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https://jurnal.ustjogja.ac.id/index.php/IEJST/article/view/12700

INDUSTRIAL ENGINEERING JOURNAL of the UNIVERSITY of SARJANAWIYATA TAMANSISWA

ISSN (Online): 2613-9812

IEJST

Data Consistency at Digital Traceability: An Overview

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ARTICLE INFORMATION

Received : 5 June 2022
Revised : 20 June 2022
Published : 30 June 2022

KEYWORDS

Data consistency
Digital
Interoperability
Supply chain management
Traceability

ABSTRACT

Digital traceability is the use of electronic records and technology to track the forward movement of a product through various stages of the supply chain and to trace back the product history, including location, transformation, and application. The basis of a traceability system is related to the efficient and precise recording of information. Digital interoperability is an essential component of digital traceability. To increase digital interoperability in Supply Chain Management (SCM), one of which is by meeting the conditions of data consistency running on the interoperability system. Data consistency makes it easy to pool data from multiple sources and allows comparative decision-making. Consistency includes data release formats, classifications, definitions, and taxonomies.

1. INTRODUCTION

Traceability consists of two distinct components, namely tracking and tracing. Tracking is the ability to determine the purpose of a particular product, following its path through the food chain from the point of production to the point of final sale or point of consumption. In other words, it was tracing looks back at the origin of the product while tracking looks forward to its destination. To work effectively, the traceability system must be verifiable, results-oriented, cost-effective, and applied consistently and fairly. The Global Food Traceability Center identifies challenges in implementing food traceability in the food industry, including the lack of unifying requirements. The current internal system does not yet provide a means with reliable and fast responses to be able to trace back data throughout the food chain. Besides, data conditions are challenging to analyze into relevant decision-making formats and lack information, whereas products are increasingly complex, requiring a complete traceability system. The components needed in the supply chain network include harmonization between internal and international standards used, transparency in the form of access and data sharing without loss, noise, delay, and distortion of information [1]. From this statement, it is known that the basis of a traceability system is related to the efficient and precise recording of information. Flexibility in data formats is finally a demand of today's traceability systems [2].

Digital traceability is the use of electronic records and technology to track the forward movement of a product through various stages of the supply chain and to trace back the product history, including location, transformation, and application [3]. Digital interoperability is an essential component of digital traceability. Digital interoperability emphasizes the exchange of data or information, which is the key to massive evolution because it will depend on digitalization, artificial intelligence, and system autonomy [4]. In this study, to equate perceptions, the terms digital traceability and digital interoperability will be referred to as traceability and interoperability.

Interoperability is the ability of different information technology systems or software programs to communicate smoothly to exchange and use data. Some of the most significant barriers to interoperability are the lack of consistent data standards and the incompatibility of integrated systems [5]. This is also identified from the survey results, which state that one of the obstacles that need to be overcome to ensure companies routinely release open data that is suitable and can be operated on their traceability system is the problem of inconsistent data [6]. In this case, it is necessary to review the system analysis for the activities and related information needed. The definition of data, including the activities it performs, must be applied to the system to ensure data exchange is consistent [7]. This study aims to provide an overview of the current state of digital traceability and the impact of data consistency on interoperability in the traceability system [8].

2. METHOD

This study method uses a qualitative approach by reviewing the topics of interoperability, data consistency, and traceability. In this study, identification, analysis, and recommendations are made on the current state of traceability and its relationship to data consistency on system interoperability. The scope of the article covers traceability in health management, logistics, pharmaceuticals, and the food industry.

3. RESULTS AND DISCUSSION

Traceability systems do not stand alone. They will be integrated into the existing data flow in the infrastructure of every supply chain stakeholder, as shown in Figure 1.

