Digital Traceability of the Supply Chain

A Case Study from the Fast-Food Industry

Ricardo Eleutério de Oliveira[1]

[1]ricardo.m.oliveira@tecnico.ulisboa.pt, Instituto Superior Técnico, Universidade de Lisboa

Cândido J. Peres M.[2]

[2]candidojperes@tecnico.ulisboa.pt, Instituto Superior Técnico, Universidade de Lisboa

Carlos Castro e Cunha[3]

[3]cfilipecunha@gmail.com, Irorima

Abstract

The path of a product from the supplier to the consumer is supported by a supply chain, where a set of transformation and distribution activities are often performed in a functional manner and disconnected from the network in which they belong.

Digitization, through the introduction of emerging technologies such as Blockchain, allows the development of ecosystems characterized by the transparent sharing of information in digital tracking systems, ensuring an active participation by the involved participants.

The main objective of the investigation is to propose a conceptual model of a digital tracking system that, consequently, will be applied along the supply chain of a transnational fast-food company operating in Portugal, considering the need of this industry to keep track of product-related data.

Through the integration of emerging technologies, it is possible to carry out the digital transformation of the supply chain, connecting physical resources to the corresponding digital information. The system proposed in the investigation uses Blockchain technology for data management and ensures its collection through intelligent sensors.

The application of this system in the reality of the proposed case study reflects an impact on the company's performance, enabling the inclusion of a new supplier that allows the company to achieve goals related to the sustainable development of the brand, while driving digital transformation at the level of information circulation in the business context, promoting the security and transparency that are essential to shaping corporate strategies.

Keywords: Blockchain, Traceability, Digital Transformation, Supply Chain.

1. Introduction

The opening of a new industrial chapter led by technology-based companies generates a renewed economic context. Within this scenario, companies are faced with a range of new technologies that can transform their Supply Chains (SC), either by implementing new strategies aimed at entering new markets or by the development of innovative products (A.T. Kerney, 2015).

The digital-based competition pushes traditional companies to change with the goal of unlocking competitive advantages, which often appear to be based on the vital role of information in the commercial scenario, namely, at the level of Supply Chain Management (SCM).

The ongoing shift that is transforming several industries is motivated the growing public awareness and interest in keeping up with the business scenario, demanding for the creation of operational “white boxes”, where companies are expected to share key and reliable information about their day-to-day activities.

To enable this information sharing flux, the market players seek to invest and implement tracking systems within their own operational scenario. On one hand, signaling a greater concern to reinforce the market's confidence in their brands, on the other, justifying the investment by using real-time operational data to better monitor their systems to find improvement opportunities.

Blockchain emerges in association with this type of tracking systems, as a technology which is characterized by cryptography and security (Haber & Stornetta, 1991) that can be applied across several industries, in which it has the potential to play a vital role as a solution that aligns information mapping with reliable tracking capabilities.

The present investigation is focused on the application of this technology onto the food industry to connect the physical and virtual reality that this new digital-based competitive scenario imposes, ensuring the efficiency and transparency of the case study's operations.

The case study depicts a company which is a reference within the fast-food sector and operates in Portugal for over 25 years, with more than 150 establishments around the country.

The company seeks to build a tracking system that maps the journey of the beef ingredient, the product with the greatest circulation in the chain, from the animal's path to the carcass path. The system should store the specific information of each batch and make it available to be consulted by the producer and other suppliers.

2. Materials and Methods

2.1. Problem Definition

The case study considers a company that entered the Portuguese market with a SC heavily dependent on international suppliers. With the establishment of its operations at a national level, the corporate strategy has passed through the fostering of commercial partnerships with local suppliers.

This investment has resulted into a set of more than 30 local partners, which currently represent around 40% of the purchases made by the national establishments of the chain.

However, the company still maintains an exclusive supplier of beef, the most common product on the menu, located in Toledo, Spain. It produces, per day, a total of more than 1.5 million hamburgers for the Iberian market, of which around 25% are made from domestic production (Pimentel, Correia & Amaral, 2015).

The company's current mission is to expand its network of local partners, introducing a new tracking system and an alternative model for its SC, building the set of this investigation's objectives as the following:

1. The proposal of a tracking system that ensures continuous monitoring of the temperature during maritime transportation, enabling the distribution of beef supplied from São Miguel, Azores.
2. An analysis of the feasibility of complementing the current exclusive producer operations with a new facility located in Portugal, considering the transportation's costs, the environmental impact, and the operational risk.

