Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 278 (2026) 401–409

Procedia Computer Science

www.elsevier.com/locate/procedia

CENTERIS – International Conference on ENTERprise Information Systems / ProjMAN – International Conference on Project MANagement / HCist – International Conference on Health and Social Care Information Systems and Technologies 2025

Needs and Requirements Assessment of Physical Product Traceability within the Portuguese Textile and Clothing Industry

Ana Teresa Campaniço[a], Armando Fontainhas[a], Joel Puga[a,c], João Oliveira[b], Filipe Meneses[a,c]*, Adriano Moreira[a,c], Marcelo Pitanga Alves[d]

[a]*Institute CCG/ZGDV, Av. da Universidade – Campus Azurém, Edifício 14, 4800-058 Guimarães, Portugal*
[b]*CITEVE, Rua Fernando Mesquita 2785, 4760-034 V. N. Famalicão, Portugal*
[c]*Centro Algoritmi, Universidade do Minho – Campus Azurém, 4800-058 Guimarães, Portugal*
[d]*INFOS – Informática e Serviços S.A, Rua Veloso Salgado, 971, 4450-801 Leça da Palmeira, Portugal*

Abstract

The Textile and Clothing Industry (TCI) has been increasingly adopting traceability solutions to maintain competitiveness amidst growing market demands for transparency, sustainability, and continuous improvements in quality and efficiency. This study investigates the needs and requirements of physical traceability in Portuguese TCI companies by assessing Information Technology (IT) companies that provide multiple solutions across various sectors of the supply chain. The findings reveal that no single solution can encompass all variables, with IT companies instead providing multiple tracking and tracing solutions with differing levels of granularity, interoperability, and adoption by the TCI companies. We also identify areas of intervention and innovation, as well as the limitations that prevent their easy adoption.

© 2025 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the CENTERIS/ProjMAN/HCist conferences

Keywords: Traceability; Manufacturing; Textile and Clothing; Portuguese Industry

* Corresponding author. Tel.: +351 253510580.
E-mail address: filipe.meneses@ccg.pt

1877-0509 © 2025 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the CENTERIS/ProjMAN/HCist conferences

1. Introduction

Due to growing market demand for transparency, sustainability, and continuous improvements in quality and efficiency, the Textile and Clothing Industry (TCI) has been increasingly adopting traceability solutions to better control production and maintain competitiveness. Part of these solutions involves the physical tracking of the products across the entire supply chain to provide quick and accurate information on location, status, quantities, and other data. This is achieved through the use of barcodes, quick-response (QR) codes, radio-frequency identification (RFID), and other technologies.

The malleable nature of the fabrics, combined with the diverse and often aggressive transformative processes, poses significant challenges when it comes to tracking a product seamlessly through the entire supply chain. This is complicated further by other issues, such as information asymmetry between clients and subcontractors. Information Technology (IT) companies attempt to address these challenges by developing customized traceability solutions tailored to this industry, despite the great variability in requirements that TCI companies present and the lack of a universal technology for location and tracking in indoor environments.

To understand the needs and requirements of physical traceability in Portuguese TCI companies, we assessed several IT companies that provide multiple solutions in this field, collectively covering the entire supply chain in this industrial sector, which provides them with a comprehensive view of the technologies used and their degree of adoption.

The results offer valuable insights into the current state of physical traceability practices and their alignment with the identified criteria. Thus, we can identify which points require intervention or determine new areas of innovation within the Portuguese TCI sector.

2. Related work

The clothing industry has progressed from basic tracking of textiles to advanced systems that ensure compliance with sustainability, quality, ethical, and human rights standards, driven by the need for traceability. As consumer expectations rise and regulatory scrutiny increases, the textile industry must now document the entire product lifecycle from sourcing to distribution [1] [2]. Barcodes, and more recently, their two-dimensional version, QR codes, are the most traditional means of tracking items used today, as they are cheap and easy to apply. The increased complexity of production, nevertheless, has led to the employment of modern technologies such as RFID and Global Positioning System (GPS) in addition to the former methods, with greater automation and accuracy of capture in several production stages [3] [4].

Over the past few years, interest in blockchain and Internet of Things (IoT) technologies has become a transformative tool for enhancing traceability in the textile sector. Blockchain ensures that data is stored in an uncentralized manner that is transparent and tamper-proof. Manufacturers, suppliers of raw materials, and retailers can record the relevant information in real-time, which generates an indelible product history. Also, this enhances consumer confidence in sustainability claims [5].

