A Food Value Chain Integrated Business Process and Domain Models for Product Traceability and Quality Monitoring: Pattern Models for Food Traceability Platforms

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Abstract: Traceability of product lots in perishable products' value chains, such as food products, is driven by increasing quality demands and customers' awareness. Products' traceability is related to the geographical origin and location of products and their transport and storage conditions. These properties must be continuosly measured and monitored, enabling products' lots traceability concerning location and quality throughout the value chain. This paper proposes pattern integrated business-process and domain models for food product lots traceability in the inter-organizational space inside a food value chain, allowing organizations to exchange information about the quality and location of product lots, from their production and first sale until the sale to the final customer, passing through the transportation, storage, transformation and sale of each lot. The paper also presents the process followed for obtaining these two pattern models. Three exploratory case studies are used, towards the end of the paper, for validating the proposed business-process and domain pattern models.

1 INTRODUCTION

Consumers have a growing interest in knowing everything about the products they consume, and have more trust in brands that have a tight control of their products' quality. They also want to know the origin of the products they are buying or eating, and where, how and in what conditions products are transported and stored. In what concerns fresh products, however, it may not be easy to know the quality or origin of what they are buying. Collecting quality control and traceability data from all steps of a fresh foods value chain, from product's harvesting (capture, creation) is a complex task involving many business partners.

Organizations in a particular value chain exchange products, documents, and information that allow them to add value to the products they buy before transforming and/or selling them to the next link in the value chain. Internationalization and digital transformation demand from a value chain's operators an increasing interconnectivity and integration. Additionally, in perishable products' value chains, such as food (e.g. fishery, meat, milk and dairy, fruits) or pharmaceutical products, increasing quality demands and customers' awareness entails knowing the geographical origin of products and that products location and their transport and storage conditions are continuosly measured and monitored. While the geographical origin is most important for fresh or transformed agricultural, dairy products, etc., especially when talking about products with protected designation of origin, transport and storage conditions are important both for perishable food products, and for other products that bear a validity date, including pharmaceutical products. Products' lots localization is also very important, especially when public health may be at stake (remember the cases of mad cow disease or african swine fever) and products' lots must be recalled.

The increasing interconnectivity of a value chain's operating organizations demands better integration of their processes, either by allowing business partners to interact with the systems that support the processes through an external business partners user interface (Cruz and da Cruz, 2018), or by directly integrating the companies processes and systems that create product information and enable the exchange of information. The supply-chain oriented business-to-business (B2B) systems' integration, aiming the interchange of information and documents about trading, payments, etc. is thoroughly covered by the state of the art.

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These B2B oriented integration solutions are not suitable for traceability and quality monitoring purposes, though, because of the following reasons:

- Information about products localisation is not typically maintained in any of the value chain's operators systems. This makes impossible for companies to be sure about the origin of a product, and impedes the knowledge of the locations to where a lot has been splited and distributed, when lot retrieval from market (lot recall) is needed.
- Products quality information is registered in each value chain operator (typically handwritten on a notebook), but is never shared among business partners. This makes impossible for a company to be sure that the products it received under apparently acceptable environmental conditions, have not been subjected to product spoiling or deterioration conditions at any point in the value chain.

Food traceability is of utmost importance, namelly as it allows to avoid forgeries, by assuring the origin of a product, especially when talking about products with protected designation of origin; and, it enables to recall products' lots, because of food contamination or other threats to the public health. Food traceability requires a common value chain's platform that enables sharing information about products and their agreed quality parameters along the value chain.

In these cases, traceability information will enable identifying the origin of each product lot and all the geographical location points where it has passed, along with information about the packaging, transport and storing conditions (e.g. temperature, humidity), and about the observed quality of the product at each point. This grants greater security to consumers.

The main contribution of this paper is the presentation of a pattern business process model for perishable products value chains, and the corresponding domain entities model. These models fill the gap space that lies between operators in a value chain.

The structure of presentation is as follows: In the next section, related work is presented. In section 3, a value chain's integrated business process model is presented as a pattern for perishable products value chains. Section 4 presents the corresponding pattern domain model. Section 5 arguments towards validation of the results obtained and section 6 concludes the paper and discusses directions for future work.

2 RELATED WORK

In 2002, the European Union created a directive regarding the traceability in food sector, assuring information flow transparency and traceability (Regulation (EC) No 178/2002). This directive defines a set of principles, requirements and procedures in matters of food and feed safety, covering all stages of food and feed production and distribution (UNION, 2002). Since then several authors proposed frameworks to support the traceability in feed and food value chains.

