Modeling of an Agro-Food Traceability System: The Case of the Frozen Vegetables

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Abstract

In the last years traceability has become a critical part of the agro-food industry. The aim of the agro-food traceability is to allow the full monitoring of a product in the food chain and to trace the history of a good from the producer to the consumer. It is therefore a preventive instrument of quality and safety management. In this paper a new method for the traceability of frozen vegetables is proposed where the supply chain was initially modeled according to the BPMN standard. The first part of the paper identifies the internal points of data acquisition used along the supply chain and the information to record in each point. The data have been classified for internal and external traceability of a product and a general data model has been generated. The data model has been integrated with a flow chart model in order to generate the Web application model. Each actor stores the data of the product handled and collaborates with other operators of the chain by making available all information necessary for traceability. The front-end generated helps the user in navigating and, subsequently, in the data management. The data modeling and management approach is achieved through the creation of a web based system.

Keywords
Food Supply Chain, Tracking and Tracing, BPMN, ER model, Web Application, Information System

1. Introduction
In recent years the traceability of food products has attracted the attention of many researchers for several reasons (Jansen-Vullers et al, 2003): first traceability, according to the Regulation of the European Community N. 178/2002, has become a legal requirement within the European Union from January 1, 2005; secondly, food companies tend to view traceability as a strategic tool needed to increase consumer confidence and improve the both image of the company and of a specific product. The traceability systems ensure the monitoring of the whole Supply Chain (SC) and assure the observation of two primary functions, tracking and tracing. Tracking refers to the ability to trace a product through the supply chain, from upstream to downstream, recording data in each production stage. Tracing is the reverse process of tracking: through the tracing systems it is possible to identify the source of a food or group of ingredients through the information recorded upstream in the SC (Schwagele, 2005).

From a regulatory viewpoint, traceability is a requirement limited to ensure the ability for businesses to identify at least the direct supplier of a product as well as the immediate client, with the exemption for retailers (European Commission, 2002, 2004). Notwithstanding, other requirements should be satisfied to ensure food security and to improve food quality (Food Standards Agency of United Kingdom, 2002). Additional information should be collected in each stage of the SC to ensure the availability of data for the production analysis and optimization (Thompson et al., 2005). The optimization of the entire SC requires a high level of information sharing, cooperation and collaboration among the participating companies (Horvarth, 2001). All trading partners in the SC must guarantee both the internal and external, or well known SC, traceability. This result can be conveniently achieved if each company in the SC provides with an internal system for information registration and control and the transactions between actors involved are regulated in a coherent and shared

form. (De Cindio et al., 2011a). If one of the partners in the chain can not handle these connections upstream or downstream, the resultant pattern is known as "loss of traceability" (Regattieri et al., 2007).

In this paper the information is proposed to be stored in a web server. Each actor records data of products and processes and collaborated with other operators in the industry by making available all the information necessary for traceability. The modeling and data management approach is achieved through the creation of a web based system. The web based systems are the most flexible way to ensure easy access to information through the creation of collaborative environments for data processing, archiving and transmission. The application model generated integrates the business process model with the data model and creates a front-end displayed in a Web browser that enables the retrieval of information using the Web.

This paper is structured as follows. Section 2 describes the food chain traceability and presents a brief review of the state of the art about systems developed to guarantee traceability. Section 3 presents a new system for traceability of frozen vegetables. The SC has been previously modeled according to the BPMN standard to create a flowchart model of the system. Then, data required for traceability have been classified according to their relevance to answer the internal or external traceability The data model has been created following the Entity-Relationship (E-R) diagram (Hoffert et al., 2006). The integration of the flowchart with the data model has led, thus, to the generation of a web application. All data were stored on a web server and made accessible via Internet. Section 4 describes the followed methodology and finally Conclusion is discussed.

2. Traceability in the Food Sector

This section deals with problems connected with the implementation of a traceability system in the food supply chain and summarizes results of the literature review on food traceability systems in order to provide some background.