RFID technology has become popular in the textile industry for non-contact automated identification and tracking, making it particularly useful in high-speed production environments. RFID tags can store information about the product that can be used in real-time, enabling tracking at different points of entry from raw materials to the shipping of finished products. However, this solution has several drawbacks, including interference from the textile, damage during production processes, and high costs [6] [7].

While subcontracting is very common in the textile industry, many companies do not use digital solutions in their processes. Another big issue for the TCI companies is the lack of infrastructure for high-resolution traceability. This absence of uniformity usually leads to data fragmentation, which makes it difficult to maintain complete traceability from raw materials to finished products and interferes with today's necessity to obtain a carbon footprint and be aware of the entire production process [8] [9].

Traceability in the textile sector requires varying levels of granularity, depending on factors such as product type, stage in the production process, and client specifications. Solutions typically track items at multiple levels, such as raw materials, batches, individual products, and finished goods, with spatial granularity extending from country-level data down to specific storage locations like shelves or boxes [10] [11].

Enterprise Resource Planning (ERP) systems play a crucial role in business management, enabling the integrated management of production, treasury, finance, and other key areas. It can also manage the data collected during traceability operations, aggregating data from RFID solutions, barcode systems, and IoT devices, among others. Combining traceability data with ERP can improve inventory levels and production scheduling, as well as enhance an organization's decision-making capabilities. Ongoing research examines ways to achieve seamless integration into ERPs, particularly through modular traceability solutions that can meet the varying needs of different ERPs [12] [13] [14].

3. Methodology

For this assessment of the Portuguese textile and clothing industry's current needs and requirements in terms of physical traceability of the production process, a sample of 7 IT companies was selected. They specialize in developing a wide array of software and hardware track & tracing solutions for this market, each covering one or more sectors of the supply chain, with varying degrees of granularity. As such, they provide a good representation of the variety of IT companies that offer solutions to the TCI companies within Portugal.

Table 1. Open-ended questionnaire of the company's physical product traceability.

Identifier	Question
1.	In which sectors and subsectors of the Textile and Clothing Industry (TCI) does your company operate in?
2.	Which stage of the production process, for each TCI sector and subsector, you already have one or more track & trace solutions implemented?
3.	Which type of track & trace solutions you use to identify the products, and which technologies to read the identifiers, for each stage of the production process?
4.	What is the granularity of the product identification for each track & trace solution used?
5.	What is the granularity of the geography, or point in space, for each track & trace solution used?
6.	What is the granularity of the production process phase for each track & trace solution used?
7.	What is the purpose of each track & trace solution used?
8.	Which phases of the production process, in each TCI sector and subsector, would you like to see track & trace solutions implemented? And for what purpose?

Each company was presented with an open-ended questionnaire (Table 1) to identify the sectors and subsectors of the TCI in which they operate, the type of physical product tracking & tracing each performs, and which future solutions they consider most desirable. The answers were compiled into a preliminary comparative matrix, and each company was presented with its column of answers in relation to all the collected responses, allowing them to both validate and revise the results.

The feedback was used to compile a new comparative matrix, with the final validation being done through individual, semi-structured face-to-face interviews, where each IT company was asked to confirm the answers they gave to each question, and to provide additional context or clarification to the non-quantitative answers that were given in the open-ended questionnaire or during the interview. Each interview was recorded and later analyzed, resulting in the final matrix (Appendix A) and providing valuable, qualitative insight into the solutions they provide and the limitations the TCI sector imposes, which are presented below.

4. Results

Because most of their Portuguese TCI clients are small or medium-sized ventures that focus on specific sectors of the industry, with varying levels of technology adoption, the IT companies develop several solutions for the whole production chain (Appendix A, Question 1). This fragmentation can represent a challenge to product traceability, especially when TCI companies often rely on outsourcing part of the production process, as subcontractors frequently do not use the same track-and-trace solutions or track products with the same level of detail.

Besides these limitations on the type of solutions IT companies can offer, clothing brands and consumers are also imposing additional pressure to increase traceability and measure the carbon footprint each product element suffers in the processes it is subjected to.

The IT companies' solutions track product information across multiple phases of the production process, putting special emphasis on the movement of stock, production itself, and shipments to subcontractors (Appendix A, Question 2). This is done through either custom-made solutions or add-ons to existing ERP software. Cloud storage and online information visualization are common in both approaches.

This diversity is due to the differing needs of TCI companies regarding the level of granularity of the tracked information. There are also issues imposed by monetary and physical constraints, which frequently limit the IT companies' ability to integrate more modern solutions into already existing machines or infrastructure.