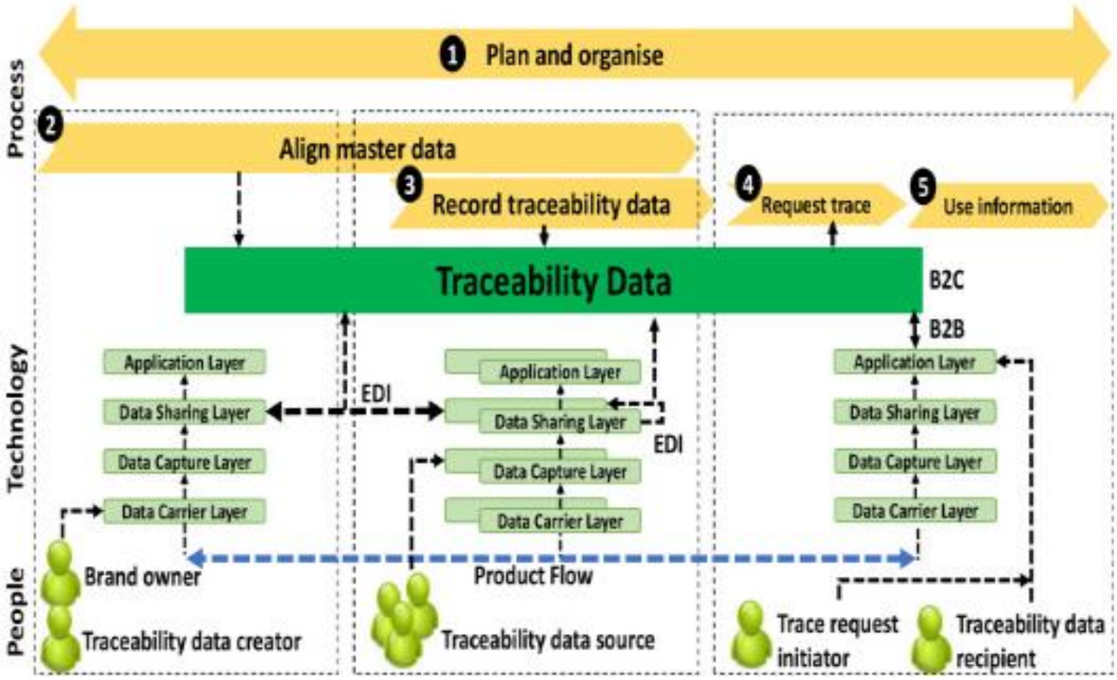

Figure 1. Interactions between roles, processes, and technology involved in traceability [8]

It is essential to allow as much flexibility as possible for file formats while standardizing only where necessary. Standard data structures (e.g., EPCIS) are more critical than specific file formats, as many modern track and tracking platforms can handle multiple file formats. Transformation (ensuring that all processed data is aligned into a standard form) and orchestration (ensuring that data flows between systems runs smoothly) should be considered. Modern commercial traceability systems should be able to perform these functions automatically.

For a traceability system to be genuinely operable, interested parties must have the capacity to share data using standard data formats (syntactic interoperability) and interpret and understand that shared data in common sense (semantic interoperability). In general, interoperability should also be considered at the physical level (e.g., standard handling), the organizational level (e.g., interorganizational protocols) and the business level (e.g., business models with shared interests), and the digital level because of the need for interoperability includes methods and standardization for information and communication structures. Adopting the type of data required in the food industry [9], then the types of data that can be identified related to the relevance of the data both as inputs and outputs for traceability, consistency, and digital SCPM mapping, in general, are shown in Table 1.

Table 1. Data types requirements (Adopted from [9])

Product data	Process data	Transport and delivery data
• Quantities of the ingredients used	• Process type	• Load carrier temperature
• Internal and external batch number(s)	• Location of the process	• Cargo location temperature
• Expire date	• Process date/time	• Shipping/delivery date
• Raw materials used	• Use of additives or others	• Shipping Product
• Product temperature	• Data for measuring device monitoring	• Location of the goods
• Origin	• Recording of in-process controls and results	• Place of departure
Company data	• Food control results	• Departure time
• Process owner/company	**Packaging data**	• Transport unit
• Company address	• Labelling	• Transport packaging
• Company registration number	• Instruction for use	• Transport marking
• Origin	• Storage advice	• Transport loads
• Stock register	• Preservation and use of packaging	• Consignee
• Internal company hygiene regulations	• Marking of the packaging	• Carrier
• Results of internal and external company controls	• Labelling materials	• Supplier information
Qualities & Grades	• The goods benefit from the information	• Manufacturer information
• Certificates	• Other information on the goods	• Packer information
• Label (organic/conventional)		