2.1 Food Chain traceability

Food chain traceability refers to “the ability to follow a food component intended to be, or expected to be into a food product through all stages of food supply chain” (European Commission, 2002).

The definition and implementation of a food traceability system depends on both the SC and the relationships between the various partners which collaborate in the production process. Manufacturers, distributors, authorities and consumers should be able to track and identify food and raw materials used for food production to comply with legislation and to meet the requirements of food safety and food quality (Ruiz-Garcia et al., 2010). This result can be conveniently achieved if each company along the SC is able to adopt a system of internal control and recording (internal traceability) and if the transitions between the actors involved are regulated and managed in a coherent and shared way.

The food SC is a complex structure formed by different actors that contribute to the production, distribution, marketing and supply of a food product. As defined by Gandino et al. (2009), a typical food SC consists of five basic entities: the producer, the processing company, the distributor, the retailer and the carrier. Each actor performs a specific task. The producer cultivates agricultural products and sells them to the processing company; the processing company transforms the raw materials; the distributor handles the food commodities; the retailer sells food directly to the consumer; the carrier moves the food products from a company to company. The presence of these actors highlights that the concept of food chain is extended both to the individuals upstream and downstream in the SC. In order to guarantee total food traceability, each actor must collaborate and share information in a coherent and shared form. In such a context it is possible to trace the path followed by a food product from “farm to fork”.

Compared to other supply chains, the time taken from manufacture of raw materials to consumption of the final products remains relatively shorter in food supply chain (Nishantha et al., 2010). Food products, in fact, are extremely time critical and, by their nature, they characterized by a short shelf. Food products are perishable and their shelf life is conditioned by the harvesting means, transformation processes, transporting ways, and storage conditions. This aspects, along with the wide variety of food products, contribute to making more difficult the design, implementation, and management of an efficient system of traceability (De Cindio et al., 2012).

2.2 Related works on food traceability

In recent years traceability has attracted the attention of industry, public authorities and researchers. The increasing interest of the scientific community in the research area about SC traceability is the result of many developments aimed at improving food quality and safety management (Opara, 2003). The relevance of product tracing in both the external supply chain and inside the production system has been underlined by Stein (1990) and Ramesh et al. (1995).

Fundamental concepts related to traceability have been well defined by Kim et al. (1995) and Moe, (1998). Kim et al. describe the fundamental and necessary core in ideal traceability systems as the ability to trace both

products and activities. Products and activities are called core entities, an entity being what can be individually considered (European Committee for standardization, 1995). They use the Traceable Resource Unit (TRU) to identify production batch. Moe (1998) has introduced the concept of traceable resource unit (TRU) for batch processes as "unique unit, meaning that no other unit can have exactly the same, or comparable, characteristics from the point of view of traceability". Important concepts in food traceability are the "batch dispersion" (Dupuy et al., 2005) or also so called "transformation" (Ridden &Bollen, 2007) and the "risk transmission" (Hu et al., 2009).

A general method for modeling and optimizing traceability systems in food industry is proposed by Dupuy et al. (2002) and Dupuy et al. (2005). Bollen, Riden, and Cox (2007) and Riden and Bollen (2007) studied and analyzed the traceability in fruit supply chains in order to improve the traceability control of the batches. The traceable information flow and risk transmission throughout food supply which contains raw material, process and distribution have been studied by Hu et al. (2009). They take into consideration the research work of Dupuy el al. (2002) and propose a graphical model to describe the risk transference problem, according to Gozinto graphs which proposed by Dorp (2003).

In the recent past the development of traceability systems in the food Supply chain has interested several author (Jansen-Vullers et al. (2003); Regattieri et al. (2007); Bechini et al. (2008); Takur and Hurburgh (2009); Thakur and Donnelly (2010); Thakur et al. (2011,a); Thakur et al. (2011, b); Bevilacqua et al. (2009); Ruiz-Garcia et al. (2010); Verdouw et al. (2010)). Some examples follow in the next lines.