Regarding tracking technology, the barcode is still the most widely used solution, followed by the growing adoption of QR codes (Appendix A, Question 3.1). According to the IT companies, both solutions are easy to print and can be read with either the specialized devices the clients already own or modern phones and tablets (Appendix A, Question 3.2). Computer vision is not widely used due to the high likelihood of visual occlusions and other limiting factors, such as the destruction of tracking labels during the dyeing or cutting stages. The TCI companies have shown interest in adopting other solutions, with RFID being particularly common after the confection stage.

The IT companies answer this need by offering multiple solutions for indoor tracking. None of the interviewed companies showed interest in exploring outdoor positioning (Appendix A, Question 3.1) because their clients often outsource the delivery services.

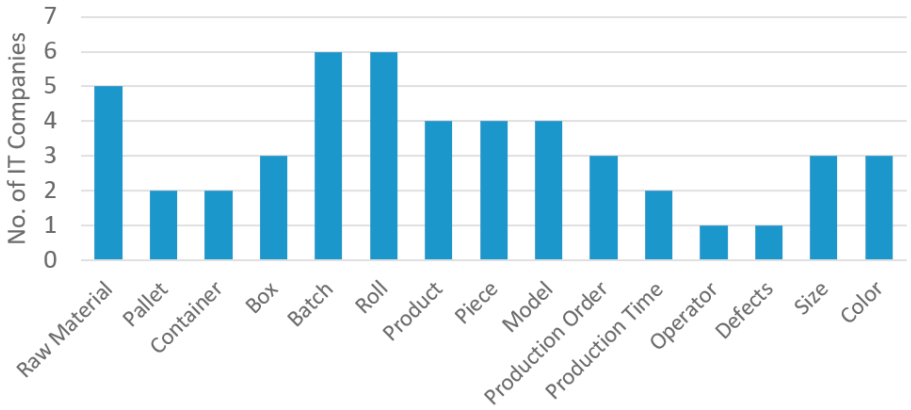


Fig. 1. Granularity of the products tracked by the TI companies' solutions (Appendix A, Question 4).

As seen in Figure 1, the IT companies track various products and information, the most common being batches, rolls, and raw materials. However, what each TCI company tracks can differ significantly, not just due to the sectors each specializes in, but also due to the lack of standardization within the industry. Namely, each company can have a very different interpretation of what comprises a batch, for example, or if they must receive identical or differing identifiers, thus impacting the solutions the IT companies provide.

Most of the physical tracking performed by IT companies takes place within the client's facilities, as Portuguese TCI companies are typically small or medium-sized ventures confined to a single space. The most common granularities are locating the product by the zone or area it's in, on which shelf, or in which box it was placed (Appendix A, Question 5), with the level of precision depending significantly on the type and size of the product being tracked. The majority of IT companies track multiple granularities simultaneously, but they do not possess an identifier that can survive the entire production process, having to be replaced periodically.

Tracking errors resulting from improper identification or failure to place the product in the designated area can be especially problematic when they occur at a subcontractor's facilities. Many do not use the same tracking solutions as those adopted by their TCI clients, nor do they share the same level of tracking detail. So, there is significant interest, both from the TCI and IT companies, in developing more resilient identifiers that require less human intervention, paired with an accessible interface to incentivize subcontractor adoption.

Regarding the tracking of which production phase the product is in, IT companies pay particular attention to when it enters or exits the warehouse, if it's in motion, or if it's entering, exiting, or currently in a production stage (Appendix A, Question 6). However, their solutions don't track standby states, such as when the product has arrived at the geographical location but is waiting for the machine to complete the current production process, or a machine malfunction or a critical non-conformity is delaying the product.

The IT companies' solutions serve a variety of purposes, but most are used to track inventory and production management, the product's geographical location, and the work in progress (Appendix A, Question 7). This is due in part to the TCI companies already using parallel solutions to manage other sectors, such as administration or accounting.

However, IT companies show great interest in exploring new traceability solutions and technologies, such as the application of RFID in parts (Appendix A, Question 8). Some of the specific examples they cited in the individual interviews were:

- Increase solution parametrization, so clients can track only the desired sectors of the production chain, while complementing the data with information from other ERPs;
- Provide information access to all associated suppliers, clients, or subcontractors;
- Determine deadline compliance of each production stage, providing feedback on the time gained or lost;
- Track the product through the entire value chain, with greater precision and rigor;
- Allow multiple tracking solutions simultaneously, with emphasis on interoperability;
- Automatically update the product's geographical location when it changes, including subcontractors, while reducing or eliminating human input;
- Allow consultation of the product's location at any moment in time;
- List the current contents of all tracked containers by warehouse;
- Automatically count the parts;
- Increase the use of wireless solutions and sensor fusion.

