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Acknowledgements:

This work is supported by the Digital Ecosystem Utilisation (CYSLOP), which has received funding from IoF2020 (http://www.iof2020.eu) with subgrand agreement 2282300206-UC002, while the IoF2020 project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement no. 731884.

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Abstract

Purpose: Traceability of food is of paramount importance to the increasingly sustainability-conscious consumers. Several tracking and tracing systems have been developed in the AgriFood sector in order to prove to the consumers the origins and processing of food products. Critical challenges in realizing food's traceability include cooperating with multiple actors on common data sharing standards and data models.

Approach: This research applies a design science approach to showcase traceability that includes preharvest activities and conditions in a case study. We demonstrate how existing data sharing standards can be applied in combination with new data models suitable for capturing transparency information about plant production.

Findings: Together with existing studies on farm-to-fork transparency, our results demonstrate how to realize transparency from field to fork and enable producers to show a complete bill of sustainability.

Originality: The existing standards and data models address transparency challenges in AgriFood chains from the moment of harvest up to retail (farm-to-fork) relatively well, but not what happens before harvest. In order to address sustainability concerns, there is a need to collect data about production activities related to product quality and sustainability before harvesting and share it downstream the supply chain. The ability to gather data on sustainability practices such as reducing pesticide, herbicide, fertilizer and water use are crucial requirements for producers to market their produce as quality and sustainable products.

Keywords: SC traceability; AgriFood SC; Internet of Things; Smart Farming; Data Sharing; EPCIS

Type of paper: Technical

1 Introduction

Smart farming based on Internet of Things (IoT) technologies enables crop farmers to collect real-time data related to irrigation and plant protection processes (Villa-Henriksen et al., 2020). IoT technologies are generally deployed to increase production volume, improve product quality, predict diseases, minimize farm input and optimize farming processes (Astill et al., 2019). Besides the financial returns offered, IoT provides unprecedented opportunities for tracking and tracing (Astill et al., 2019; Villa-Henriksen et al., 2020).

Smart farming the last decades is evolving rapidly, following data sharing practices and providing an innovative way to overcome various AgriFood problems (Kittipanya-ngam and Tan, 2020; Spanaki et al., 2021c). Preview studies on the AgriFood sector and the relevant operations have provided evidence that the adoption of technological and innovative applications based on IoT and data sharing practices is imperative (Linaza et al., 2021; Spanaki et al., 2021b, 2021a). The requirements for sustainability and food security as they appear in the SDG agenda call for the development of new ways for enhancing and sustaining the AgriFood production (Sony and Naik, 2019). The SDGs provide an impetus for further research in the AgriFood supply chains and operations, in particular, as they are areas where specific challenges appear due to the specific conditions related to the environment and the land where the AgriFood practices are applied (Moazzam et al., 2018). Targeted solutions have to tackle specific problems for AgriFood supply chains as these problems are unique and relevant to the features of the agricultural sector, and therefore specific data should be extracted for each case (Spanaki et al., 2021a). Challenges of the AgriFood supply chains span from fresh food perishability (Vlajic et al., 2018), production seasonality, variability in quality and quantity (Despoudi et al., 2018), transportation requirements (Zissis et al., 2017) and risks (Iakovou et al., 2014; Moazzam et al., 2018). Data sharing practices provide a way to meet the SDGs and specifically "Food Security" goal with tailored solutions required for AgriFood traceability and quality problems.

In order to promote the large-scale uptake of IoT in agriculture, a large-scale pilot-based project called the Internet of Food and Farm (IoF2020[1]) was launched in 2017. The project comprises over 30 use cases grouped into five coherent trials that aim to specific AgriFood sectors: meat, fruit, vegetables, arable and dairy farming; the project aimed at IoT implementation for smart farming. Each pilot was evaluated on verifiable Key Performance Indicators (KPI's), including sustainability goals. IoF2020 aimed explicitly at four key goals: demonstrate business cases of IoT in diverse AgriFood sectors (arable, dairy, fruit, vegetable and livestock farming and the associated industries); facilitate re-use and integration of IoT systems by adopting and adapting open architectures and standards; enhance adoption and diffusion of IoT solutions by engaging end-users from the start and addressing all their concerns including usability and security; and, formulate business models and setting up IoT ecosystems for the sustainability of the IoT solutions (Verdouw et al., 2017).

This research is based on the results of two pilot studies within IoF2020: The Digital Ecosystem Utilisation pilot (called CYSLOP, based on the pilot's original name: CYpriot and SLOvenian IoT Pilot) and the Meat Transparency and Traceability (MTT) pilots. CYSLOP aimed to demonstrate IoT solutions for fruit and vegetable farms in Cyprus and Slovenia. Specifically, the study is based on a pilot study at a producer of table olives. The transparency system demonstrated mainly covers the growing and harvest cycle processes, but the data model covers the transparency table olives from field to retail. Data is collected using IoT devices and then processed through a FIWARE[2]-based data sharing IoT platform. One soil and one air sensor were deployed on a half-hectare olive farm to achieve this. The CYSLOP case study aimed at a 10% reduction in the use of pesticides, equal reduction in irrigation water use, overall cost reduction and a 20% reduction in farm visits.

The use of a standards-based transparency system is well established in the meat sector. The MTT use case developed by the partners EECC, GS1 Germany and Wageningen University has deployed an EPCIS[3]-based transparency system which we re-used in CYCLOP. Remarkably, the processes of modelling transparency data and the standard EPCIS solution used in MTT

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[1] The IoF2020 is a 4-year project with a budget of 35M€. The consortium consisted of 71 public and private partners from 16 different countries.

[2] https://www.fiware.org/

[3] https://www.gs1.org/standards/epcis

demonstrate that transparency can be realized across the different sectors of AgriFood following the same steps standards and transparency solutions. This paper describes data generated by IoT devices to provide transparency and help achieve planned sustainability goals. Therefore, this paper aims to guide future researchers through the multidisciplinary approach needed to apply IoT to realize transparency and verifiable sustainability goals successfully.

In both use cases, in order to achieve the overarching goal, an initial understanding and modelling the supply chain was required, as well as the desired sustainability goals, the data requirements and how data can be captured uniformly. Therefore, the following research questions guided the study herein: (1) How does the supply chain of table olives look like (2) Which sustainability aspects can a transparency system help verify (3) How can transparency data in the table olives sector be captured and modelled using the GS1 set of standards. And (4) How can a transparency system for the table olives sector be built using the EPCIS standard for transparency systems.

To address these research questions, initially a modelling phase of the olives supply chain was conducted. Then an identification phase followed for the events of interest (traceability events) from the supply chain analysis and the subsequent focus group discussions held with the farmer, members of GS1 Greece, and the researchers involved in this study. Subsequently, the traceability events were modeled using the EPCIS standard. An implementation phase was applied through the traceability software systems, which consists, on the one hand, of developing a software component and, on the other hand, the integration of the new component with the existing standard EPCIS system. Finally, a demonstration was provided on how the developed solution was applied using real-life data.

2 Background

Smart agricultural practices draw on the notion of precision farming technology yet also take recourse to intelligent networks and data management tools (Spanaki et al., 2021a, 2021c). Internet of Things (IoT) and data management applications collect, extract and analyze all the available information so as the expertise can leverage the automation of sustainable processes in agriculture (Wolfert et al., 2017). Agricultural Technologies (Agri-Tech) are expected to leverage the latest development and introduce data sharing, artificial intelligence and machine learning techniques in the farming sector (Spanaki et al., 2021c).

The radical transformation of the traditional agricultural landscape is encompassed in the evolution of smart farms and goes beyond primary food production (Kamilaris, Kartakoullis and Prenafeta-Boldú, 2017; O'Grady and O'Hare, 2017). Smart Farming context has substantial influence on the entire production systems (O'Grady and O'Hare, 2017; Pham and Stack, 2018) and ties closely with the AgriFood supply chain, transportation and logistics (Vlachos et al., 2008; Zissis et al., 2017) and food-waste (Despoudi et al., 2018) and therefore is reshaping the whole sector following the same way as most digital transformations have gone through (Li et al., 2016). Data are used to provide visibility of the processes from farm-to-fork (Wolfert et al., 2014), as well as predictive insights in farming operations, drive real-time operational decisions, and redesign business processes for game-changing business models (Nukala et al., 2016; Wolfert et al., 2017).

As the context of smart farming infers to a digital transformation of the Agricultural sector (the processes, actors, and relationships), the background and the strong linkages to Supply Chain Management (SCM) should not be neglected. The SCM, specifically the field of AgriFood Supply Chain (AgriFood SC), is the required theoretical stream to inform studies in the smart farming field. The paradigm of smart farms sets the technology aspect at the core of attention but also examines the processes, actors and relationships. The theoretical framing that informed the example case in our study follows the foundations of Supply Chain Management (SCM), the AgriFood Supply Chain (AgriFood SC), and specifically the Information Sharing aspects of AgriFood SC. The background of AgriFood SC informs the case specifics and the associated steps; therefore, the consideration and links of these theoretical streams will be presented in this section.

The AgriFood SC encompasses a set of activities that move agricultural products across the chain from production to consumption; the set of operations includes *farming, processing, packaging, warehousing, transportation, distribution, marketing*, and sales (Iakovou et al., 2014) Several stakeholders act as part of these activities such as farmers, agricultural cooperatives, intermediaries, distributors, traders, wholesalers, retailers, and consumers (Jaffee et al., 2008). Except for the AgriFood SC actors, different stakeholders, i.e., primary and secondary stakeholder groups, influence business operations (Clarkson, 1995). Primary stakeholder groups are vital for the company's existence, while the secondary stakeholders' actions may have a low impact on the business operations (Bremmers et al. 2007). Some examples of AgriFood SC stakeholders are NGOs, governments, statistical institutes, international organizations, companies' vendors, other agricultural companies' competitors (Dentoni and Peterson 2011; World Bank 2010). Stakeholder interactions enable firms to interact with each other in order to learn, negotiate, set standards, and make future plans (Glasbergen 2007; Braziotis et al. 2013).