ISO 22000 series on food management systems also addresses the safety of food products. ISO 22005:2007 Traceability in the feed and food chain General principles and basic requirements for system design and implementation, is the most recent series of food safety standards. ISO 22005:2007 gives the principles and specifies the basic requirements for the design and implementation of a feed and food traceability system (22005:2007, 2007).

In (Regattieri et al., 2007) the authors propose a platform to support the traceability of the famous Italian cheese Parmigiano Reggiano from the bovine farm to the final consumer. The framework supports the identification of the characteristics of the product in its different aspects along the value chain: bovine farm, dairy, seasoning warehouse and packaging factory. The system developed is based on a central database that collects data in all identified steps in the food chain. Some of the information is automatically collected by using sensors, bar codes, etc. Other information is collected manually.

In (Ioannis Manikas, 2009) the authors present the first step in a project to design and create a Web platform to support food traceability for dairy products. The first phase of the project includes the design of a reference model for a generic dairy supply chain. The authors identified three main phases in a supply chain, namely natural environment, transformation and distribution. The authors also identify the main entities involved (actor, container, material and sample) and present a class diagram for each entity.

Folinas et al. propose a web application for modeling agricultural processes and data. The proposed application highlights the collaborative effort in modeling and integration of logistics processes assuring that all business partners have access and share information (Folinas et al., 2003). For that, they define standards and specify the exchanged information.

Dabbene and Gay present new methods for measuring and optimizing the performance and cost of traceability systems by using graphs. A food production process is seen as a sequence of storage/carrying actions and of unit operations. A unit operation represents a product at a time. Each container/processing-unit that individually stores/processes a product, at a certain time, is modeled as a node in a graph (Dabbene and Gay, 2011).

Palma-Mendoza and Neailey proposed an approach to integrate the business processes of the entities involved in a supply chain. The main aim is to guide the business process redesign to support e-business, thus focusing supply chain B2B integration and not a value chain oriented organizational collaboration (Palma-Mendoza and Neailey, 2015).

Bevilacqua *et al.* propose a business process reengineering for a supply chain of vegetable products (fresh vegetables, canned vegetables, mixed vegetables, cooked and pre-cooked vegetables) (Bevilacqua et al., 2009). They also suggest software system design models for managing product traceability. The authors present a framework based on EPCs (event-driven process chains) and use ARIS tool to create a Web interface to provide information to the final consumer (Bevilacqua et al., 2009).

Meroni *et al.* propose an approach to integrate and coordinate multi-party business processes and present a prototype to demonstrate the proposed approach (Meroni et al., 2018). The paper presents a methodology to translate BPMN processes to E-GSM (Extended-Guard-Stage-Milestone) notation.

All the mentioned approaches propose specific solutions for specific problems, and only a few present specific business process or domain models. Here, a pattern solution is proposed for any food value chain traceability problem, namely a pattern business process model and the associated pattern domain model.

3 MODELING THE INTEGRATED BUSINESS PROCESS

This section presents the creation of the integrated business process model for traceability and quality monitoring of food products.

After having visited several producers, small farmers' associations, food processing industries, distributors, and supermarkets, and having participated in the identification and design of several food chain operators' product traceability processes, of which two are presented here, the similarity of different food value chains, in terms of activities needed to address traceability and quality monitoring, became apparent.

The approach consisted in eliciting and analyzing a set of productive business process models from different food value chains' operators (milk and dairy, fruit, fisheries, vegetables), understand their occurring order in the chain and integrate them, to obtain a pattern business process model for traceability and quality monitoring in food value chains.

To model business processes we are using BPMN (Business Process Model and Notation), which is the main standard process modeling language and one of the most used for that purpose (Cruz et al., 2014). Created by OMG for providing a notation clear to all stakeholders involved in Business Process Management (BPM), BPMN is easy to understand and usable by people with different roles and training from top managers to IT professionals (OMG, 2011), and is actually used both in academia and in organizations.

Business Process (BP) model diagrams define a set of business activities carried out by an organization for the attainment of a goal (product or service). This type of model describes a BP internal to a specific organization(OMG, 2011). Yet, in this paper, we do not use BPMN in the "usual" form. In fact, the BPMN business process model is being used as a simple and easy way to understand and identify all the activities that affect a product lot (or batch). So, in this paper, the main lane (in the main pool) does not represent nor a company neither a business partner. Instead, it represents a product lot. So, business processes are used here to focus our attention in the activities that involve, or affect, a products lot and about which a traceability platform needs to receive and store information. External participants, in the models, represent the value chain operators responsible for providing information about the activity with which they are exchanging messages. These messages represent the information that a participant needs to provide. The activities are, in fact, executed by the participants, represented as external participants sending messages to the corresponding value chain activity.