Some of the critical roles of digital interoperability [4] are, first, digital interoperability is needed to ensure the fast, reliable, secure, and smooth sharing of data or information between different systems, companies, or networks. This goal has two main perspectives: strengthening collaboration between companies (business-to-business communication) and supporting automated and autonomous systems (M2M communication). Effective and efficient Information and Communication Technology (ICT) is beneficial for this purpose, for example, Industrial Internet of Things (IIoT), digital and cloud platforms, Application Programming Interfaces (API), low power wide area networks such as Lora, Narrow Band Internet of Things (NB-IoT), or 5G. Second, privacy security is an important attribute expected in digital interoperability. Digital interoperability is undoubtedly used to share information in a collaboration that aims to improve work efficiency, but information privacy must still be protected during collaboration. Third, sharing trackable and traceable data is another expected goal of digital interoperability. Communication or distributed data storage techniques are more likely to achieve this goal.

In line with the statement above, the Global Food Traceability Center-Institute of Food Technologists [10] states that for scalability and resiliency of the traceability architecture, as presented in Figure 2, it is specified that there is no use of a central database (either physically in the data center or "in the cloud") to hold all traceability data from the supply chain system. Instead, the data will be stored in a peer-to-peer distributed network database with access provided for queries according to pre-agreed controls.

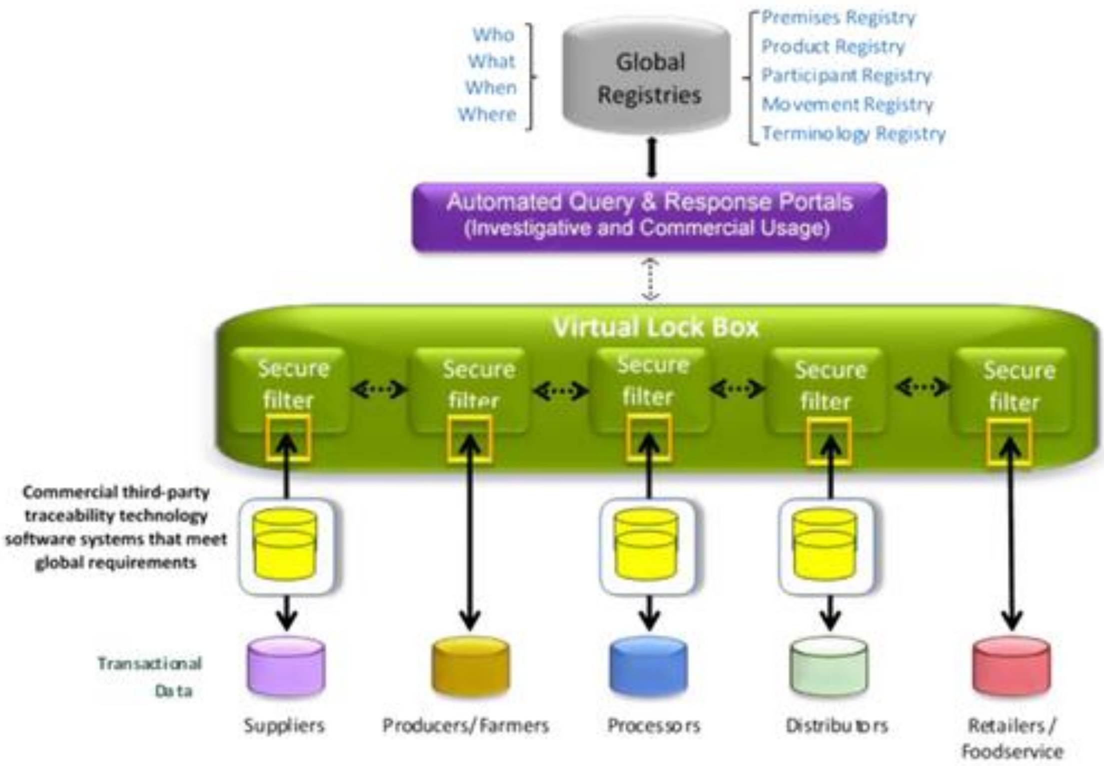

Figure 2. The interoperable traceability architecture [10]

Using a distributed system, stakeholders and government agencies in the industrial sector can maintain control over the data in their internal database systems. The virtual lockbox concept is built on the premise that data is called upon only as needed and not stored locally and is responsible for enabling access controls to receive, interpret, and respond to inquiries from supply chain partners.