Supply chain visibility and transparency appear in extensive reviews like those of Sodhi and Tang (2019) and Montecchi et al. (2021). The information and data flows can provide a better view of the SC processes and ensure the quality and origins of the products while informing the final consumers. The study of Rogerson and Parry (2020) presents traceability as an aspect of the value of blockchain in food supply chains. Traceability in these studies improves the quality of the products of the AgriFood SC and links with the strategic pricing decisions, therefore increasing the revenue of each SC stakeholder. Overall, SC traceability can be defined as the ability to trace the history, application or location of a product in relation to the origin of its materials and parts; the processing history; and the distribution and location after delivery (Corallo et al., 2020). Due to supply chain crises relevant to food scandals and disruptions, the requirement for transparency and sustainability in AgriFood SC appears more in recent studies of SC (Garcia-Torres et al., 2019). Sustainability and AgriFood SC traceability have been highly linked and related the last few years due to the urgency for new production models and the evolution of data-driven practices and technology for AgriFood SC (Spanaki et al., 2021c).

Information sharing practices of the AgriFood SC emphasize recently on the use of data and technology in the cyber-physical farm management cycle, with a strong focus on data-intensive, informed decisions for the agricultural practices (Kaloxylos et al., 2012; Nukala et al., 2016). The agrarian data, linked data, metadata, information, and knowledge could be vast and include anything associated with them. Examples could include yield monitoring data (crop yield by time and distance, distance and bushels per load, number of loads and fields), spatial coordinates (mapping fields), fertilization management data, data from mapping weeds, variable spraying data, topographic data, salinity data, field assessment data, pertinent data, images, geospatial data etc. (Kamilaris et al., 2017). The volume of this list is enormous and unlimited and is continuously expanding as more technological developments arise. The volume of the data could sometimes hinder the progress and confuse the processes if it is not handled with the required capabilities (Spanaki et al., 2021a). The capabilities require advanced intellectual and technical resources to capture, store, distribute, manage and analyze the data (Kruize et al., 2016; O'Grady and O'Hare, 2017).

3 Research Method

The study develops a design through a real case and, based on principles of Design Science Research (DSR), is deemed most appropriate to *understand better how operations can be structured so as to contribute to the design of systems* (O'Keefe, 2014). Therefore, the study proposes a conceptual design artefact as a template for traceability applications for AgriFood SC processes. The design/ artefact poses a representation of how the proposed solution to a specific problem could be enacted in practice (Hevner et al., 2004; Hevner and Chatterjee, 2010; O'Keefe, 2014). The DSR approach arises from the specific problems which inform the defined case while ensuring that all aspects of the problem will be captured. The DSR approach proposed in this study will examine a variety of aspects and propose solutions for the specific AgriFood SC traceability problems. The objectives that represent a solution will also be articulated (O'Keefe, 2014, 2016) in the form of an evaluation of the case study. Initially, the data sharing standards will be explained in order to understand the way data are processed throughout the proposed design, and then the data sharing context will be presented through the case study that follows.

The AgriFood SC Traceability and Data Sharing context underpin this study theoretically. The data sharing standards (GS1 and EPCIS) are used to define the traceability specifics for the applied solution. The background relevant to AgriFood SC and traceability as well as information sharing in AgriFood SC will assist in identifying the suitable approach for the problem area while informing the case study with the data sharing standards that will be used to develop the solution. The solution explained in this study can provide an example template for future development of similar approaches to other AgriFood SC problems while encouraging practitioner communities to pursue further research towards novel applications of smart farming initiatives. The research strategy followed for this study is similar to previous studies describing AgriFood problems (Spanaki, Karafili and Despoudi, 2021; Spanaki, Karafili, et al., 2021), adapting the design science principles as presented by O'Keefe (2014). The research design of this study follows five steps: a) problem identification, b) objectives of the solution, c) development, d) testing and demonstration, e) evaluation.

4 The Data Sharing Context and Standards

Key to the sharing and processing of transparency data is transparency standards. GS1 set of standards is the most complete widely used for transparency (GS1, 2021). GS1 provides three sets of standards for sharing transparency data across businesses: standards for identifying objects, including products, locations and assets, standards for accurately and automatically capturing and standards for data sharing. In CYSLOP, the focus was particularly on GS1 Identification and Sharing of visibility data.

4.1.1 GS1 Identification standards

GS1 is widely known for barcodes that are essentially on almost every product and packing that come from the processing industries. For instance, nearly all products sold at supermarkets with scanning systems have a GTIN encoded in GS1 barcodes following the GS1 product identification scheme. GS1 identification standards include a system of unique identification codes (called GS1 identification keys) that are used by information systems to refer to real-world entities unambiguously. GS1 identification keys are used for most industrially processed products, packaging, and ingredients, but only rarely for identifying fields and plants that serve as field crops, such as olive trees. We will be using GS1 identification keys for fields, the crops and the harvested farm products and therefore introduce here the system of GS1 identification scheme. A check digit at the very end is part of every GS1 Key. Sometimes single GS1 Keys are transferred to companies directly. Still, worldwide uniqueness is always guaranteed. The responsible company of a GS1 Keys can be found via GEPIR – the Global Electronic Party Information Registry (https://gepir.gs1.org/).

Table 1. Description of GS1 standards in the Case Study

GS1 Number	Description	In the Case Study
GS1 Company Prefix	Every GS1 Key consists of a GS1 Company Prefix (GCP), which is generally allocated by GS1 to the company, enabling the company to allocate worldwide unique identifiers (IDs) for its products, objects, locations or assets on its own. It guarantees the uniqueness of every GS1 Key worldwide.	The farmer was GCP 5214001880 by GS1 Greece.
Global Trade Item Number (GTIN)	One type of ID a company generates from its GCP is Global Trade Item Numbers, GTINs. GTINs are used to identify products	The farmer is allowed to use his GCP 5214001880 to allocate

	and services of a given company uniquely. GTINs are class-level identifiers that represent products of the same type and share the same master data (product name, brand, weight, etc.). In order to identify products more uniquely, the GTIN of the product class is combined with the *Lot number* to form an LGTIN in order to identify a group of product items uniquely, or the GTIN is combined with the *Serial number* of a specific product to form SGTIN in order to identify the given single product uniquely. The GTIN can be 8, 12, 13 or 14 digits long (GTIN-8, GTIN-12, GTIN-13, GTIN-14).	a range of GTINs from 5214001880**00**3 to 5214001880**99**7
Global Location Number (GLN)	Another set of IDs a company generates from its GCP is the global location numbers, GLNs. As with GTINs, the first part of GLNs is the company's GCP. The GLN uniquely identifies any type of location used in the company's business processes. These can be the location of the company, its warehouses, a field or even more granular places such as loading stations or sorting areas.	In the project, the farmer was allocated the GLN 5214001880003.

4.2 The EPCIS standard

Electronic Product Code Information Service[4] (EPCIS) is a GS1 standard that enables trading partners to share information about products' physical movement and status as they travel throughout the supply chain – from business to business and ultimately to consumers. It helps answer the "what, where, when and why" questions to meet consumer and regulatory demands for accurate and detailed product information. The goal of EPCIS is to enable disparate applications to create and share visibility event data, both within and across enterprises. This sharing aims to enable users to gain a shared view of physical or digital objects within a relevant business context.

EPCIS is intended to be used in conjunction with the GS1 Core Business Vocabulary (CBV) standard. The CBV provides definitions of data values that may be used to populate the data

[4] EPCIS and Core Business Vocabulary (CBV): https://www.gs1.org/standards/epcis. Website. Last accessed 2021-03-12.

structures defined in the EPCIS standard. The use of the standardized vocabulary provided by the CBV standard is critical to interoperability and to provide for data querying by reducing the variation in how different businesses operate in a coordinated and commonly accepted way.

EPCIS is a global standard to track the status and movements of goods throughout any supply chain. It allows depicting physical processes with a chain of digital events. An EPCIS event reflects a process step within a relevant business context. It contains information in the four major dimensions "what", "when", “where” and “why”.

Table 2. Description of the EPCIS standard

Dimension	Description	Example
What	refers to the objects which are observed within a business context. Objects are typically trade items, logistics units, assets, physical or virtual documents.	End consumer goods, pallets of goods, farm equipment, coupons. Within this approach, crops and the resulting end consumer products are observed objects.
When	refers to the point in time when the objects were observed within a business process.	This is the time when a specific process step was executed and the time when the event was captured. This includes additionally the time zone in which the event occurred
Where	refers to the location where the event took place and the location of the objects after the event.	(sub-)locations of farms, production sites, warehouses, distribution centres and retailers.
Why	refers to the business context of a physical process. The business step specifies the executed action of the process.	• Business steps can refer to many different physical processes like production, logistics (packing, shipping, receiving), storing and selling. • The state (disposition) of the objects immediately after the event. The disposition always reflects the state within a business context, e.g. whether the objects are created, available for customers, stored, in transit to a destination, damaged or recalled. • Individual master data for the specified objects and references to external documents.