The traceability platform's main goal is to gather and store all the relevant information from value chain activities, to be able to identify: what was done; who did it; when it was done; where it was done; under what conditions it was executed. Thus, all operators involved in the value chain must be identified.

For this presentation, and due to space limitations, we have selected two different flows of activities in food value chains. The next subsections present two value chain business process models, respectivelly about fresh vegetables, in subsection 3.1, and freeze-dried apples, in subsection 3.2. Finally, subsection 3.3 presents a process model integrating all food value chain's activities, not just from the two cases presented, but also from case studies from other food value chains (e.g. fishery, meat, aquaculture, dairy).

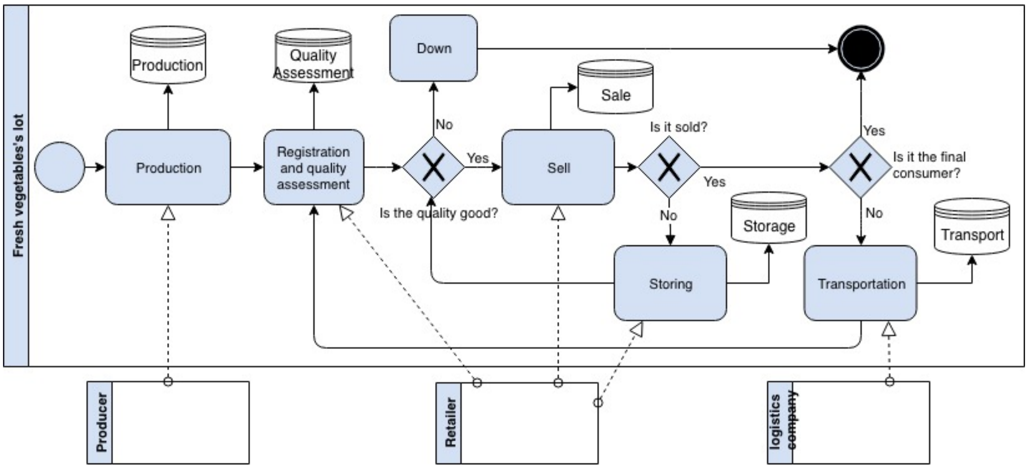

Figure 1: Value chain process for fresh vegetables.

3.1 Fresh Vegetables

Fresh vegetables, like fresh sardines, fresh milk or other fresh food products, have several conditioning factors for transport and storage. The fresh vegetables BP model is represented in Figure 1. In a value chain of fresh vegetables, major producers, typically owning their own brand, register and control the information about harvesting (activity *Production* in the Figure 1), and assess, control and register the products quality (*Registration and Quality Assessment*) before selling them (*Sell*) to retailers. In these cases, the producers are responsible for providing all that information. Smaller producers, typically deliver their products in an agricultural cooperative or producers' association, which is responsible for registering information about producers, products, and quality assessment, and to sell products to retailers.

After being sold, products' lots are usually transported to other sites. The information about who transports and under what conditions the product is transported must be stored. This information may be provided by the transporter itself, but typically it is the operator who receives the product that evaluates the products' lots quality conditions after the transport.

When products' lots are received by a new owner, this registers and assesses the products' quality, before storing, transforming, or selling them. If, anytime, a product's lot quality is not acceptable, that lot is downed. Information about storage conditions (dates, cleaning conditions, temperature, etc.) must also be registered. Products sold to the final customer end their path through the value chain.

3.2 Freeze-dried Apples

Freeze-drying is a form of drying that removes all moisture with almost no effect on a food's taste. In freeze-drying, food is frozen and placed in a strong vacuum. The water in the food then sublimates. This example deals with freeze-dried apples. The process begins in the orchard in the production of apples (see Figure 2). Once again, there are big and small producers. Major producers negotiate directly with industry, while smaller ones deliver their products in associations or farmers cooperatives, responsible for controlling the quality and negotiating with industry. After being sold, the apples are transported. The conditions under which they are transported are always checked. In any case, whenever apples arrive in the freeze-dried factory plants, apple lots are received and registered, and the quality is checked again before being submitted to the transformation. A set of activities are executed to obtain the final product. First the apples are washed, then are sliced and freeze-dried, then pass through vacuum and finally are packed. After packaging, packet lots of sliced freeze-dried apples are stored and wait their turn to be sold.

For enabling traceability, it must be possible to know which new lots of freeze-dried apples came from which previous lots of fresh apples. In other words, lots of fresh apples may be transformed into one or more lots of freeze-dried apples. In fact, a given lot may be partially sold for a retailer, and partially sold for a restaurant, and even partially sold for being transformed. And industrial transformation processes, such as freeze-drying apples, will create lots of products from previous lots of fresh apples.