There are various electronic data systems used for interoperability. Integrating with an ERP system is generally easier than integrating with a cloud-based traceability system. However, outdated system conditions, custom-built systems, and platforms built on outdated operating systems can cause irreparable non-compliance, and, as a result, interoperability functionality cannot be optimized. In many cases, interoperability requires system-to-system customization. Linking the entire supply chain can mean designing custom integrations with several very different systems built on its platform.

Interoperability with data sharing methods using machine-to-machine communication is possible without needing any interpreter services or service providers, enabling data sharing and communication and cross-supply and industry communication. In other words, it allows unlimited and unfettered data sharing because the two systems can share and interpret data effectively without translation services. Such interoperability relies on the standards they set themselves. Even though standards such as GS1 have been developed, their adoption in the industrial sector is still minimal.

Interoperability requires a set of standard data formats and data fields that all systems can follow. Even though specific standards (e.g., GS1) exist, some companies still do not use them, due to cost issues and lack of conformity to their needs, given that most companies have their internal standards. If the system is made to communicate with the same language (syntactic interoperability), the system must also be able to exchange data correctly (semantic interoperability). So, if the technology system complies with GS1, for example, but the data received from the supplier is not formatted correctly, the information cannot be passed on. The absence of a universal product code is one of the most significant barriers to interoperability. Further, it complicates the situation due to forced customization that does not accommodate the company's needs.

Lack of standardization across systems leads to inconsistent and incompatible data. Data consistency makes it easy to pool data from multiple sources and allows comparative decision-making. Consistency includes data release formats, classifications, definitions, and taxonomies. Many companies focus on internal consistency and ensuring data is fit for the purpose for which it was collected. However, this means that companies only use classifications that meet their own needs, and there is little consideration for future use by others, thereby limiting the potential value of the data. Consistency is a particular issue when it comes to local-level data access. With the diversity of resources, capacities, and capabilities of data providers at the local level, it is not easy to apply consistent standards. This makes data comparison more complicated. Therefore it is necessary to fulfill the conditions of comparable, precise, and interoperable data through standardization, consistent formats, metadata, and thoroughly explained documentation. Standardization of data in the exchange of traceability information will provide a fast response and allow data reuse in the future [11]. This condition will create a data system where data sets can be integrated, and the system can communicate adequately. Data published in a way that allows integration will provide insights beyond the purpose for which the data was created.

The interoperability requirements serve to incorporate all the demands for a digital framework. Interoperability requirements include conditions for managing production and logistics processes in an information system. There is a need for the communication structure, product and company identifiers, and means used to anticipate the disruption to activities (internet connection failures, missing identifiers on products) involved. When setting requirements, it must be ensured that the selected aspects are objectively defined and validated and do not conflict. First, the objectivity of the terms of use is established when multiple stakeholders/people/sources formulate the exact requirements for a particular use context.

Furthermore, the requirements submitted must be traceable. To ensure that requirements elicitation is carried out unbiasedly, only one aspect is declared a critical requirement if at least two stakeholder groups request it. Second, the requirements collected must be valid, i.e., the data must be confirmed or, if necessary, corrected. Third, a requirement must not conflict with other existing requirements. They should be analyzed, discussed, and clarified if the requirements conflict. Stakeholder-based requirements are evaluated and transferred to the Information system to determine relevant vital issues. In this way, the technical implementation and requirements of the data provider and user perspective can be aligned so that the two main categories of interoperability requirements can be met.

4. CONCLUSION

Digital transformation has provided solutions and created digital tools to solve systems interoperability problems and trace the supply chain. However, a single service provider at the local operational level is often used only. As a result, this solution cannot be used for interconnected and integrated systems. Instead, it leads to information silos (as opposed to others). This has led to the need to increase digital interoperability in SCM, one of which is by meeting the conditions of data consistency running on the interoperability system.

ACKNOWLEDGEMENT

I want to thank my colleagues in the Faculty of Engineering, Universitas Sarjanawiyata Tamansiswa, for their support.

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