In addition to the four standard dimensions, EPCIS provides extension mechanisms to support adaption to specific business situations. Within IoF2020, extensions are used to add

environmental information as well as sensor/ quality data of crops and products to the process depictions.
EPCIS aims for standardized data exchange between two or more business partners within a supply chain. Thus, the captured event information abstracts from technical raw data, filters, combines and aggregates information from different source systems. As a result, EPCIS events only hold information that is relevant within the business context. EPCIS is located on top of (potentially many different) operational solutions and IoT implementations in a typical software stack and provides aggregated, standardized information to the business layer.
The EPCIS standard describes the overall structure of events. It defines two major interfaces to capture and access such event data consistently and uniformly. Implementation specifications are not part of the standard. Interface specifications are sufficient to enable cross-company data exchange as well as the interchangeability of different EPCIS implementations. The accompanying Core Business Vocabulary (CBV) provides a generic terminology for common processes in arbitrary supply chains. Domain-specific vocabularies (user vocabularies) can be used to support sector-specific demands and to enhance the set of supported process steps.

5 The Case Study

The overall project involved eighteen (18) farms where new IoT devices were deployed in Cyprus and Slovenia and one (1) farm from Greece. The project in Greece already existed and was extended to explore its integration to additional services and applications (i.e. traceability). The farm is located in Western Greece in the area of Aitoliko, very close to the sacred city Messolongi where English poet Lord Byron died during the war for its independence in 1821. The place is surrounded by a beautiful wetland protected by the international conditions RAMSAR and NATURA 2000 due to its great ecological value. At the same time, the availability of water makes the surrounding land very fertile and suitable for cultivation. Olives is the main crop here, seasonal vegetables, and some other high-value products like unrefined sea salt blossom (fleur de sel) and fish eggs (caviar).

Figure 1. The farm in which FINT demonstrated IoT and traceability integration through IoF2020 collaboration

The area cultivates fifty per cent (50%) of the famous and protected “Kalamata” natural black olives in olive production. Kalamata table olives is a highly recognized product across the world, and thus, it is massively exported, and only fifteen per cent (15%) is consumed domestically. The farmer, a third-generation grower, is a young man who decided to invest in the land and the relevant activities and teamed up with like-minded people to create a dynamic and modern new cooperative. This gradually invests in new technologies across all layers, from crop production, raw and semi-final products’ processing and packaging up to future digital marketing campaigns. Future Intelligence (FINT) is selected to digitally consult and transform the farmers’ activities with a cooperation from the company’s IoT solution portfolio and Smart Farming application QUHOMA. QUHOMA is deployed at this challenging land of 3,5 hectares with high and very productive irrigated trees. More specifically, powerful FINT IoT platform (FINoT) communication devices (FINoT nodes and a FINoT gateway) and air and soil sensors available on the market were installed. The FINoT nodes acquired and transmitted sensor data wirelessly to the FINoT gateway and from there on to the Cloud. Then, the QUHOMA application retrieved the data and presented the information required by the user (in this case, the pilot farmer) in a format that addressed the farmer's day to day needs. The gathered data include air temperature and relevant humidity, soil temperature and moisture and soil electrical conductivity and salinity. Data services are information that enables the farmer to optimize plant protection and irrigation applications.

5.1 Problem Identification

The table olive production from the first step of planting the trees harvested in later production is worth considering from a standardization point of view. The process of planting the trees and harvesting the olives in several cycles, building batches and making a reference to the field or even to a single tree is remarkable. It allows adding production steps like fertilizing, irrigation, and sensor derived IoT data like the temperature of the soil or the air to a batch of olives. This can be helpful for the prevention or root cause analysis of diseases, improve quality, and enrich downstream communication up the consumer.

Since the farmer had not been a user of GS1 identification schemes before, contact to the local GS1 Member Organization, GS1 Greece, was established, and the farmer became a member of GS1 Greece and allocated the GLN 5214001880003 with the GCP 5214001880. This GCP he can use to allocate GLNs to every location relevant for an EPCIS event like fields, plots or shipping points. He also can allocate GTINs to the crops and GIAIs (Global Individual Asset Identifiers) to sensors placed in the plots. These GS1 identification keys are used to populate EPCIS events. For example, many olives are identified by an (L)GTIN. It can appear in the "What" dimension of a harvesting event, whereas data on humidity or temperature can be shared with a unique GIAI for every sensor. By querying for a certain (L)GTIN, relevant events along the supply chain that happened with this lot, like the plot it was harvested, the temperature condition or the consumer units it was filled in, can be derived.

The use case shows that small farmers can benefit from using unique GS1 identification schemes and EPCIS to gain transparency and provide traceability to their customers.

5.2 Objectives of the solution

Within IoF2020 and CYSLOP in particular, traceability modelling had to adjust to the solution's core architectural orientation. QUHOMA's IoT modelling was done based on the FIWARE entity model and the powerful Orion Context Broker (Orion) for handling real-time IoT data. Orion Context Broker is included in the core pillars of European Commission Connected European Facilities. Practically, this means that additional Member States easily re-uses data services based on Orion. FINT is a proud member of the FIWARE community and founder of Hellenic FIWARE iHub[5], through which training on its use is undertaken along with cross-sectorial FIWARE pilots are prototyped.

However, in order to interoperate IoT and traceability events, the latter were analyzed so that data re-modelling was done. Training on the use of GS1 standards, including EPCIS, was delivered by GS1's technical partner EECC. Bilateral meetings (FINT and EECC) were set up, and a test server instance was created. An interdisciplinary team of domain experts, IT architects and EPCIS consultants developed the business event model for CYSLOP. The physical processes were translated into EPCIS events under consideration of existing systems and identifiers. In parallel, FINT, on behalf of the farmer organization, contacted the local GS1 office to proceed with the creation of the basic GS1 keys like EPC, GLN, GTIN, GIAI, among others mentioned in the Background section above. Furthermore, GS1 Greece also advised on the specific use case (farming business) and how things practically work in the local economy in order to clarify certain aspects of the GS1 identification procedure).

After an introductory meeting, both FINT and GS1 Greece teams decided to collaborate as follows: Guidance from GS1 Greece to FINT team regarding the correct application of GS1 Identification keys (concerning that the pilot's company was a GS1 Greece member), validation from GS1 team of the scenarios deployed and the correct application of EPCIS XML schemas and GS1 Greece team's knowledge sharing on common fruits and vegetable traceability practices applied by Greek companies. Based on this, initially, GS1 Greece and FINT team examined the critical events scenarios selected and the correct application of GS1 standards in terms of GS1 keys (GTINs for trade units, GLNs for locations, GIAIs for the sensors in the farm fields, EPC tags for the EPCIS schemas). A brief training on the correct adoption, implementation, and deployment was offered, mainly focusing on key elements like the Global Company Prefix, the EPC tag data standard, the GTIN management standard, and the GLN allocation rules. Data quality issues were adjusted during this process, basically concerning the GS1 identification keys used structure. As soon as these basic topics were

[5] https://www.fiwareihub.gr/

clarified, the GS1 team proceeded into evaluating the EPCIS XML schemas and Core Business Vocabulary correct application in the model. FINT team analytically presented the critical events selected for tracking and tracing in the company's operations and explained the basic metadata selected from the IoT sensors on-site and what added value offer to the system. GS1 team proposed specific events' naming changes based on EPCIS Core Business Vocabulary (CBV) standard and in conjunction with the actual activities of the tracked events as well as minor alterations in the XML schemas. The biggest debate on the topic was the selection of a Serialized GTIN (SGTIN) or not. GS1 team, based on the experience from training and project collaborations with the Greek fresh food industry, insisted on selecting a batch/lot based GTIN (LGTIN). The GS1 team proposal led to changes in the architecture of the schemas. FINT team proceeded to the necessary changes. A final evaluation was performed and agreed as final iteration, with suggestions from the GS1 Greece team for potential future developments so FINT could add them to the product's backlog.

GS1 Greece allocated 100 unique numbers to be used by the farming business, indicating the GPC and initial GLN code that represents the company's headquarters. Every company uses the various codes that were shared with it as it wishes. In detail, the codes can be used for identifying locations, assets, trading items or else. Several issues may arise for this sector (table olives) in Greece. The current business reality of Greek table olives producing companies mandates the assignment of GTINs to trade items and printing of associated barcodes on their labels (e.g., EAN-13 for retail trade items, ITF-14 or GS1-128 for wholesale trade items etc.). GLN numbers are requested from Greek companies, especially during their export's activities (where Greek olives and olive oil companies excel) and lately as per the latest IFS Food version 7 Standard. Finally, both GTIN and GLN identification keys are mandated from the GS1 Global Standards Synchronization Network (GDSN), which is again requested from (mainly) external partners of the Greek companies. Concerning the selection of the batch/lot number as the additional traceability identifier, it is worth mentioning that Greek food companies in general, due not only to the important collaborations they develop with international markets and stakeholders but also the demand from consumers for safe food products, need to conform to food industry global standards (e.g., FAO/WHO Codex Alimentarius, IFS, ISO 22000:2018 etc.) as well as regional regulations (e.g., EU 1169/2011). These standards require companies to establish food management systems and keep recorded information for production processes and other similar details. One of the most critical ones is the “Batch/Lot” number. According to ISO 22000:2018 standard, it is defined quantity of a product produced and/or processed and/or packaged essentially under the same conditions. GS1 Greece team comments that a lot based GTIN offers resilience to the traceability system developed under this scope as well as interoperability with other traceability, proprietary or not, systems with which an EPCIS standard-based traceability platform can exchange information.

5.3 Development of the solution

FINT upgraded the QUHOMA application for the purposes of CYCLOP, and it also integrated the traceability work as the outcome of its collaboration with MTT. QUHOMA currently targets farming organizations, so prioritization was given to traceability events that are relevant for the production phase of the supply chain. However, proper modelling was done for the whole table olives supply chain. As shortly explained above, the process of including interested Smart Farming adopters in GS1 traceability schemes requires their contact with GS1 local offices, with or without FINT’s mediation. Then, their output, the globally unique identification codes of the interested company, is integrated with QUHOMA through FINT actions on the platform’s backend entity model under farmers’ confirmation.