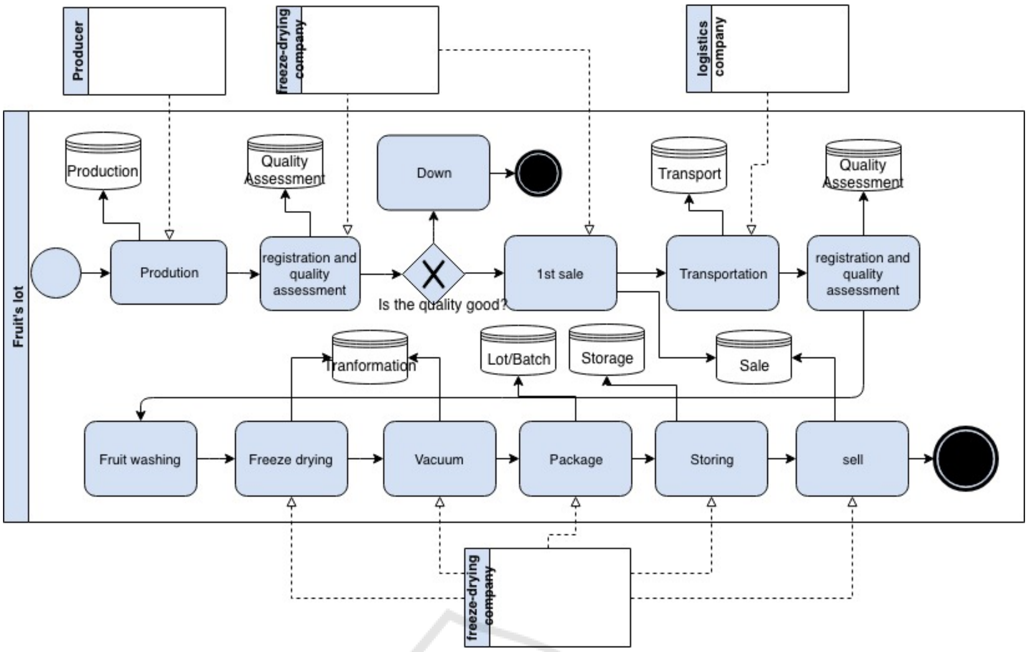

Figure 2: Value chain process for freeze-dried apples.

3.3 Food Value Chain's Integrated Process

The model of a BP at value chain level, represented in Figure 3, serves as a pattern for representing any food value chain inter-organizational collaboration space, for enabling the traceability and quality monitoring of products. In this BP model, six main activities have been identified: *Production, Registration and Quality Assessment, Sell, Store, Transportation* and *Transformation*. Additionally, there is activity *Down*, which is executed if the product lot is spoiled or deteriorated, or its validity date is expired.

With the exception of the *Production* and *Down* activites, which may only happen once per each product lot, every other activity may happen several times in the product lot lifespan.

The value chain starts in the producer, where information about production (fishing, harvesting, fruit picking, etc.) must be gathered. This information may be provided by the producer itself (major producers) or by associations of producers or agricultural cooperatives for small producers. Products are, then, registered and have their quality assessed.

As we may see in the process represented in Figure 3, after the registration and quality assessment, a product lot may be sold or stored or transformed. After each of these activities, the product lot is received and its quality assessed. It may stay within this iteration of activities during some time.

When a product lot is subjected to various processing stages, the quality is verified at the end of each stage (transformation task). The quality of the product is assessed every time the product suffers a transformation, a storage or a transportation. Some of those times new lots are created and registered (as is the case of transformation). Usually, after being stored, a lot of product is sold. And, after being sold, if the buyer is the final consumer, the process ends, otherwise the product may be transported to the purchasing organization, and that event must be registered for tracing purposes.

Transformation processes, together with the identified fresh products value chain's activities, are represented in the Food Value Chain Integrated Business Process for product traceability and quality monitoring (see Figure 3). This comprises the value chain activities (corresponding to value chain operators' business processes) of both the fresh products and the transformed products. Note that, despite each value chain activity corresponds to a business process in the value chain operator that is responsible for it, in the interorganizational traceability business process model, in Figure 3, each activity refers to the gathering of information from the process with the same name. It is this information, gathered in a common shared integration platform, that will enable products traceability and quality monitoring along the full value chain path of each product lot.