Jansen-Vullers et al. (2003) propose a reference-data model for tracking and tracing goods based on the Gozinto Graph, a tree-like graphical representation of raw materials parts, intermediates and subassemblies, in which a particular production process transforms into an end product through a sequence of operations. The development of the reference data model is described by explaining the model-part of the bill of lots and/or batches, the model-part of operations and variables and the integration of these two model-parts. The bill of lots is designed analogous to the bill of materials and registers each relation between a sub-ordinate entity and super-ordinate entity via the concept of aggregation. Aggregation is an abstract concept for building composite objects from their component objects (Elmasri & Navathe, 2000).

Regattieri et al. (2007) developed a traceability system for Parmigiano Reggiano, the famous Italian cheese, and introduced a general framework based on the integration of alphanumeric codes and RFID. The product characteristics are identified in their different aspects along the entire supply chain, from the bovine farm, the dairy, the seasoning warehouse, and lastly the packaging factory. The complete supply chain of Parmigiano Reggiano is traced by an RFID system using an alphanumerical code. Technically the system developed is based on a central database that collects data from bovine farms and from dairies. Manufacturers can check the progress made in production at any time and if some problem occurs in the market place they can re-trace the development of the portion and introduce effective re-call strategies.

Bechini et al. (2008) introduce a data model for identifying assets and actors and show a formal description of the lot behavior throughout the supply chain. The lot behaviour has been modelled by six activity patterns (integration, division, alteration, movement, acquisition, providing) using a UML activity diagram. The standard Unified Modelling Language (UML) notation is adopted to formally describe the different aspects of the modelled system. The model of a simply cheese supply chain with a UML communication diagram is presented in the paper. An independent, private data-sharing network (PDSNs) is proposed as proper infrastructure for business process integration and Enterprise Service Bus (ESB) as architectural scheme for connecting third party applications. The ebXML Message Service (ebMS) is used to transport business documents in a secure, reliable, and recoverable way in the inter-enterprise business collaboration scenario. In case one of the business partners cannot manage ebMS messages (for instance, in the case of legacy systems), the communication is handled via ESB.

A model for implementing internal traceability system for a grain elevator has been developed by Takur and Harburg (2009) and extended by Thakur et al. (2011,a). In the first reference a UML sequence diagram shows the information while the UML (Unified Model language) Use Case diagram technique defines the usage requirements of the traceability system. The internal traceability system is developed using the Integrated Definition Modeling (IDEF0) and the lot information is recorded in a RDBMS (Relational Database Management System) form presented in Thakur et al. (2011,a). Thakur and Donnelly (2010) present a new model for information capturing in the soybean SC and develop a UML class diagram for modeling products, processes, quality and transformed information. The UML state charts and EPCIS framework are presented by Thakur et al. (2011, b) as a new methodology for modeling traceability information. EPCIS is an EPCglobal standard designed to enable EPC-related data sharing within and across enterprises. The model presented is used for mapping of food production processes to provide improved description and integration of traceability information. The method follows the approach of defining states and transitions in food production. A generic state charts for food production is presented and applied to two supply chains; pelagic fish and grain. A state-transition model with emphasis on identifying both traceability transitions and food safety and quality data is

developed. The application of current EPCIS framework for managing food traceability information is presented by mapping the transitions identified in two product chains to the EPCIS events: Object Event and Aggregation Event. The corresponding states where the quality parameters are recorded are also identified and linked to these EPCIS events.