Data privacy plays a major role at this point, and this is why FINT follows a privacy-by-design approach validated by the Security, Privacy and Trust framework communicated within the IoF2020 project. Initially, every customer’s IoT entity model falls under an isolated tenant while they own the IoT equipment, instead of being rented or other subscriptions-based or pay per use models. Consequently, data belong exclusively to them, and FINT agrees to use them to deliver meaningful and usable services. That said, traceability information is only shared with value-chain stakeholders after the farm business gives an explicit declaration to the system. When this is done, the deployed microservices enable sharing farm data with consumers, among other actors of the ecosystem. A prototype mobile application for consumers was also created to check the seamless flow of information between the farm devices, the Cloud and the services’ interface with the EPCIS engine.

Farming is a highly risky business largely depends on weather fluctuations. Yet, these increase year by year mainly due to the climate change phenomenon, which is evidenced in several places across the world. Having said that, the idea of QUHOMA and other Smart Farming applications is to optimize farm inputs by precisely identifying agro-environmental conditions of the cultivation field. Not a single farm is identical to another, and thus input products and doses are not necessarily applicable to all regional farms. Moreover, not all parcels or parts of parcels require the same treatment. These are the challenges that Precise Farming faces, and to a certain extent, it copes with them, although not always cost-effective.

In this regard, data acquired from the land are analyzed, correlated and further processed to fit into models that create value offerings and return on investment for the end-users. Such offerings usually come with the performance indicators of the most impactful farm practices regarding environmental and business sustainability. Such Key Performance Indicators (KPIs) usually assess the use of plant protection, fertilizer and irrigation applications before and after introducing any agricultural technology. QUHOMA builds services that notify the user when to proceed with such inputs and, at least, for now, the user self-records them digitally on the QUHOMA dashboard. FINT modelled this cultivation practices' record to fit the EPCIS format and thus share them with traceability-interested stakeholders. As a result, a phytosanitary spraying event can now be shared directly with the provider of the chemical product leading to unparallel computer-mediated collaboration. Or, to re-phrase it to the recent buzzword, digital transformation goes beyond the digitization of mere, partial and standalone business practices and eases business to business relationships.

5.4 Demonstration

The conceptual architecture of the solution is presented below. The reader may see that three different middleware systems interoperate: A) the core IoT platform implementation in which infrastructural and security and privacy modules are hosted, B) the data and information processing layer where FIWARE has the major part. FIWARE is an open-source community with several tools and APIs to handle IoT data and entities based on NGSi standards. FIWARE's Orion Context Broker module is also one of the Connecting European Facilities (CEF) foundational components, meaning it is a tool that is accepted to provide interoperable data and information services to every EU member state, C) the traceability layer where GS1 and EPCIS in particular dominates. The integration of layers B and C is analyzed in this paper.

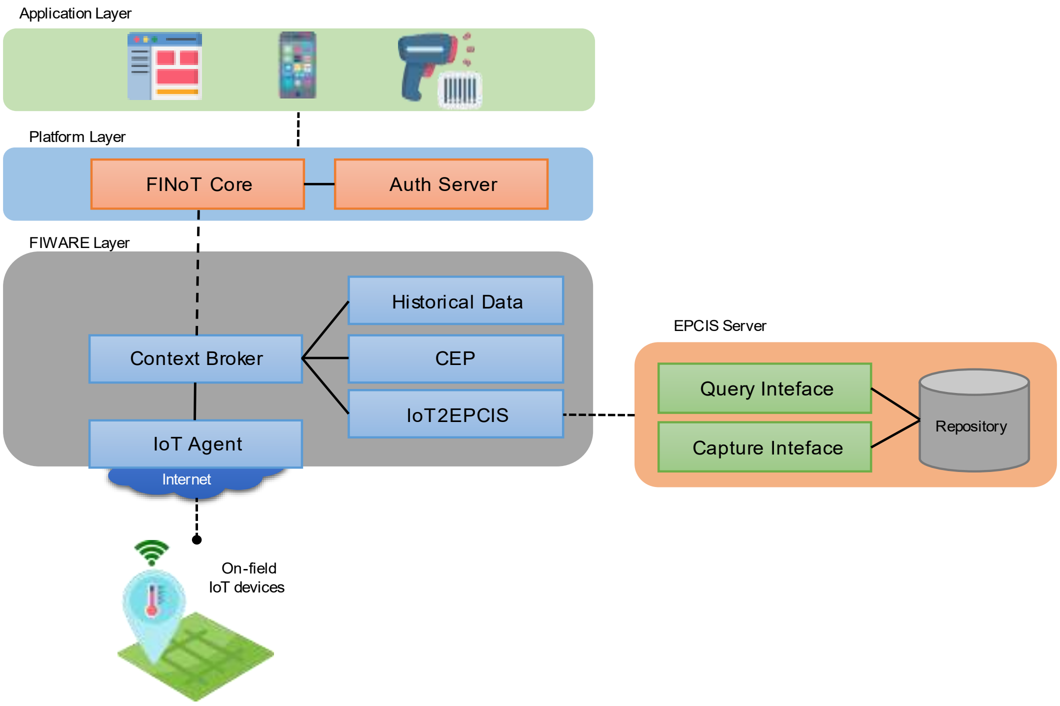


Figure 2. Conceptual Architecture

In the implementation phase, FINT:

1. selected the supply chain part to implement in a software platform and decided to work from planting to harvest phase where minimum references exist.
2. identified the IDs to use based on the fruitful interaction with the GS1 offices (Germany and Greece).
3. used the barcode encoding to prove the seamless flow and integration of IoT data and traceability events.
4. developed the software system that includes the backend mechanisms presented in the architecture, the farmer's application that manages the sensors and the traceability information and created a beta mobile app for consumers' interaction.

Global Location Number (GLN) is a unique identification number for supply chain locations or entities such as farms, plots, distributors' loading dock, or retail shops. They help a company record each stop a product has made in the supply chain.

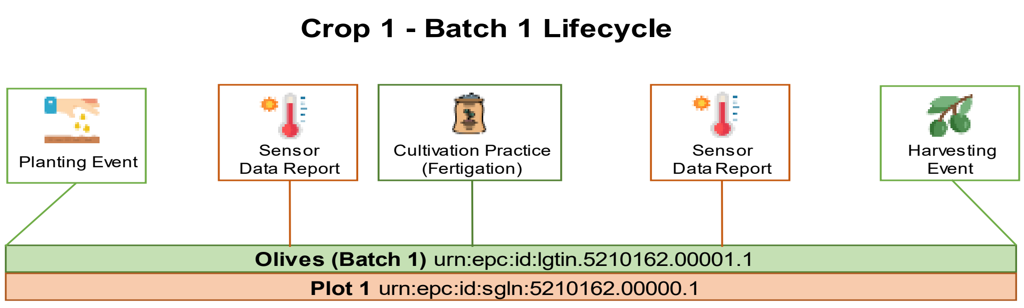
Global Individual Asset Identifier (GIAI) is used to capture the information on the asset used in the field or along the supply chain. GIAI can carry information of the weather data collected on the farm or a truck during the transportation from the processing plant to the terminal. In this case, FINT used the GIAI to identify the IoT microclimate sensor kit. Finally, Global Trade Item Number (GTIN/LGTIN) is a globally unique identifier of products that are recognized in all trading partner systems. In our case, the team used two (2) LGTINs to identify the raw material after the harvesting event and the final product.

Table 3. The elements of the EPCIS events

Event	Custom Business Steps
Planting	http://epcis.f-in.io/bizstep/planting
Harvesting	http://epcis.f-in.io/bizstep/harvesting
Sensor Data	http://epcis.f-in.io/bizstep/sensor-data
Cultivation Practice	http://epcis.f-in.io/bizstep/cultivation-practice
Washing	http://epcis.f-in.io/bizstep/washing
Fermenting	http://epcis.f-in.io/bizstep/fermenting