As for the specific interest in RFID solutions, IT companies aim to use them to increase performance, reduce costs, and fulfill deadlines by reducing the dependency on human operators and all consequent limitations. Although they are willing to explore other technologies that achieve the same goals.

However, older TCI companies restrict this technological adoption. They are generally reluctant to invest in more modern solutions until forced by the market. This forces IT companies to continue supporting barcodes, as they remain the standard solution for such clients.

Conclusions

The study conducted made it possible to characterize the Portuguese market from the perspective of both TCI and IT companies in terms of tracking and managing products during the production process.

Regarding the physical tracking of the products across the entire TCI supply chain, the analysis reveals that there is no single solution that encompasses all variables. A perfect solution should support various product tracking technologies, allow for the dynamic definition of granularity in terms of physical spaces, integrate with different ERPs, be scalable and inexpensive, and ensure secure interoperability between companies, while also resolving the issue of subcontractors.

Until such solution is achieved the IT companies get around this issue by providing several, smaller solutions that are tailored to each production process and the respective level of technological adoption each TCI company possesses. The results also show the IT companies have a great interest in exploring new technological solutions, or refining existing ones, as well as expanding into new production sectors, increase granularity and allow greater interoperability, while also reducing human error and other sources of cost.

But as we can observe the TCI companies, and the subcontractors, can prove to be a strong limiting factor to such evolutions. Besides having differing levels of maturity in terms of technological adoption, they often prove reluctant in exploring new solutions unless there are very significant direct benefits that justify the investment, or if the market imposes them.

Acknowledgements

This work has been supported by the European Union under the NextGenerationEU, through a grant of the Portuguese Republic's Recovery and Resilience Plan (PRR) Partnership Agreement, within the scope of the project TEXP@CT - Innovation Pact for the Digitization of the Textile and Clothing Industries (Project ref. nr. 61 - C644915249-00000025).

References

[1] Dias, Ricardo Abreu (2023). “Plataforma de rastreabilidade para a cadeia de valor do setor têxtil e do vestuário” *Master's thesis.* http://hdl.handle.net/20.500.11960/3524.

[2] Matos, Geovane Machado de (2018) “A relevância do processo de controle de qualidade interno em uma indústria têxtil do extremo sul catarinense” *Universidade do Extremo Sul Catarinense.* http://repositorio.unesc.net/handle/1/6684.

[3] Moretti, Eduardo de Araujo (2017) "Estudo das dificuldades observadas na implantação de sistemas RFID." *Master's thesis, Universidade Estadual de Campinas. Faculdade de Engenharia Mecânica*. *Campinas, SP:[sn]*. https://doi.org/10.47749/T/UNICAMP.2017.986604.

[4] Vaz, Paulo José das Neves (2021) "O design de moda como fator dinamizador da competitividade externa do subsetor da indústria de malhas portuguesa." *Doctoral thesis, Universidade do Minho (Portugal.)* https://hdl.handle.net/1822/75609.

[5] Oliveira, Renan Jacob, and Thiago Castello Menezes (2023) "Implantação de RFID na indústria têxtil." *Trabalho de conclusão de curso (Curso Superior de Tecnologia em Produção Têxtil) - Faculdade de Tecnologia de Americana "Ministro Ralph Biasi", Americana, 2023*. https://ric.cps.sp.gov.br/handle/123456789/15434.

[6] Rodrigues, Joana Salgado Lago (2020) “Avaliação da viabilidade da implementação de uma solução RFID numa empresa de retalho eletrónico” *Master's thesis, Universidade do Minho (Portugal.)*. https://repositorium.sdum.uminho.pt/handle/1822/72682.

[7] Júnior, Everaldo and Roberto Minadeo (2018) "Sistema RFID: Vantagens e desvantagens observadas na implementação em estudos de casos", *XXV Simpósio de Engenharia de Produção Inovação e Sustentabilidade na Gestão de Processos de Negócios,* Bauru, SP, Brasil.

[8] da Silva, Sérgio Ricardo Tavares (2021) "Relacionamento Empresa-Cliente na Inovação: Estudo Aplicado à Indústria Têxtil e Vestuário Portuguesa." *Master's thesis, Universidade da Beira Interior (Portugal)*. http://hdl.handle.net/10400.6/11613.

[9] Rodrigues, Ana Sofia Ferreira (2021) "Fatores de Flexibilização e Produtividade na Indústria Têxtil e Confeções." *Master's thesis, Universidade da Beira Interior (Portugal)*. http://hdl.handle.net/10400.6/11596.

[10] Germany, G. S., and W. Partners (2007) "Supply chain management in the European textile industry." *Building Radio Frequency Identification for the Global Environment:* 1-39.