Despite the traceability and quality data being directly persisted in the interorganizational space in the

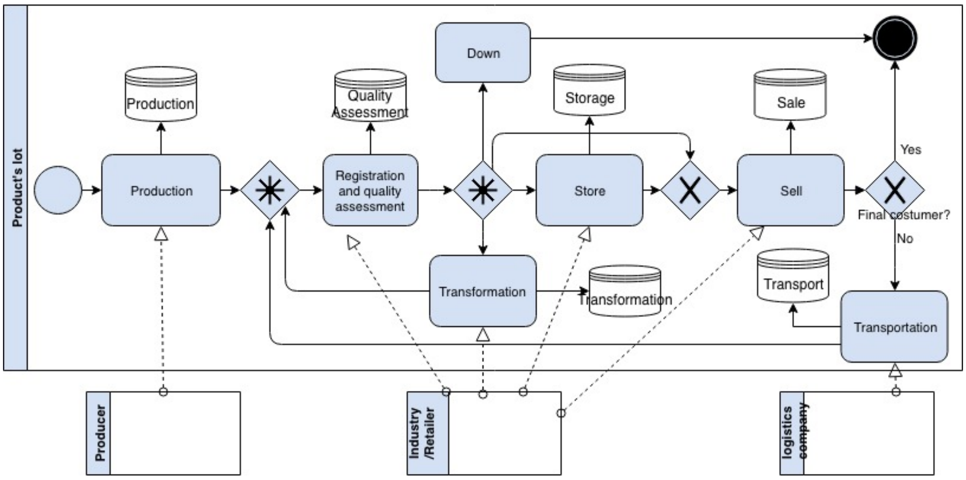

Figure 3: Value chain integrated process model.

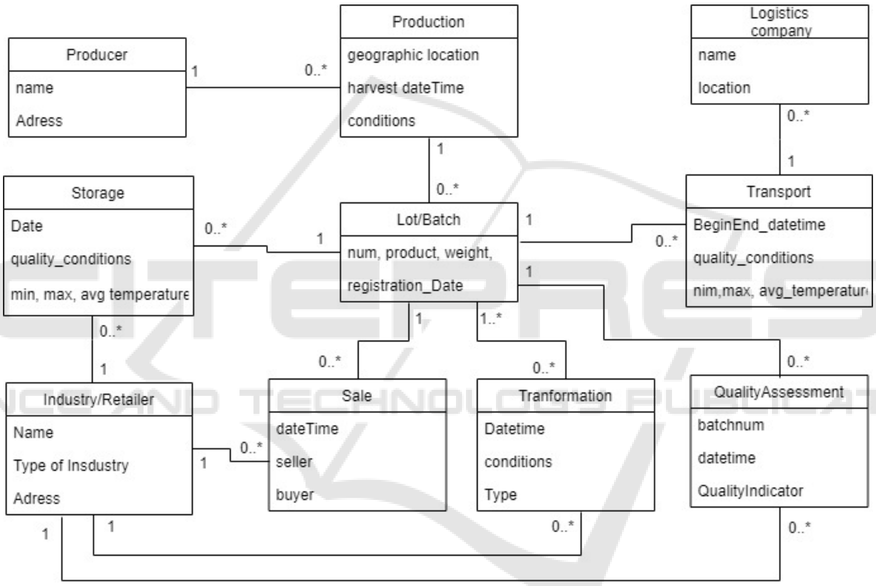

Figure 4: Derived domain model.

value chain, the data itself must be communicated by the involved chain operator's relevant process. Thus, each activity can be seen as a value chain event.

4 DOMAIN ENTITIES MODEL

This section presents the domain model to support the integrated process for traceability and quality monitoring in food value chains. In the next subsection, we apply the approach presented in (Cruz et al., 2012; Cruz et al., 2015) to derive a default domain model from the integrated business process model presented in subsection 3.3. Then, in subsection 4.2 we refine the domain model to obtain a pattern domain model that supports integrated platforms for traceability and quality monitoring in food value chains.

4.1 Deriving the "Default" Domain Model

In (Cruz et al., 2015) an approach has been presented, to derive a domain (data) model by aggregating all the information about persistent data that can be extracted from business process models. In summary, in that approach (Cruz et al., 2012; Cruz et al., 2015):

- A participant in the business process model gives origin to an entity in the domain model;
- A data store also gives origin to an entity;