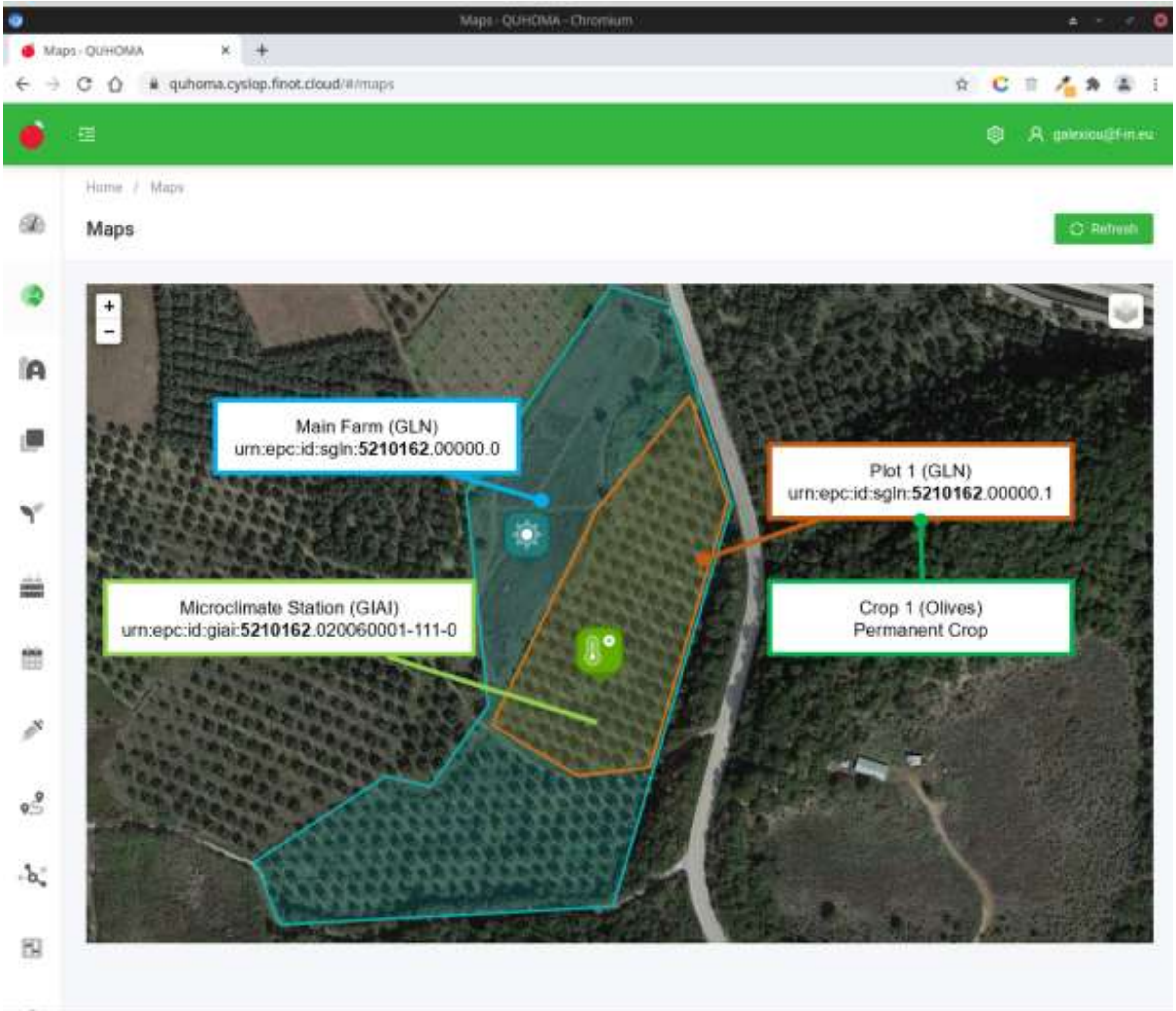
The previous use of GS1 application identifiers, when exploited by an IoT platform that also provides sensor data and services to the end-user (farmer), results in the unique identification of the yield outputs. Food being globally traded requires globally unique identification. The GS1 Application Identifiers (AI) provide an open standard that all companies can use and understand in the trading chain; when these couple with IoT data, business partners and consumers are informed on quality and sustainability indicators.

Figure 3. Implementing the application identifiers



QUHOMA end-user (farmer/ farming industry/ food industry) allocates the different GS1 application identifiers to the various entities that wish to identify (farm, parcel, sensors and so on). When farm applications occur, such as irrigation, fertilization, and so on, the user shall also record them. Then, these are uniquely identified and stored in a format that the whole industry may access through the use of the EPCIS standard.

Figure 4. Representing and explaining the use of GS1 application identifiers in the QUHOMA solution



Cultivation practices from planting to harvesting worth tracking and tracing include soil management, fertilization, irrigation, plant protection application, waste management. When the end-user or the business partner or consumer tracks such practices and can also trace the agro-environmental conditions under which the practices applied, there is a clear indication of how necessary or "harmless" these were. For example, when a farmer sprayed with a phytosanitary product, an on-field humidity sensor can prove that humidity was less than 45%, for instance. This is the national threshold above which praying is forbidden. Furthermore, this stakeholder (buyer, consumer) sees that harvest was done after more than two weeks from the farmer records.

Similarly, the soil moisture average shall be much less than the previous week, so irrigation needs to be performed. As these approaches go mainstream, then the validity of data may need to be proved using more sophisticated technologies (distributed ledger technologies - DLTs). Until then, a farmer who invests in sensor kits to reduce production costs can also use QUHOMA to focus on sustainable approaches. Especially, farm businesses close to Natura ecosystems or other protected schemes shall be among the first adopters of QUHOMA or like-minded solutions. In this paper, the team proved that technically IoT and traceability solutions nicely complement each other, and further business development in the era of Green Deal and Farm-to-Fork agendas will happen.

5.5 Evaluation of the solution

After (hand-picked) harvesting, the table olives are inserted into crates and then washed, debittered and fermented in farmers' premises. Raw olives are bitter and require processing in order to become suitable for consumption. Processing should be conducted under good sanitary practices in order to maintain all ingredients and comply with all necessary chemical and microbiological standards. The processing affects the concentration of the major compounds, depending on the type of olive. For high-quality table olives, the following requirements are important: good quality water, excellent quality of raw olives and excellent quality of the additives used are required (in most of the cultivars but not for natural black). The flavor and taste of processed olives depend on the variety, fermentation conditions, and packing solutions such as vinegar, olive oil and flavorings.

When all statutory food and safety standards are ensured, table olives derived from good quality raw material and harvested at the appropriate ripening stage can give a tasty and safe product provided that they have been subjected to proper fermentation. Various table olive processing methods are used, depending on cultivar, ripeness, cultural condition and processing technology. The main equipment includes washing machines, sorters, graders, tanks (food grade fiberglass), pumps and packing equipment. After processing is finalized, the go-to-market channels include two options, either the wholesaler arrives and picks the bulk semi-final products, or the olives will be further processed so they launch the market as branded goods. When products refer to the retail market, the olives are moved to the packaging partner facilities. Their quality is checked again, and retail trade characteristics (size, color) are grouped accordingly.

Figure 5. Traceability of the supply chain for table olives case

Table Olives Product Flow Model with object events (when an object is or is not observed), aggregation events (in tags) when an object is added to or removed from a containment-mainly used to track palletized objects, transformation (when one or more input objects are consumed and transformed into output objects) and transaction (when an object is (dis)associated with a business transaction) events.

Table 4. Mapping CYSLOP post-farm case with GS1 Critical Type of Events (CTE)

Table olive specific event	**Description**	**CYSLOP IoT data**	**EPCIS core event**	**Business cycle**
Planting	Planting of seasonal crops or start of cultivation cycle of permanent crops	Farm data: raw data throughout cycle	Object event (“Transformation input”)	Cultivation period
Treatment	Irrigation, spraying, fertilizing, pruning	Farm data: raw data throughout cycle	Object event (“Transformation input”)	Cultivation period

Harvesting	Collecting the ripe olives	Aggregated farm data	Object event ("Transformation output")	Harvesting
Shipping	Raw olives ready to leave the field	(IoT data during transportation)	Object event ("Transportation")	Raw olives
Receiving	Raw olives ready for primary processing	(IoT data during temporary storage)	Object event ("Transportation")	Entering the processing phase
Washing / fermenting	Raw olives are washed/ fermented	(IoT data for pH, salinity)	Object event ("Transformation input-output")	Primary processing (a) + (b)
Shipping / receiving	Re-entering the SC transportation	(IoT data during transportation/ storage)	Object event ("Transportation")	Semi-final products
Sorting/ Packaging/ Storing	Quality / size grading	N/A	Object event ("Transformation")	2nd processing phase/ packaging
Shipping / receiving	Transported to retail stores	(IoT data during transportation/ storage)	Object event ("Transportation")	Consumable products
In-store processing / selling/ replenishing	Reseller performs quality control when receives the products and finally displays them	Product data-story telling is presented	Object event ("Depletion (disposal")	Product-traceability story

Thus, these identification schemes were used in the EPCIS compliant event model developed for this use case, including:

1. Planting event
2. Sensor data event
3. Cultivation event
4. Harvesting event
5. Shipping to warehouse event
6. Arriving at warehouse event
7. Washing event
8. Fermenting event
9. Shipping to packaging house event
10. Arriving at packaging house event
11. End processing event
12. Shipping to retail shop event
13. Arriving at retail shop event

14. Selling end product event

Eventually, consumers would find the product on the shelf along with an easy-to-use tag (QR) from which all information and (aggregated) data from the farmer and field can be accessed. In this study, we focused on the upstream part of the supply chain: Plant to Harvesting events. The above farm-related practices are currently missing from the existing traceability platforms and solutions. These activities unveil the major role of the farmer in respect to sustainability and local biodiversity protection. Apart from those farm owners that already understand and respect their impact on food security and safety, CYSLOP created the services that can differentiate them from their colleagues and guarantee better living standards for their families—modelling transparency data from the field to retail (Appendix).

6 Discussion and Implications

The project, however, was not solely technology-focused. Trivial was to identify collaboration opportunities between different trials and use-cases and launch joined activities in areas where technology fusion can create additional value for the AgriFood chain. The AgriFood supply chain aspects (Iakovou et al., 2014; Tsolakis et al., 2014) were utilized and extended through this study, where the sector specifics where required to identify the context for the data sharing standards. Furthermore, the supply chain traceability was deemed as an important aspect, which was further investigated and explored in detail through all the stages in this study (Corallo et al., 2020, 2018; Garcia-Torres et al., 2019). In this respect, the Digital Ecosystem Utilization project (called CYSLOP, based on its original name: Cypriot and Slovenian IoT pilot) explored the integration of IoT and traceability technology into a single Web Platform built to enable and promote quality farming. Future Intelligence (FINT), an innovative SME and an original IoT solutions provider from Greece, coordinated CYSLOP and offered the platform mentioned above for further experimentation. CYSLOP collaborated with another use case within the IoF2020 ecosystem working on transparency and traceability of meat. The partners have significant know-how of traceability and transparency standards and demonstrate the compatibility of the approach across the diverse AgriFood domains.