Both objectives are constructed with a theoretical basis that covers the key concepts being used, as well as a practical reference through real-life industry's cases. The applicability of the introduction of the tracking system across the new supply chain is represented through a proof of concept, which represents the suppliers' and customers' interaction with the new digital traceability platform.

2.2. Methodology

For the theoretical framework, a Systematic Literature Review was carried based on the volume of materials published on selected academic sources, found using Online Knowledge Library based on the EBSCO service. The materials consulted on this platform originate from different content providers, and the selected academic sources are those that are relevant in the context of Industrial Engineering and Management.

The development of more specific topics related to tracking and digital transformation allowed the construction of a practical case in line with the objectives proposed for this investigation, with the following deliverables:

- A conceptual model of the digital tracking system, which details the participants, technology, and mechanisms to be used at each point.
- A SC map which details the geographic distribution of the different points of the network, as well as the characterization of the means of transport used for each one.
- A strategic analysis of the proposed new SC configuration supported by three criteria – environmental, economic, and social.

A proof of concept was built to depict the application of the conceptual model to the new SC model, in order to solve the obstacles identified by the case study's company.

3. Results and Discussion

3.1. Blockchain System

A digital tracking system based on Blockchain creates a decentralized network that relies on transparent data sharing and ensures an advanced level of security (Azaria, Ekblaw, Vieira & Lippman, 2016).

To understand the potential application of this technology to the operational context of the case study's company, the study presents a conceptual model of a Blockchain network.

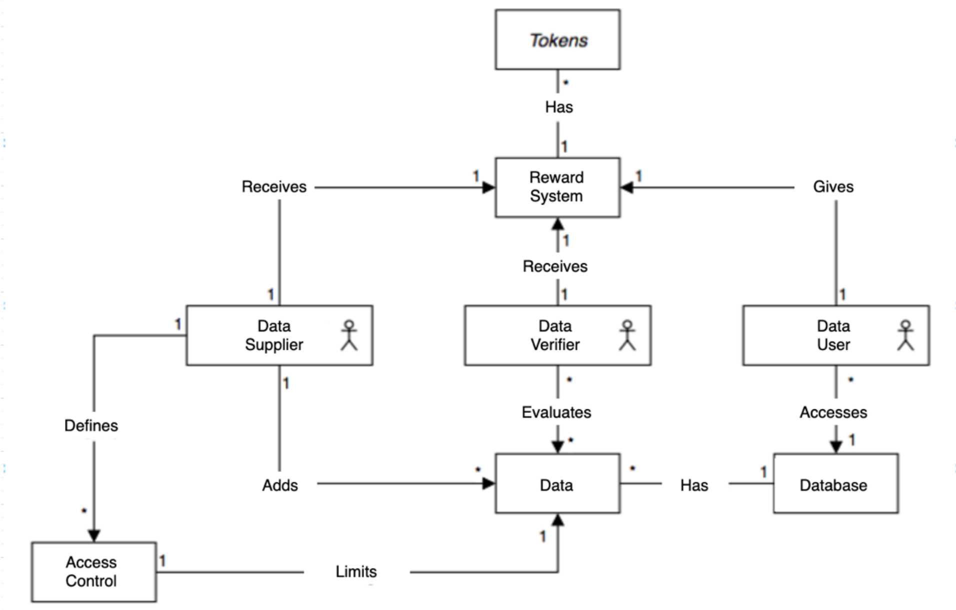
The model is built with a mechanism that manages accesses according to the role of each participant, restricting its roles in the network to the introduction, validation or use of data in circulation. Using the functionalities of technology, this system does not need centralized management by the company, promoting the democratization of data, not only through the involvement of participants, but also using incentives that promote their active participation (Erhan, Tarhan & Ozsoy, 2019).