[11] Oner, Mahir, Alp Ustundag, and Aysenur Budak. (2017) "An RFID-based tracking system for denim production processes." *The International Journal of Advanced Manufacturing Technology* **90.1**: 591-604. https://doi.org/10.1007/s00170-016-9385-7.

[12] Amara, Souha Ben, Mariam Hammouda, Nada Kharroubi, Sondes Hammami, and Rim Ben Amara (2023) “The Production Tracking Process in a Real Textile Company” *2023 IEEE Third International Conference on Signal, Control and Communication (SCC),* Hammamet, Tunisia, pp. 01-05. https://doi.org/10.1109/SCC59637.2023.10527732.

[13] Rambola, Radhakrishna, and Mandar Jatkar (2018) "An Effective Synchronization of ERP in Textile Industries." *2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA),* Coimbatore, India, pp. 969-973. https://doi.org/10.1109/ICECA.2018.8474686.

[14] Kumar, Senthil M.M., P. Raghuram, and Naveen Kumar A. (2021) "Design of an integrated in-line traceability and ERP system–A case study approach." *Journal of Industrial Engineering International* **17.4**: 25-37. https://doi.org/10.30495/jiei.2022.1936851.1147.

Appendix A. Comparative matrix of the questionnaire results

Question Identifier	Answers	IT Companies						
		A	B	C	D	E	F	G
1. TCI Sectors	Spinning		x	x	x	x		
	Weaving	x	x	x	x	x		
	Knitting		x	x		x		x
	Finishing		x	x		x		x
	Dyeing		x	x	x	x		x
	Stamping		x	x	x	x		
	Cutting	x	x	x	x	x		
	Confection (Woven)	x	x	x		x		
	Confection (Knitted)	x	x	x	x	x		
	Other		x	x		x	x	
2. Areas of Track & Trace	Product Design		x					
	Budget	x	x			x		
	Sample Orders	x	x	x		x		
	Tender Documents		x			x		
	Warehouse Management	x		x	x	x		
	Storage	x		x	x	x		
	Stock Movement	x	x	x	x	x		x
	Production	x	x	x	x	x		x
	Subcontractors	x		x	x	x		x
	Other				x	x		
3.1. Identifiers	Barcodes	x	x	x	x	x	x	
	QR Codes			x		x	x	x
	RFID Tags		x	x		x		
	Indoor Positioning		x					
	Outdoor Positioning							
	Chemical/Physical Additives							x
3.2. Readers	Barcodes	x	x	x	x	x		
	RFID		x	x		x		
	Wi-Fi		x					
	Bluetooth							
	Smartphones/Tablets			x		x		x
	Other							x
4. Product Granularity	Raw Material	x		x	x	x		x
	Pallet			x	x			
	Container			x	x			
	Box			x	x	x		
	Batch	x	x	x	x	x		x
	Roll	x	x	x	x	x		x
	Product	x		x		x		x

	Piece	x		x	x	x	
	Model	x		x	x	x	
	Production Order	x		x			x
	Production Time	x					x
	Operator						x
	Defects						x
	Size	x		x		x	
	Color	x		x		x	
5. Location Granularity	Country						x
	Factory						x
	Internal Warehouse	x		x	x	x	
	Subcontractor Warehouse	x				x	x
	Zone/Area	x		x	x	x	x
	Shelf	x	x	x	x	x	
	Cart	x		x	x	x	
	Box	x	x	x	x	x	
6. Production Granularity	Factory Entry		x	x		x	x
	Factory Exit		x	x		x	x
	Warehouse Entry	x	x	x	x	x	
	Warehouse Exit	x	x	x	x	x	
	Production Entry	x	x	x	x	x	
	In Production	x	x	x	x	x	x
	In Micro-Production		x	x		x	
	Production Exit	x	x	x	x	x	x
	In Motion	x	x	x	x	x	
	Between Operations		x	x		x	x
7. Purpose	Inventory	x		x	x	x	x
	Work in Progress	x		x	x	x	
	Production Management	x		x		x	x
	Cost Management	x			x		
	Resource Management		x				
	Product Location	x	x	x		x	
	Certification						x
	Quality control			x			x
	Production Transparency						x
	Sustainability			x			x
8. Future Solutions	Expand in the Current Sectors	x					x
	Expand to New Sectors	x		x			x
	External Management		x				
	Increase Granularity			x			
	Track Individual Parts						x
	New Technologies	x		x	x		x
	New Solutions	x		x	x	x	x

RFID in Parts	x		x	x	x
Usability	x		x		
Standardization	x	x	x		