The results of this cooperation are analyzed and discussed in this paper. Due to the highly innovative orientation of this collaboration, the project managed to leverage external to IoF2020 interest. Practitioners of the ecosystem in Greece and the local GS1 office also contributed with comments and parameters to be considered during the design-thinking phase. The project was based on collaboration and multidisciplinary, as this is supported by various research directions (Dwivedi et al., 2019). Methodologically, the paper also contributes to the Design Science Research cases, based on O'Keefe's (2014) approach and steps and provide an example for future research with the same research template. Overall, the results of this prototype solution and the system-of-system design of the exploited platform extends the traceability panopticon currently provided by existing academic designs and market solutions (Spanaki et al., 2021b). In addition, it paves the way for creating new business models for data and information sharing within AgriFood value chains (Spanaki et al., 2021a). Their outcome, this additional tangible value, would ideally favor crop producers in economic and marketing terms while highlighting their role in sustaining biodiversity. Moreover, their activities and attitude as role models in modern societies' connection to nature would be emphasized. In return, the society and market would then call for a virtuous cycle creation by embracing circularity and design of novel no-food waste supply chains (Patwa et al., 2021; Yamoah et al., 2022).

IoT technologies have progressed commercially since the initial hype five years ago, and nowadays, low-cost systems are commercially available. These interconnect numerous sensors online while their power lies on data exhaustion and reusability by various services or applications. That said, European farmers should be Smart Farming early adopters since they belong in the region with the world's largest lands devoted to agriculture (Moysiadis et al 2021). However, AgriFood stakeholders usually are not aware of their existence, believe they are too expensive, do not trust them yet, lack the (digital) skills to follow them and do not have the investment capacity to re-currently use them (Spanaki et al., 2021b; Tsolakis et al., 2019). What's more, in a ubiquitously connected world where traditional physical habits are transferred online, and international mobility takes over, experience-based consumption is rising.

Digital Ecosystem Utilization (CYSLOP) is a new sub-grantee open can project that aims to deliver tailored services based on IoT data acquired on-field, integrate traceability technology with the support of relevant experts (MTT IoF2020 use case) and create a digital area where consumers, food professionals and AgriFood producers interact based on data services.

The scope of this study is to describe in detail the integration of a standard-based traceability system into an IoT platform adding to the previous research agenda of relevant AgriFood studies relevant to technology for smart farming (O'Grady and O'Hare, 2017; Spanaki et al., 2021c; Wolfert et al., 2017, 2014). The overall objective of this work is to enrich the value offering of a FIWARE-backed commercial IoT solution (QUHOMA) with tools that enable the traceability of farmers' activities, so this transparency influences consumer behavior and preference on their product.

Moreover, collaboration with MTT was confirmed along with its supporting role to FINT in order for the latter to understand the main principles of traceability in AgriFood. The contact points for managerial and technical cooperation were shared, and the initial meetings aimed to share the two trials' objectives were held. The business process flow of a single case from CYSLOP was then discussed, and technical material on traceability cornerstones was forwarded to FINT. Collaboration is ongoing, and it is now getting into more technical details. This learning and engineering process primarily targeted farmers from Greece since they served as the single case paradigm on which traceability is applied – but it is very important to also scale on the Slovenian and Cypriot farmers even after the project's official end.

Early September 2018, Digital Ecosystem Utilization (CYSLOP) identified MTT stakeholders as a nice fit to work together to create a new pilot to be included as a new Use Case in the IoF2020 family of projects. Both sides agreed that it would be nice to work together for such a project integrating EPCIS into a FIWARE-powered platform during these initial email interactions. This was finally formalized during CYSLOP final negotiations phase that successfully engaged MTT collaborating partners.

7 Conclusion and the Way Forward

Overall, the study focused on the traceability through data sharing in AgriFood supply chain. The approach is based on a design for the specific standards applied in the data sharing practices and the relevant traceability milestones. The main impetus and idea for the project was to extend the diffusion of relevant data sharing technologies to the initial customer base (farmers) – that is already tried to be reached using direct and in-direct channels (go-to-market actors) and faces certain limitations – by providing services for post-farm operations. The concept is innovative since there is no other solution that merges production and post-farming data into single data services that can be accessed by products' end-users, final consumers. This way, farmers can also see another – marketing – benefit of using IoT devices for all their production cycles that enhances trust and brand loyalty with their customers and partners. Thus, the interaction with the consumer is a core feature that FINT and CYSLOP aim to accomplish however the transformation of raw materials to sellable products found in retail packaging and the encapsulation of relevant tracking events are the sole focus of this case study and the cooperation itself. The project achieved to expand the proposed solution to eighteen (18) new farms and farmers with a diverse production portfolio and a variety of business relationships while overcoming an initial major challenge. In our study there is an example of a single "vegetable" producer, at the same time, the project worked on the backend integration of the traceability service and mobilized GS1standards.

Furthermore, as a future goal the project is designing a consumer app enabling the farm to fork traceability for the products that are part of the described project. Last, although the project's web dashboard is very user-friendly and fully mobile-responsive, a separate mobile app was designed and soon launched commercially to enable field users to upload geo-localized field observations. In terms of theoretical underpinnings, the study provides an extension of the DSR case studies within the AgriFood sector. It is imperative nowadays to provide example cases where innovative data-sharing practices are applied as templates for observation of various traceability steps, but also as directions for future research in designing and regulating the field. The AgriFood sector requires further investigation in terms of the various technological applications, but also the way these are applied for the operational and supply chain processes, as the implications for policy in the field are still in their infancy and there is high interest for informed- solutions towards this direction.

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9 Appendices

1.1 Modelling critical traceability events of table olive

The following section describes the 14 critical traceability events we identified. Each of the events has 6 data elements: type of event, the type of action that took place, the business process step, the effect of the process step, the location where data is read and the location of the business process. In the following subsections, we discuss the 14 events we identified.Then , we describe the elements of the event in detail and provide a detailed description of the WHAT. WHEN, WHERE and WHY dimension of the event. We will describe only the additions of new elements for the subsequent events.

1.1.1 Planting event

The planting event depicts the seeding of crops at a specific planting plot.

Table 5. Description of the planting event

Dimension	Data Element	Contents	Comments/ Example
Planting Event	Event Type	ObjectEvent	
	Action	ADD	
What	EPC List	A list containing the LGTIN of the planted crops	urn:epc:class:lgtin:5210162.00001.1
When	Event Time	Datetime when the crops where planted	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the planting plot (location where the event took place)	urn:epc:id:sgln:5210162.00000.PLOT_1
	Business Location	SGLN of the planting plot (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00000.PLOT_1
Why	Business Step	http://epcis.f-in.io/bizstep/planting	Sector specific business step for the planting process
	Disposition	urn:epcglobal:cbv:disp:active	

The event type ObjectEvent represents an event that happened to one or more objects. Action ADD specifies that the identifiers of the objects are initially created. The planting event is the first event for every crop and represents the beginning of life for corresponding crop identifiers.

- **What**: contains the LGTIN as a class level identifier of the crops planted. The first two numeric components represent the GTIN which refers to a specific plant species. The lot number identifies the exact set of crop entities that were planted within this event. As the crops are not identified uniquely but as a set of entities, the lot number is used instead of a serial number. In the example, the GTIN components 5210162 and 00001 refer to a species of olives. Lot number 1 identifies the first lot of these species which was planted at the specified plot location.
- **When**: The event time defined when the planting happened. In case a process is executed over a longer time period, the event time consists of the point in time when the process ended. The event time zone offset contains the time zone in which the event happened. In the example, the time zone is +02:00 for the Greek time zone.
- **Where**: The readpoint is an SGLN representation of the location where the event took place. In the example, this is the agricultural area named PLOT_1. The business location specifies where the objects of the what dimensions (i.e. the crops) are after the event. In the case of planting, this is identical to the readpoint.
- **Why**: the business step element specifies that a planting process was observed within this event. As there is no cross-sector term defined for planting in the CBV, a domain-specific user vocabulary is applied in the form of a URL term. The disposition active is used in this beginning-of-life event to illustrate that the crops are now part of the supply chain.

Figure 6. Example planting event

```
<ObjectEvent>
    <eventTime>2020-01-01T02:00:00.000+02:00</eventTime>
    <eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
    <epcList>
        <!-- Crop 1 (Cycle/Batch 1 for Olives) -->
        <epc> urn:epc:class:lgtin:5210162.00001.1</epc>
    </epcList>
    <action>ADD</action>
    <bizStep>http://epcis.f-in.io/bizstep/planting</bizStep>
    <disposition>urn:epcglobal:cbv:disp:active</disposition>
    <readPoint>
        <!-- Plot 1 -->
        <id>urn:epc:id:sgln:5210162.00000.1</id>
    </readPoint>
    <bizLocation>
        <!-- Plot 1 -->
        <id>urn:epc:id:sgln:5210162.00000.1</id>
    </bizLocation>
```

1.1.2 Sensor data event

The sensor data event is used to periodically track environmental measurements, even when no operational process step took place.

Table 6. Description of the sensor data event

Dimension	Data Element	Contents	Comments/ Example
Sensor Data Event	Event Type	Object Event	
	Action	OBSERVE	
What	EPC List	A list containing the LGTIN of the crops for which sensor data was tracked	urn:epc:class:lgtin:5210162.00001.1
When	Event Time	Datetime when the sensor data was captured	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the plot (location where the event took place)	urn:epc:id:sgln:5210162.00000.PLOT_1
	Business Location	SGLN of the plot (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00000.PLOT_1
Why	Business Step	http://epcis.f-in.io/bizstep/sensor-data	Sector specific business step for capturing sensor data at a plot
	Disposition	urn:epcglobal:cbv:disp:in_progress	
	Sensor Metadta	List of attributes which specify the measurent period and the device id of the sensor	startTime="2020-06-08T02:00:00.000+02:00" endTime="2020-07-08T02:00:00.000 +02:00" deviceID="urn:epc:id:giai:5210162. 020060001-111-0"
	SensorReport	one or more aggregated measurement values	type="sensor:airTemperature" uom="CEL" averageValue="15.9" minValue="9.8" maxValue="26.1"

The what dimension contains the LGTIN of the crops which reside in the plot where the sensor data was measured. In contrast to the planting event, the LGTIN is not initially created but observed at a later point in time. Hence the action is OBSERVE. The sensor measurements are captured in a list of sensorReports. All sensor reports have attributes specifying the type of measurement, the unit of measure (UOM) and a set of aggregated sensor data. All sensorReport elements share a set of sensorMetaData, containing the start and end time of the measurement and the sensor device ID.