Following the global view presented above and in line with research carried out by other authors (Xia et al., 2017; Cruz et al., 2018; Desai et al., 2018; Ozyilmaz et al., 2018; Kabi et al., 2018; Erhan et al., 2019), the conceptual model encompasses three types of participants according to their specific roles and associated rewards:

- Supplier: inserts information in the system's database about the products in circulation within the SC and defines which participants have access to the submitted content. This role has exclusive control over the submitted data. This participant's reward is awarded when the submitted information is consulted by a data user.
- Verifier: validates the information entered by the data provider, ensuring the reliability of the contents for the query carried out by a data user. This participant's reward is awarded after the verification and validation of the content under review has been carried out, according to the standards defined in the network.
- User: consults the information in the network's database, accessing the contents shared by the data providers and validated by the data verifiers. This participant plays a vital role in maintaining the rewards mechanism, contributing to it to access data in the system.

The development of this digital tracking system is based on three essential pillars – decentralization, security, and transparency. In this, participants are encouraged by trust and potential rewards to receive, building relationships through functional interactions depicted in Figure 1, using a common modelling language.

Figure 1 – Conceptual Model Diagram (UML)



Source: Erhan et al., 2019 (Adapted); Author, 2021.

3.2. Supply Chain Configuration

The new model for the SC was created according to the company's mission, contemplating the following integrations into an alternative configuration:

- New Supplier: addition of a new entity in the supply phase that is located on the island of São Miguel, in the Azores.
- New Location: change of the location of the processing phase to national territory, ensuring greater accessibility by the other entities involved.

To perform the strategic analysis about the added costs and environmental impact, the following assumptions are made:

- The new supplier will be in São Miguel, Azores, and the transport of products to mainland Portugal will be carried out by sea.
- The new processing location will be on the Leixões Logistics Platform, due to the proximity of infrastructures such as the Porto and the Railway Terminal (Associação Empresarial de Portugal, 2021), as well as the ease of access by the other entities involved.

As stated in Table 1, it is possible to see the distance and time interval between the entities participating across the SC are lower than the current model which demands the transportation of the goods to outside of Portugal and then back.

Table 1 – Strategic Analysis on Proposed SC Model

Stage	Origin	Destination	Transport	Distance (km)	Duration	Cost (€)	Emissions (ton CO_2)	Carbon Cost (€)
Supplier	Ponta Delgada	Leixões	Sea	1852	48 hours	1222.32	0.41	61.12
	Vila Nova de Famalicão	Leixões	Road	40	1 hour	35.20	0.07	1.27
	Barcelos	Leixões	Road	34	1 hour	14.96	0.03	0.54
Producer	Matosinhos	Carregado	Road	285	4 hours	125.40	0.25	4.51
	Matosinhos	Canelas	Road	19	1 hour	8.36	0.02	0.30
Total						**1406.24**	**0.78**	**67.74**

Source: Author, 2021

With the new national facility, there is a reduction – by approximately 7.6% - of the length of the SC route, improving the distance traveled between all locations in the current configuration from 2413 kilometers (km) to 2230 km.

Additionally, the proposed model has a considerably lower environmental impact, with a reduction of 70.4% compared to the current model, from 2.7-tonnes (ton) CO_2 to 0.8-ton CO_2.

The new model contemplates the case study's objectives for the SC, introducing the new supplier and the processing plant located in the national territory. Although the length of the network is reduced and the environmental impact is lower, the economic trade-off makes the proposed model result in slightly higher costs – approximately 5.4% - than the current model.

4. Proof of Concept

The definition of the model that represents the digital tracking system under study and its consequent application in the proposed configuration for the SC enable the elaboration of a proof of concept, a phase described as critical in the innovation process (Bendavid & Cassivi, 2016).

With the identified base technology, it is necessary to build the connection between physical goods and the corresponding digital information, namely, through a tool that allows its automatic and continuous capture, guaranteeing reliable results.

This autonomous ecosystem will reduce the need for intervention by the participants, ensuring the feasibility of implementation and, at the same time, the validity of the information shared with the network.

In terms of physical goods, two similar technologies are used, although their unique characteristics make them more appropriate for different phases and different target groups – suppliers and customers.

4.1. Smart Box

In different phases, new unique identification tags (UIT) are created for new products that are put into circulation, duly associated with the UIT of the beef used for its genesis. These changes are carried out using a dedicated mobile application that will be accessible by network participants.

The combination of these two tools creates the smart box's concept proposed in this investigation, which, in addition to digitally identifying the physical merchandise, enables the remaining functionalities related to the digital monitoring using the Blockchain-based platform.

Considering that this is a condition that must be ensured throughout the entire SC, the monitoring process is carried through technology-enabled sensors placed in the smart box which, being connected to the Blockchain network, allow the automatic collection of the temperature and its consultation in time real.