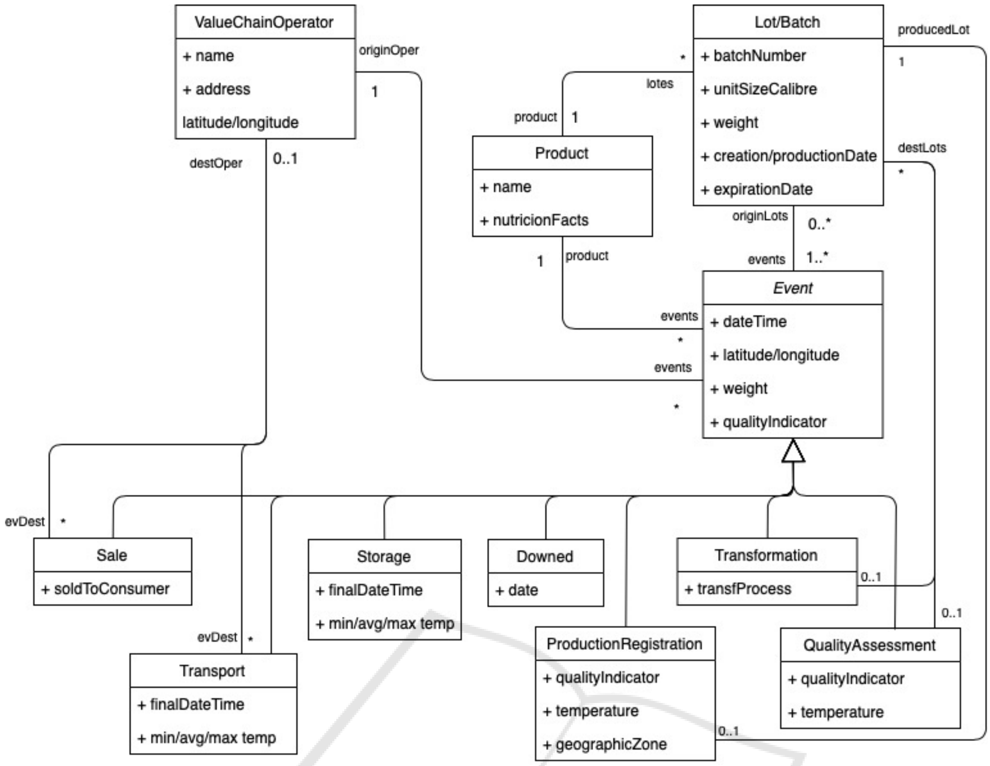

Figure 5: Refined domain entities model.

- The relation between entities is derived from the information exchanged between participants and the activities that operate the data stores, and from the information that flows through the process.
- The entity that represents the participant represented by the main lane (pool) is related with all entities in which information is stored (represented as data stores).
- Entities representing external participants that send messages to activities that store information in a data store are related with the entity that represents that data store.

By applying the approach presented in (Cruz et al., 2012; Cruz et al., 2015) to the final integration business process model (represented in Figure 3) we obtain the domain model presented in Figure 4. In this derived domain model, the entity Lot/Batch is derived from the main lane (Products lot), after renaming. The entities Producer, Industry/Retailer, Logistics Company are derived from the external participants with the same name. The entities Production, Quality Assessment, Sale, Lot, Storage, Transport and Transformation are derived from the data stores with the same name.

Messages sent by external participants to the activities represented in the main lane, represent the information received by the activity that needs to be stored (represented by the data store). This way, in the domain model, the entity that represents the data store is related with the entity that represents the external participant that sends the message (Cruz et al., 2012; Cruz et al., 2015). Following this approach:

- A Producer, responsible for a Production, sends a message to the activity that stores Production information, so entities Producer and Production are related. The Producer may execute this process several times so the relation is one to many.
- Store, Sell and Transformation are responsibility of Industry/Retailers;
- Transport information is sent by the logistics company (or by the truck or driver), so entities Transport and Logistics Company are related.
- Both logistics companies and Industry (tranformation companies, such as canning industries) send information about quality assessment, storage and sales, so entities Logistics Company and Industry are related with all those entities.
- Entities *Production, Transport, Storage, Sale, Transformation* and *Quality Assessment* are related with entity *Lot/Batch* because the activities that store information in the corresponding data stores are executed inside the main lane (in the main pool) and according to (Cruz et al., 2012;