The review of the previous references shows that although many authors have been interested in the traceability issue, at the present time there are no works that completely integrate the process flow chart model of the SC with the data model for managing the data required for traceability and automatically generate a web application useful for data track and trace. Moreover, those papers where a web model is presented are limited. Bevilacqua et al. (2009) use the business process reengineering (BPR) approach to create a computer-based system for the management of the supply chain traceability information flows. They present a computer-based system for the traceability of fourth range vegetables. They use the Event-Driven Process Chains (EPCs) technique to model the business processes. To ensure the traceability, each single unit or lot of the food products has been uniquely identified combining global trade item number GTIN (GS1 traceability, 2006) and the lot code. The business processes database generate follows the Entity Relationship Model (ERM). In the paper, moreover, the data model is not presented, and the front-and generated using the software ARIS is only discussed. Ruiz-Garcia et al. (2010) present a web-based system to process, save and transfer data for tracking and tracing agricultural batch products along the supply chain. The development of the prototype involved the integration of several information technologies and protocols. The tracking system is based on a service-oriented architecture (SOA) and the communication is through messages in XML. Moreover, the work not deals with the problem of process and data modeling. In addition, there are only few authors who use the BPMN standard for process modeling. Referring to the food sector, only Verdouw et al. (2010) modeled the SC of fresh fruit using the BPMN standard to model the business process diagrams.

3. New Model for the Traceability of Frozen Vegetables

The analysis of the state of the art highlights that, despite the numerous efforts made to develop effective traceability systems, current deployments results reveal some critical limitation of existing traceability systems (Bechini et al., 2005). Successful implementation of traceability systems requires elevate investment costs, staff training, global legal requirements. In such a context, the authors investigated how a traceability system can be developed and implemented in a cost and user friendly way. The results of this study led to the definition of a new model for traceability capable to support the business processes of a food chain through: (1) the modeling of business processes, (2) the definition of the data model to support SC and (3) the generation of a Web Application that allows to record, edit and retrieve data via the web.

The model has been developed studying and analyzing the supply chain for frozen vegetable. In the next sub-section are described and the investigation framework. Particular importance has assumed the definition of lots throughout the supply chain.

3.1 Company description

The new model will be implanted in an ideal framework where there is a company that is engaged in the production of frozen foods. The business activities of the company include the cultivation, harvesting, processing, packaging and marketing of a wide assortment of frozen vegetables. The company directly controls the entire production chain, from sowing to harvesting. All operations are scrupulously monitored and controlled: this allows achieving the best results not only from the organoleptic but also from a bacteriological and health point of view. The company delivers many products for prestigious multinational and important companies belonging to large retailer and large organizations both national and international of catering and restaurants, representing its main clients. It keeps in its portfolio a wide range of products, from ready meals to soups, from grilled vegetables to natural plant, from legumes to prepared cereals. The variety of finished products is extremely wide. From the suppliers point of view it has established supply agreements with more then 50 companies and two big cooperatives of agricultural producers that provide about 90% of the vegetable products it needed.

3.2 Description of the production process

The studied SC has been modeled through the Business Process Modeling and Notation (BPMN) because technique allows the representation of processes and associated data resources in a unique model. According with the BPMN, the actors involved in the SC has been classified into pools. In particular four different pools: (1) the seed company, (2) the nursery company, (3) the agricultural company and (4) the processing company. The seed company provides the processing company with the seeds needed for the production of plants and vegetables. The processing company receives seeds and stock in form of batch. These batches are then sent to the nursery companies which are interested in the growing of the seedlings and are involved in all the stages of the seedlings growing, from the germination to the production of batches of seedlings. All batches of seedlings

are then delivered to the agricultural companies responsible for the production of the needed vegetables. The processing company adopts a particular policy for the management of seed: periodically it determines the number of seeds to be delivered to the nurseries and communicates to each nursery company the conferring agricultural company to which provide with a particular batch of seedlings. The first controlling phase is done when the unprocessed vegetables batches income into the processing company. They unprocessed vegetables batches are administered in form of input bins and each bin is coded and labeled. The controlling phase is followed by a transformation phase. At the beginning of this phase, each bin of raw material, depending on the type of the scheduled destination, is subjected to particular manufacturing processes.