The use of these sensors based on *Internet of Things* (IoT) technology facilitates continuous monitoring, as well as the creation of alerts that signal goods that were transported, both partially and completely, outside the necessary conditions.

Being an effective resource, the placement of these sensors allows the remote monitoring of each smart box, by the issuing entity, carrier and receiving entity, allowing the reading of the temperature levels of the merchandise, such as tracking its location, through the mobile application associated.

4.2. Mobile Application

The application of sensors connected to the network allows the continuous collection of data relating to the location and conditions of transport of the goods, namely, the average and real-time temperature recorded during movement between points in the chain and in the entire route, as required.

With the permanent transmission of data to the Blockchain network, it is possible to use the dedicated mobile application to consult, based on the desired UIT, real-time information about a particular product.

To do this, the user must read the QR associated with the smart box that is supposed to be tracked, being directed to an interface which shows the location and relevant conditions of the transport in progress.

Carrying out this reading, using the dedicated mobile application with view-only permissions, the customer will have at their disposal the interface where they will also be able to confirm the authenticity of the characterization of the product they are consuming.

The use of the application as a means of interaction with the system allows its scalability, facilitating the introduction of relevant factors for monitoring, either from a global perspective of SC or locally to the operation of network participants. From an ecological perspective, it would be possible to include an environmental cost calculator, related to the emission of pollutants during transport, following the procedure that was carried out in the analysis of the new configuration proposed for the SC.

5. Conclusion

5.1. Summary

Following the guidelines of this investigation, the previous sections portrayed the relevant contextualization about tracking systems, the applicable technology, and the conditions for their implementation.

The digital transformation of the SC enables digital monitoring of physical resources in circulation on the network, through the integration of emerging technologies such as Blockchain and IoT, recognizing their disruptive role in terms of connectivity and transparency.

Blockchain technology acts as a database for information about products, participants and payments made on the network, fostering trust within the ecosystem. In addition, the integration of IoT sensors allows for automatic data collection, reducing the lack of precision associated with manual input by participants.

The proposed traceability system uses Blockchain technology as a data management platform, using intelligent IoT sensors to ensure continuous transmission of information about the real-time conditions and locations of physical products.

This system includes three types of participants that are related through action dependencies, involved in a positive feedback cycle that allows suppliers to be rewarded for the quality of their content, verifiers for validating them and users feeding this mechanism based on the usefulness of the contents.

The different parties can access this system through a mobile application that presents the operational data, more targeted for the suppliers, as well as product data, aimed at the consumers.

The solution proposed for this case study allows the monitoring of the product's transport conditions, unlocking the inclusion of the new supplier located in the Azores.

The proposed changes to the SC of the company under study reflect a reduction of approximately 70.4% in environmental costs, related to the volume of polluting emissions and their neutralization, and are therefore in line with the initial mission of reinforcing the company's sustainable position.

On the other hand, the new configuration represents an increase of 5.4% in economic costs, as a result of the introduction of a new means of transport.

The application of this technology in the context of SCM is perceived as advantageous to improve the databases currently used, not only for the ability to decentralize access to several participants, but also for the added difficulty related to the possible falsification of shared information (Laosa & Relvas, 2019).

This dynamic is evidenced by the sharp growth in the market volume of this type of solution, from approximately 800 million euros in 2020 to 11.7 million euros in 2022. While the overall perspective reveals a compound annual growth rate of 73.2% for Blockchain-based solutions, if the focus is set exclusively in the space of digital traceability this number increases to 76.2% (Deloitte, 2017).

5.2. Further Developments

As an emerging technology, Blockchain reveals potential applications in several industries (Oliveira & Peres, 2020; Oliveira & Peres, 2021; Oliveira, Matos & Peres, 2021), so it is relevant to explore additional research areas to contribute to a better understanding of the digital capabilities of this mechanism.

Simultaneously, studying the application of this technology in areas that are complementary to the central theme of this investigation enriches the literature review carried out, adding content about the role that this technology plays in selected topics.

With this approach, it was possible to conduct broader research and, therefore, to present a broader view of the need for the advantages of Blockchain technology in the context of SCM, considering other applications beyond the digital tracking system proposed in this investigation.