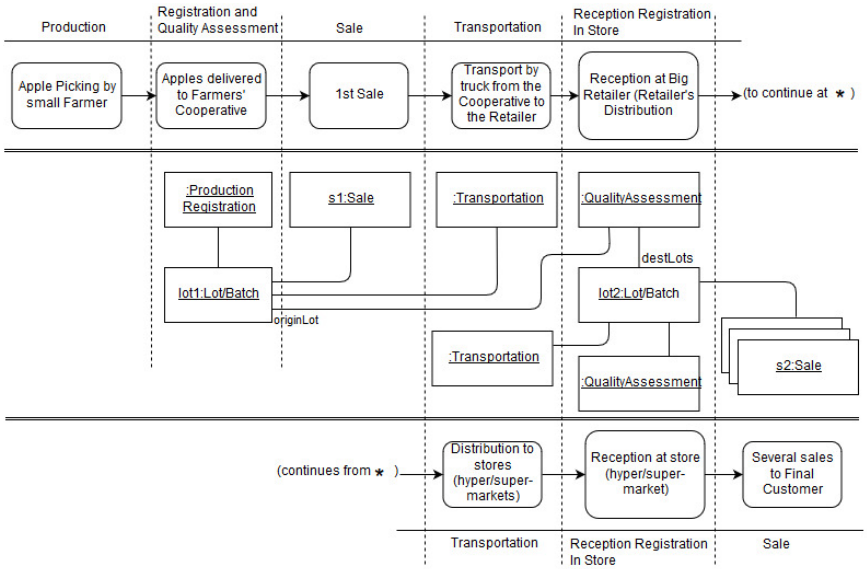

Figure 6: Fresh Apples from Small Farmer to Big Retailer.

Cruz et al., 2015), when a participant is responsible for an activity that writes information in a data store, the entity that represents the participant must be related with the entity that represents the data store.

The information about transport, quality assessment, sale and transformation may be stored any number of times and the information may be provided by different value chain operators.

The next section refines this model for a better object-oriented structuring, and with reusability in mind.

4.2 Refining the Domain Model

The derived domain model (Figure 4) is a default model that may be now used for refinement into a complete and fully understandable object-oriented domain model. This section illustrates the refinement of the derived model.

First, let's remember that:

1. *Producer*, *Industry*, *Retailer* and *Logistics Company* are all **Value Chain Operators**;
2. *Production*, *Quality Assessment*, *Sale*, *Storage*, *Transport* and *Transformation* are **Value Chain Events** (that gather traceability and quality information about product Lots);
3. Small producers do not register their production. Only when delivered to a farmers association or cooperative the production is wheighed and the product lot is registered.
4. When receiving fresh products, some value chain operators wheight and assess the quality of received products and create/register a new product batch, with a new reference or Lot number. This new lot reference must be associated to the previous lot reference, for traceability.
5. After a transformation process, new lots of products may be created, referring to the new transformed product.
6. Lots are allways about a product. E.g.: Lot of fresh sardines, canned sardines, frozen sardines.

From item 1, above, in the refined Domain Model (Figure 5) we can then find a *ValueChainOperator* entity, which is an abstract class representing any value chain operator: *Producer*, *Industry*, *Retailer* and *Logistics Company*. These are then subclasses of *ValueChainOperator* (not represented in the diagram). We have, also, from item 2, an *Event* entity, which is an abstract class representing any event about Lots in the value chain. By value chain event, we mean any activity that leaves a trail of information on the platform. Namely, *Production*, *Quality Assessment*, *Sale*, *Storage*, *Transport* and *Transformation*, which are represented as subclasses of *Event*.

In the figure, *originLots* represents the lots that are associated to the event. A *ProductRegistration* is where a value chain operator (a *Producer*, which, by 3 may be a major producer or a producers' association) typically creates a new Product Lot. It doesn't have an origin lot, having a *producedLot* instead. Additionally, there are events that may imply the creation of new lots from previous ones, namelly *Transformation* (from item 5, above) and

QualityAssessment (from item 4). These events may be associated to the set of newly created lots (*destLots*). In the refined diagram (Figure 5), the many-to-many relation between *Lot/Batch* and *Transformation*, from the diagram in Figure 4, has given place to a many-to-many relation from *Lot/Batch* to *Event* (a lot may have many events; and, an event may have many original lots), and a one-to-many from *Transformation* to *Lot/Batch* (a transformation may create several new product lots). Event *QualityAssessment* has been given the same lot association properties as *Transformation*. All other events have one and only one original Lot.

A product lot is always about a product (see item 6 above, and entity *Product* in the refined diagram).

A Lot's *Sale* or *Transportation* may be associated to a destination value chain operator (*destOper*). A Lot may yet be stored (event *Storage*) during an amout of time or it may be shut down (*Downed*) if it is deteriorated or its validity date has been reached.

The diagram in Figure 5 presents only the main attributes of each entity class. The real appropriate attributes depend from case to case, from which products' lots properties are being monitored and traced in each case. The next section presents three case studies for validating the presented business process and domain models.

5 VALIDATION

In this section we validate our resulting models through three exploratory case studies. Figures in this section are organized into three lines where, the first line contains the events that happen, from the value chain integrated process. The second line explains the case study situation from the point of view of each operator. And, the third line shows an object diagram with objects created by the traceability platform, when the events happen.