Figure 7. Example sensor data event

```xml
<ObjectEvent>
    <eventTime>2020-07-08T02:05:00.000+02:00</eventTime>
    <eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
    <epcList>
        <!-- Crop 1 (Cycle/Batch 1 for Olives) -->
        <epc>urn:epc:class:lgtin:5210162.00001.1</epc>
    </epcList>
    <action>OBSERVE</action>
    <bizStep>http://epcis.f-in.io/bizstep/sensor-data</bizStep>
    <disposition>urn:epcglobal:cbv:disp:in_progress</disposition>
    <readPoint>
        <!-- Plot 1 -->
        <id>urn:epc:id:sgln:5210162.00000.1</id>
    </readPoint>
    <bizLocation>
        <!-- Plot 1 -->
        <id>urn:epc:id:sgln:5210162.00000.1</id>
    </bizLocation>
    <sensor:sensorElementList xmlns:sensor="http://ns.eecc.info/epcis/sensor">
        <sensorElement>
            <sensorMetaData
                                startTime="2020-06-08T02:00:00.000+02:00"
                                endTime="2020-07-08T02:00:00.000+02:00"
                                deviceID="urn:epc:id:giai:5210162.020060001-111-
0"/>
            <sensorReport type="sensor:airTemperature" uom="CEL"
                                      averageValue="15.9" minValue="9.8"
maxValue="26.1"/>
            <sensorReport type="sensor:soilTemperature" uom="CEL"
                                      averageValue="19.0" minValue="15.3"
maxValue="22.4"/>
            <sensorReport type="sensor:airHumidity" uom="P1"
                                      averageValue="55.0" minValue="44.0"
maxValue="87.0"/>
            <sensorReport type="sensor:soilHumidity" uom="P1"
                                      averageValue="74.0" minValue="68.0"
maxValue="99.0"/>
            <sensorReport type="sensor:soilElectricalConductivity" uom="B99"
                                      averageValue="0.8" minValue="0.6"
maxValue="0.9"/>
            <sensorReport type="sensor:soilSalinity" uom="M1"
                                      averageValue="48.0" minValue="41.0"
maxValue="49.0"/>
            <sensorReport type="sensor:soilTDS" uom="M1"
                                      averageValue="44.0" minValue="42.0"
maxValue="46.0"/>
        </sensorElement>
    </sensor:sensorElementList>
```

1.1.3 Cultivation event

The cultivation event depicts the process of cultivation at a specific plot.

Table 7. Description of the cultivation event

Dimension	Data Element	Contents	Comments/ Example
Cultivation Event	Event Type	Object Event	
	Action	OBSERVE	
What	EPC List	A list containing the LGTIN of the crops	urn:epc:class:lgtin:5210162.00001.1
When	Event Time	Datetime when the cultivation took place	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the cultivated plot (location where the event took place)	urn:epc:id:sgln:5210162.00000.PLOT_1
	Business Location	SGLN of the cultivated plot (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00000.PLOT_1
Why	Business Step	http://epcis.f-in.io/bizstep/cultivation-practice	Sector specific business step for the cultivation process
	Disposition	urn:epcglobal:cbv:disp:in_progress	
	fint:cultivationPractice	type of cultivation practice	FERTILISER

The type of cultivation is persisted in the cultivationPractice events. In the example event, the crops at the specified plot were treated with fertilizer.

Figure 8. Example cultivation event

```
<ObjectEvent>
    <eventTime>2020-06-10T11:15:00.000+02:00</eventTime>
    <eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
    <epcList>
        <!-- Crop 1 (Cycle/Batch 1 for Olives) -->
        <epc>urn:epc:class:lgtin:5210162.00001.1</epc>
    </epcList>
    <action>OBSERVE</action>
    <bizStep>http://epcis.f-in.io/bizstep/cultivation-practice</bizStep>
    <disposition>urn:epcglobal:cbv:disp:in_progress</disposition>
    <readPoint>
        <!-- Plot 1 -->
        <id>urn:epc:id:sgln:5210162.00000.1</id>
    </readPoint>
    <bizLocation>
        <!-- Plot 1 -->
        <id>urn:epc:id:sgln:5210162.00000.1</id>
    </bizLocation>
```

```
    <fint:cultivationPractice xmlns:fint="http://epcis.f-in.io/epcis"
type="FERTILISER"/>
```

1.1.4 Harvesting event

The Harvesting event represents the harvesting of crops.

Table 8. Description of the harvesting event

Dimension	Data Element	Contents	Comments/ Example
Harvesting Event	Event Type	Object Event	
	Action	OBSERVE	
What	EPC List	A list containing the LGTIN of the crops	urn:epc:class:lgtin:5210162.00001.1
	quantityList	the amount of harvested crops	quantity: 500 uom: KGM
When	Event Time	Datetime when the harvesting took place	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the harvesting plot (location where the event took place)	urn:epc:id:sgln:5210162.00000.PLOT_1
	Business Location	SGLN of the harvesting plot (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00000.PLOT_1
Why	Business Step	http://epcis.f-in.io/bizstep/harvesting	Sector specific business step for the harvesting process
	Disposition	urn:epcglobal:cbv:disp:in_progress	
	fint:cropType	type of crops	OLIVES

In this use case, the fruits and vegetables share the same identifier as the crops they were harvested from. In addition to the LGTIN, the amount of harvested products is specified. The fint:cropType element holds additional information about the type of crops.

Figure 9. Example harvesting event

```
<ObjectEvent>
    <eventTime>2020-10-11T13:35:00.000+02:00</eventTime>
    <eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
    <epcList>
        <!-- Crop 1 (Cycle/Batch 1 for Olives) -->
        <epc>urn:epc:class:lgtin:5210162.00001.1</epc>
    </epcList>
    <action>OBSERVE</action>
    <bizStep>http://epcis.f-in.io/bizstep/harvesting</bizStep>
```

```xml
    <disposition>urn:epcglobal:cbv:disp:in_progress</disposition>
    <readPoint>
        <!-- Plot 1 -->
        <id>urn:epc:id:sgln:5210162.00000.1</id>
    </readPoint>
    <bizLocation>
        <!-- Plot 1 -->
        <id>urn:epc:id:sgln:5210162.00000.1</id>
    </bizLocation>
    <extention>
        <quantityList>
            <quantityElement>
                <epcClass>urn:epc:class:lgtin:5210162.00001.1</epcClass>
                <quantity>500</quantity>
                <uom>KGM</uom>
            </quantityElement>
        </quantityList>
    </extention>
    <fint:cropType xmlns:fint="http://epcis.f-in.io/epcis" type="OLIVES"/>
```

1.1.5 Shipping to warehouse event

The shipping to warehouse event tracks the movement of goods from the production farm to a warehouse.

Table 9. Description of the shipping event

Dimension	Data Element	Contents	Comments/ Example
Shipping Event	Event Type	Object Event	
	Action	OBSERVE	
What	EPC List	A list containing the LGTIN of the crops	urn:epc:class:lgtin:5210162.00001.1
When	Event Time	Datetime when the shipping took place	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the shipping location (location where the event took place)	urn:epc:id:sgln:5210162.00000.1
	Business Location	SGLN of the shipping location (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00000.1
Why	Business Step	urn:epcglobal:cbv:bizstep:shipping	CBV vocabulary
	Disposition	urn:epcglobal:cbv:disp:in_transit	
	fint:coords	coordinates of the destination location	lat="38.476748" lng="21.29863"

Shipping as a common process step is part of the CBV. This is the first event that does not need to use a domain-specific business case. The element fint:coords contains the geo-coordinates of the destination location, in this case, the warehouse.

Figure 10. Example shipping event

```xml
<ObjectEvent>
	<eventTime>2020-10-12T08:40:00.000+02:00</eventTime>
	<eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
	<epcList>
		<!-- Crop 1 (Cycle/Batch 1 for Olives) -->
		<epc>urn:epc:class:lgtin:5210162.00001.1</epc>
	</epcList>
	<action>OBSERVE</action>
	<bizStep>urn:epcglobal:cbv:bizstep:shipping</bizStep>
	<disposition>urn:epcglobal:cbv:disp:in_transit</disposition>
	<readPoint>
		<!-- Plot 1 -->
		<id>urn:epc:id:sgln:5210162.00000.1</id>
	</readPoint>
	<bizLocation>
		<!-- Plot 1 -->
		<id>urn:epc:id:sgln:5210162.00000.1</id>
	</bizLocation>
	<fint:coords xmlns:fint="http://epcis.f-in.io/epcis" lat="38.476748"
lng="21.29863"/>
```

1.1.6 Arriving at warehouse event

This event confirms the receiving of goods at the warehouse.

Table 10. Description of the receiving event

Dimension	Data Element	Contents	Comments/ Example
Arriving Event	Event Type	Object Event	
	Action	OBSERVE	
What	EPC List	A list containing the LGTIN of the crops	urn:epc:class:lgtin:5210162.00001.1
When	Event Time	Datetime when the receiving took place	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the receiving location (location where the event took place)	urn:epc:id:sgln:5210162.00010.0

	Business Location	SGLN of the receiving location (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00010.0
Why	Business Step	urn:epcglobal:cbv:bizstep:receiving	CBV vocabulary
	Disposition	urn:epcglobal:cbv:disp:in_progress	
	fint:coords	coordinates of the receiving location	lat="38.476748" lng="21.29863"

This event is a counterpart to the previous shipping event. The disposition of goods switches from in_transit back to in_progress, which is the default disposition for goods in logistical processes. The location of the goods is now set to the warehouse SGLN.

