranasinghe, D.C., Sheng, Q.Z., Zeadally, S., Eds.; Springer: Berlin/Heidelberg, Germany, 2011; pp. 309–329, ISBN 978-3-642-03461-9.
42. Pigni, F.; Crave, S.; Ravaini, A. Traceability in the textile and clothing industry: Issues and implications for RFId adoption. In Proceedings of the 2nd Mediterranean Conference on Information Systems, MCIS 2007, Venice, Italy, 4–8 October 2007.
43. Bechini, A.; Cimino, M.G.C.A.; Marcelloni, F.; Tomasi, A. Patterns and technologies for enabling supply chain traceability through collaborative e-business. *Inf. Softw. Technol.* **2008**, *50*, 342–359. [CrossRef]
44. Nativi, J.J.; Lee, S. Impact of RFID information-sharing strategies on a decentralized supply chain with reverse logistics operations. *Int. J. Prod. Econ.* **2012**, *136*, 366–377. [CrossRef]
45. Wyld, D.C. Taking out the Trash (And the Recyclables): RFID and the Handling of Municipal Solid Waste. *Int. J. Softw. Eng. Appl.* **2010**, *1*, 1–13.
46. Cheng, Z.; Xiao, J.; Xie, K.; Huang, X. Optimal Product Quality of Supply Chain Based on Information Traceability in Fashion and Textiles Industry: An Adverse Logistics Perspective. *Math. Probl. Eng.* **2013**, *2013*, e629363. [CrossRef]
47. MacKenzie, C.A.; Apte, A. Modeling disruption in a fresh produce supply chain. *Int. J. Logist. Manag.* **2017**, *28*, 656–679. [CrossRef]
48. Meuwissen, M.P.M.; Velthuis, A.G.J.; Hogeveen, H.; Huirne, R.B.M. Traceability and certification in meat supply chains. *J. Agribus.* **2003**, *21*, 167–181.
49. Kwok, S.K.; Wu, K.W. RFID-based intra-supply chain in textile industry. *Ind. Manag. Data Syst.* **2009**, *109*, 1166–1178. [CrossRef]
50. Jansen-Vullers, M.H.; van Dorp, C.A.; Beulens, A.J.M. Managing traceability information in manufacture. *Int. J. Inf. Manag.* **2003**, *23*, 395–413. [CrossRef]
51. Sun, C.-H.; Li, W.-Y.; Zhou, C.; Li, M.; Ji, Z.-T.; Yang, X.-T. Anti-counterfeit code for aquatic product identification for traceability and supervision in China. *Food Control* **2014**, *37*, 126–134. [CrossRef]
52. Guercini, S.; Runfola, A. The integration between marketing and purchasing in the traceability process. *Ind. Mark. Manag.* **2009**, *38*, 883–891. [CrossRef]
53. Roosen, J. Marketing of Safe Food Through Labeling. *J. Food Distrib. Res.* **2003**, *34*, 77.
54. Rijswijk, W.V.; Frewer, L.J. Consumer needs and requirements for food and ingredient traceability information. *Int. J. Consum. Stud.* **2012**, *36*, 282–290. [CrossRef]
55. Lumsden, K.; Mirzabeiki, V. Determining the value of information for different partners in the supply chain. *Int. J. Phys. Distrib. Logist. Manag.* **2008**, *38*, 659–673. [CrossRef]
56. Phau, I.; Teah, M.; Chuah, J. Consumer attitudes towards luxury fashion apparel made in sweatshops. *J. Fash. Mark. Manag. Int. J.* **2015**, *19*, 169–187. [CrossRef]
57. Radhakrishnan, S. The Sustainable Apparel Coalition and the Higg Index. In *Roadmap to Sustainable Textiles and Clothing*; Textile Science and Clothing Technology; Springer: Singapore, 2015; pp. 23–57, ISBN 978-981-287-163-3.
58. Bar-Joseph, Z.; Gifford, D.K.; Jaakkola, T.S. Fast optimal leaf ordering for hierarchical clustering. *Bioinformatics* **2001**, *17*, S22–S29. [CrossRef]
59. Chaudhuri, A.; Srivastava, S.K.; Srivastava, R.K. Propagation of risks and their impact on performance in fresh food retail. *Int. J. Logist. Manag.* **2015**, *26*, 568–602.

60. Giannakis, M.; Papadopoulos, T. Supply chain sustainability: A risk management approach. *Int. J. Prod. Econ.* **2016**, *171*, 455–470. [CrossRef]
61. McMillen, D.; Alvarez, M.; Craig, S. *Security Trends in the Manufacturing Industry [White Paper]*; IBM: New York, NY, USA, 2016; pp. 1–19.
62. Algayerova, O. *TEXTILE4SDG12: Transparency in Textile Value Chains in Relation to the Environmental, Social and Human Health Impacts of Parts, Components and Production Processes*; United Nations Economic Commission for Europe: Geneva, Switzerland, 2017; pp. 1–27.
63. Bradu, C.; Orquin, J.L.; Thøgersen, J. The Mediated Influence of a Traceability Label on Consumer's Willingness to Buy the Labelled Product. *J. Bus. Ethics* **2014**, *124*, 283–295. [CrossRef]
64. Goswami, S. Traceability to Farm and Factory, Country of Manufacturing, and Apparel Purchase Scenario. University of Missouri–Columbia, 2014. Available online: https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/44421/Research.pdf?sequence=1 (accessed on 20 February 2019).
65. Agrawal, T.K.; Sharma, A.; Kumar, V. Blockchain-Based Secured Traceability System for Textile and Clothing Supply Chain. In *Artificial Intelligence for Fashion Industry in the Big Data Era*; Thomassey, S., Zeng, X., Eds.; Springer Series in Fashion Business; Springer: Singapore, 2018; pp. 197–208, ISBN 9789811300790.