Fresh Apples from Small Farmer to Small Retailer. In the first case, a small farmer produces apples and delivers them to a farmers' cooperative. The cooperative, then, registers the production lot, assesses the products quality and packs the apples for being sold and transported to retailers. After being received at small retailers' stores, they put the apples ready for sale. For reasons of space and simplicity of the case, there is no figure for this situation. Here, the original Lot makes its way until the final consumer. At any point, it is possible to know the information about the lot and all of its events, as long as the lot's packages at the several retailers bear the lot reference or number, because all the events are linked to the original lot.

Fresh Apples from Small Farmer to Big Retailer. Figure 6 shows a similar case, but having the apples' lot sold to big retailers. These, typically create lots in their ERP system, when ordering products from the suppliers. And then, when receiving the supplied lots, they re-assign them to the lots they had created before. In this case, then, when being received by the retailer, the traceability platform instantiates class *QualityAssessment* which allows to create a new lot, enabling to trace between the original lot and the newly created lot. After this event, all subsequent value chain events must refer to this new lot.

In this case, it is possible to know the information about the last lot and all of its events because all the events are linked to that lot. As events have a timestamp (*dateTime*), it is also possible to order the events of the last lot and see that it has been created in a *QualityAssessment* event associated to another original lot, and, from there, trace all the information about the original lot.

Fresh Apples from Small Farmer to Freeze-drying Industry. In Figure 7, the situation depicted refers to when fresh products are sold to industries for being transformed. After the first sale, products are transported to a factory and their quality is assessed and registered in the object instance of *QualityAssessment*. Then, after being submitted to the industrial process, the resulting lot is registered and has its quality assessed. This creates an instance of *Transformation*, which alows to associate the resulting lot to the previous lot of the original fresh product. In this case, the resulting lot will refer to a new product (freeze-dried apples, not fresh apples). In this case it is possible to trace back to the original lot, from the reference of the last created lot.

6 CONCLUSIONS

For coping with the growing need of food products traceability and quality monitoring, this paper presents a pattern business process model and a corresponding pattern domain model derived from a set of situations observed in food value chains. In the proposed food value chain business process model, seven activities have been identified. These activities correspond to events in the value chain where information must be delivered for an integrated traceability platform, which lies in the space between value chain operators. This information enables to know when, where and how each product lot has been treated and who participated in the process.

The proposed domain model has been obtained

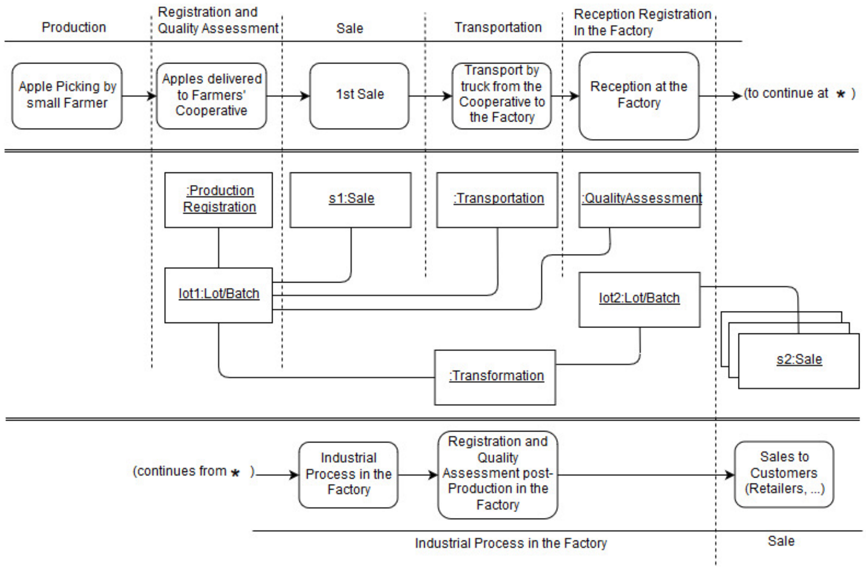

Figure 7: Fresh Apples from Small Farmer to Freeze-drying Industry.

from the pattern BP model in two steps. First, a default domain model has been derived from the pattern BP model by using the approach presented in (Cruz et al., 2012; Cruz et al., 2015). Then, the derived domain model has been refined for improving model structure and reusability.

Three case studies have been presented to illustrate the approach. The two pattern models may now serve as template models for designing traceability platforms for food value chains. The entities' attributes, in the domain model (Figure 5), are not complete. Their completion depends on the information that needs to be monitored and traced, in each real case traceability scenario.

The models obtained in this work are being used and adapted to a fishery products value chain, for quality monitoring and traceability. Future work will also apply these to other products value chains.

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