Figure 11. Example shipping event

```
<ObjectEvent>
	<eventTime>2020-10-12T08:40:00.000+02:00</eventTime>
	<eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
	<epcList>
		<!-- Crop 1 (Cycle/Batch 1 for Olives) -->
		<epc>urn:epc:class:lgtin:5210162.00001.1</epc>
	</epcList>
	<action>OBSERVE</action>
	<bizStep>urn:epcglobal:cbv:bizstep:receiving</bizStep>
	<disposition>urn:epcglobal:cbv:disp:active</disposition>
	<readPoint>
		<!-- Warehouse -->
		<id>urn:epc:id:sgln:5210162.00010.0</id>
	</readPoint>
	<bizLocation>
		<!-- Warehouse -->
		<id>urn:epc:id:sgln:5210162.00010.0</id>
	</bizLocation>
	<fint:coords xmlns:fint="http://epcis.f-in.io/epcis" lat="38.476748"
lng="21.29863"/>
```

1.1.7 Washing event

Washing represents the cleaning process of the goods.

Table 11. Description of the washing event

Dimension	Data Element	Contents	Comments/ Example
Washing Event	Event Type	Object Event	
	Action	OBSERVE	
What	EPC List	A list containing the LGTIN of the crops	urn:epc:class:lgtin:5210162.00001.1

When	Event Time	Datetime when the washing took place	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the washing location (location where the event took place)	urn:epc:id:sgln:5210162.00010.0
	Business Location	SGLN of the washing location (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00010.0
Why	Business Step	http://epcis.f-in.io/bizstep/washing	
	Disposition	urn:epcglobal:cbv:disp:in_progress	

Figure 12. Example washing event

```
<ObjectEvent>
	<eventTime>2020-10-12T11:10:00.000+02:00</eventTime>
	<eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
	<epcList>
		<!-- Crop 1 (Cycle/Batch 1 for Olives) -->
		<epc>urn:epc:class:lgtin:5210162.00001.1</epc>
	</epcList>
	<action>OBSERVE</action>
	<bizStep>http://epcis.f-in.io/bizstep/washing</bizStep>
	<disposition>urn:epcglobal:cbv:disp:in_progress</disposition>
	<readPoint>
		<!-- Warehouse -->
		<id>urn:epc:id:sgln:5210162.00010.0</id>
	</readPoint>
	<bizLocation>
		<!-- Warehouse -->
		<id>urn:epc:id:sgln:5210162.00010.0</id>
	</bizLocation>
```

1.1.8 Fermenting event

The fermentation takes place after the cleaning process.

Table 12. Description of the fermenting event

Dimension	Data Element	Contents	Comments/ Example
Fermenting Event	Event Type	Object Event	
	Action	OBSERVE	
What	EPC List	A list containing the LGTIN of the crops	urn:epc:class:lgtin:5210162.00001.1

When	Event Time	Datetime when the fermenting took place	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the fermenting location (location where the event took place)	urn:epc:id:sgln:5210162.00010.0
	Business Location	SGLN of the fermenting location (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00010.0
Why	Business Step	http://epcis.f-in.io/bizstep/fermenting	
	Disposition	urn:epcglobal:cbv:disp:in_progress	
	fint:fermenting	start and end time of the vermenting process	startTime="2020-10-12T13:000:00.000+02:00" endTime="2020-11-15T09:30:00.000+02:00"

In addition to the process depiction itself, the start and end time of the fermentation process is captured in the fint: fermenting element, as the duration of the fermentation has an impact on the product quality. In the next steps, FINT shall also provide additional IoT fermentation data relevant to the final product's quality and durability.

Figure 13. Example fermenting event

```
<ObjectEvent>
	<eventTime>2020-11-15T09:30:00.000+02:00</eventTime>
	<eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
	<epcList>
		<!-- Crop 1 (Cycle/Batch 1 for Olives) -->
		<epc>urn:epc:id:lgtin:5210162.00001.1</epc>
	</epcList>
	<action>OBSERVE</action>
	<bizStep>http://epcis.f-in.io/bizstep/fermenting</bizStep>
	<disposition>urn:epcglobal:cbv:disp:in_progress</disposition>
	<readPoint>
		<!-- Warehouse -->
		<id>urn:epc:id:sgln:5210162.00010.0</id>
	</readPoint>
	<bizLocation>
		<!-- Warehouse -->
		<id>urn:epc:id:sgln:5210162.00010.0</id>
	</bizLocation>
	<fint:fermenting xmlns:fint="http://epcis.f-in.io/epcis"
				startTime="2020-10-12T13:000:00.000+02:00"
				endTime="2020-11-15T09:30:00.000+02:00"/>
```

1.1.9 Shipping to packaging house event

Shipping to a packaging house and shipping to a warehouse are depicted identically, only with different SGLNs representing the different locations.

1.1.10 Arriving at packaging house event

Arriving at a packaging house and arriving at a warehouse are depicted identically, only with different SGLNs representing the different locations.

1.1.11 End processing event

During the final processing, the goods are packed, and the result is end consumer trade items.

Table 13. . Description of the processing event

Dimension	Data Element	Contents	Comments/ Example
Production Event	Event Type	Transformation Event	
	Action	OBSERVE	
What	Input EPC List	A list containing the LGTIN of the crops	urn:epc:class:lgtin:5210162.00001.1
	Output EPC List	A list containing the LGTIN of the final products, including quantity	urn:epc:id:lgtin:5210162.00002.1 quantity=100
When	Event Time	Datetime when the production took place	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the production location (location where the event took place)	urn:epc:id:sgln:5210162.00020.0
	Business Location	SGLN of the production location (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00020.0
Why	Business Step	urn:epcglobal:cbv:bizstep:creating_class_instance	CBV vocabulary
	Disposition	urn:epcglobal:cbv:disp:active	

Processing is a Transformation Event. In contrast to Object Events, the items of the what dimension are not just observed but also processed to another type of output. In the example, loose olives are turned into end-consumer products, and the end consumer products receive a new LGTIN identifier. The input and output identifiers in this transformation event create a link between the different types of goods so that even for the trade items, all information captured for the raw olives is fully traceable.

Figure 14. Example processing event

```
<TransformationEvent>
	<eventTime>2020-10-16T08:05:00.000+02:00</eventTime>
	<eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
	<inputEPCList>
		<!-- Crop 1 (Cycle/Batch 1 for Olives) -->
		<epc>urn:epc:class:lgtin:5210162.00001.1</epc>
	</inputEPCList>
	<outputEPCList>
		<!-- Final Product (Batch 1) -->
		<epc>urn:epc:class:lgtin:5210162.00002.1</epc>
	</outputEPCList>
	<outputQuantityList>
		<quantityElement>
			<epcClass>urn:epc:class:lgtin:5210162.00002.1</epcClass>
			<quantity>100</quantity>
		</quantityElement>
	</outputQuantityList>
	<bizStep>urn:epcglobal:cbv:bizstep:creating_class_instance</bizStep>
	<disposition>urn:epcglobal:cbv:disp:active</disposition>
	<readPoint>
		<!-- Packaging House-->
		<id>urn:epc:id:sgln:5210162.00020.0</id>
	</readPoint>
	<bizLocation>
		<!-- Packaging House-->
		<id>urn:epc:id:sgln:5210162.00020.0</id>
	</bizLocation>
```

1.1.12 Shipping to retail shop event

Shipping to a retailer and shipping to a warehouse are depicted identically, only with different SGLNs representing the different locations.

1.1.13 Arriving at retail shop event

Arriving at a retailer and arriving at a warehouse are depicted identically, only with different SGLNs representing the different locations.

1.1.14 Selling end product event

The final event in this business event model depicts the selling of goods by a retailer to a customer.

Table 14. Description of the selling event

Dimension	Data Element	Contents	Comments/ Example
Selling Event	Event Type	Object Event	
	Action	OBSERVE	
What	EPC List	A list containing the LGTIN of the product	urn:epc:class:lgtin:5210162.00001.1
When	Event Time	Datetime when the selling took place	2020-01-01T02:00:00.000+02:00
	Event Time Zone Offset	Time zone where the event took place	+02:00
Where	Read Point	SGLN of the selling location (location where the event took place)	urn:epc:id:sgln:5210162.00030.0
	Business Location	SGLN of the selling location (Location where the objects are imediately after the event)	urn:epc:id:sgln:5210162.00030.0
Why	Business Step	urn:epcglobal:cbv:bizstep:retail_selling	CBV vocabulary
	Disposition	urn:epcglobal:cbv:disp:retail_sold	

With this event, the tracing of goods ends.

Figure 15. Example selling event

```
<ObjectEvent>
	<eventTime>2020-10-15T14:15:00.000+02:00</eventTime>
	<eventTimeZoneOffset>+02:00</eventTimeZoneOffset>
	<epcList>
		<!-- Final Product (Cycle/Batch 1) -->
		<epc>urn:epc:class:lgtin:5210162.00002.1</epc>
	</epcList>
	<action>OBSERVE</action>
	<bizStep>urn:epcglobal:cbv:bizstep:retail_selling</bizStep>
	<disposition>urn:epcglobal:cbv:disp:retail_sold</disposition>
	<readPoint>
		<!-- Retail Shop-->
		<id>urn:epc:id:sgln:5210162.00030.0</id>
	</readPoint>
	<bizLocation>
		<!-- Retail Shop-->
		<id>urn:epc:id:sgln:5210162.00030.0</id>
	</bizLocation>
```