Additional research areas can be selected according to: (i) thematic relevance to academic conferences to take place during the period of this research, (ii) complementarity with the SCM area and existence of practical applications in the industry and (iii) the expressiveness of the literature available in the consulted sources.

6. References

Associação Empresarial de Portugal. (2021). Plataforma Logística do Porto de Leixões. Retrieved from: https://www.apdl.pt/plataforma_logistica

Azaria, A., Ekblaw, A., Vieira, T. & Lippman, A. (2016). MedRec: Using Blockchain for Medical Data Access and Permission Management. 2nd International Conference on Open and Big Data pp. 25-30.

Azevedo, P. (2019). Supply Chain Traceability Using Blockchain. Instituto Superior de Economia e Gestão. Retrieved from: https://www.iseg.ulisboa.pt/aquila/getFile.do?fileId=1307348&method=getFile

Bendavid, Y., & Cassivi, L. (2012), A 'living laboratory'environment for exploring innovative RFID-enabled supply chain management models. International Journal of Product Development, 17:1-2, 94-118. https://doi.org/10.1504/IJPD.2012.051150

Beulens, A. J. M., Broens, D. F., Folstar, P., & Hofstede, G. J. (2005). Food safety and transparency in food chains and networks. Food Control 16 (6): 481 - 486. https://doi.org/10.1016/j.foodcont.2003.10.010

Bharadwaj, S. (2019). The Engineering Behind a Successful Supply Chain Management Strategy: An Insight into Amazon.com. International Journal of Scientific & Technology Research Vol. 8, Issue 10.

Biblioteca do Conhecimento Online. (2021). A b-on.

Casey, M.; Wong, P. (2017). Global supply chains are about to get better, thanks to blockchain. Harvard Business Review.

Chang, Y., Iakovou, E. & Shi, W. (2020). Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities, International Journal of Production Research, 58:7, 2082-2099.

Chinosi, M. & Trombetta, A. (2012). BPMN: An introduction to the standard. Computer Standards & Interfaces (34): 124-134. https://doi.org/10.1016/j.csi.2011.06.002.

Cruz, J.P., Kaji, Y. (2015). The Bitcoin Network as Platform for Trans-Organizational Attribute Authentication. The Third International Conference on Building and Exploring Web Based Environments (WEB).

Cruz, J. P., Kaji, Y., Yanai N. (2018). RBAC-SC: Role-Based Access Control Using Smart Contract. IEEE Access (6): 12240-12251.

Deloitte. (2017). Using Blockchain and Internet-of-Things in Supply Chain Traceability. Continuous Interconnected Supply Chain.

Dierksmeier C. e Seele P. (2020). Blockchain and Business Ethics. Business Ethics: A European Review 29, n. 2.

Dogru, T., Mody, M., Leonardi, C. (2018). Blockchain technology & its implications for the Hospitality Industry. Boston Hospitality Review, pp 1–12.

Durães, P. (2016). Breve História da Presença do Mcdonald's em Portugal. Meios e Publicidade. Retrieved from: https://www.meiosepublicidade.pt/2016/08/breve-historia-da-presenca-do-mcdonalds-em-portugal/

Haber, S., & Stornetta, W. (1991). How to Time-Stamp a Digital Document, Journal of Criptology, 3: 99 - 111. https://doi.org/10.1007/BF00196791

Kabi, O.R., Franqueira, V.N.L. (2018). Blockchain-Based Distributed Marketplace. In: Abramowicz W., Paschke A. (2018). Business Information Systems Workshops. Lecture Notes in Business Information Processing (339). Springer.

Laosa, B. & Relvas, S. Blockchain Within Logistics: a SWOT analysis. Master Thesis, Instituto Superior Técnico.

Pimentel, A., Correia, A., Amaral, H. (2015). Sabe como (e de que) são feitos os hambúrgueres da McDonald's? Retrieved from: https://observador.pt/especiais/sabe-como-e-de-que-sao-feitos-os-hamburgueres-da-mcdonalds/

World Freight Rates. (2021). Freight Calculator. Retrieved from: https://worldfreightrates.com

Xia, Q., Sifah, E.B., Asamoah, K.O., Gao, J., Du, X., Guizani, M. (2017). MeDShare: Trust-Less Medical Data Sharing Among Cloud Service Providers via Blockchain. IEEE Access (5): 14757-14767.