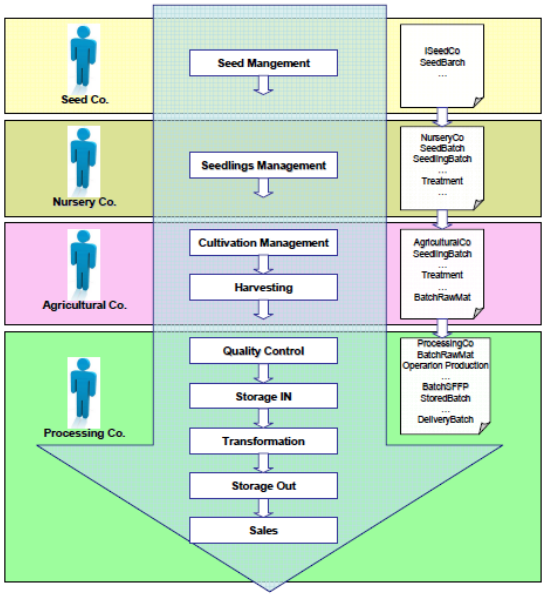

Figure 1: Process Flow of fruit and vegetable industry, actors and data required

The manufacturing processes of the company are divided into three lines:

(1) Industry Line, for the production of legumes and cereals, mix of vegetables, rice and pasta, grilled vegetables, condiments for pizza, soups,

(2) Catering Line for the production of legumes and cereals, grilled vegetables and mix,

(3) Retail line, for the preparation of appetizers, prepared meals based on pasta, ready meals based on meat, soups and stews.

Each production line has four phases: washing and cutting, cooking and/or freezing and packaging. The last phase includes the labeling phase. The company adopts codes that are different depending if the product is a semi-finished or a finished product. In case of semi-finished product the vegetables are stored in form of pallets. A label is generated for each pallet containing information about type of product, date of transformation, date of packaging and, cold room number of storing. In case of a finished product a label is generated for each batch package.

Figure 1 shows the main processes involved in SC and the main data flow and information. The column in the middle of figure 1 shows the processes in a logical sequence. On the left side of this column the actors involved in the proposed activities are represented. Finally on the right side of the column all the information needed to maintain the product traceability is represented.

3.2 Batch definition

The batch definition is fundamental when constructing traceability systems (Revision Committee on the Handbook for Introduction of Food Traceability Systems, 2007). Unique identification and traceability in any system hinges, in fact, on the definition of what is the batch size, or using the terminology used by Kim et al. (1995), the traceable resource unit (TRU) (Moe (1998)).

Taking into account this, in this paper products are managed in form of batches or traceable units and different batches types are defined for each actor in the supply chain. Usually the identification of the batches is necessary at least in two fundamental stages: at the beginning of each process and at the end. At the beginning of each process, it is necessary to identify the different batches of incoming raw materials, semi-finished products or auxiliary materials (additives, flavorings, spices, etc.). At the end of each process, instead, it is necessary to identify and distinguish the different batches of semi-finished products that are generally bound to other companies for further processing, and also the batches of finished products that are sent directly on the

market. In above mentioned moments the batches must be recognizable and uniquely identifiable using the most appropriate tools (codes, alphanumeric codes, barcodes, tags, etc.) in order to define the lines of responsibility and to identify all those individuals who have contributed to their formation. The identification of batches and elements to trace depends on the processing stages under analysis. Notwithstanding each batch is characterized by products obtained under homogeneous conditions by location, type and date of treatments.

The composition of the batches represents a critical point in determining the accuracy of the traceability system. To this end, in order to avoid confusion keeping the product traceability, the authors have identified different batches types for the phases of seeds production, seedlings production and cultivation. These batches are described below:

- *Seed Batch*. It is defined in the phase of seed production. Each batch contains a certain number of seed envelopes. The elements necessary to characterize each single batch are species, variety, category, size, origin, plant of selection, packing date and usability period.
- *Seedling Batch*. It identifies the individual batch of seedlings on the stage of growing at the nursery. The information which characterizes a batch of seedling contains additional information through which is possible to track the batch of the seed from origin, location of plantation (land cultivation, cultivation in greenhouse, etc.), method of cultivation (conventional, integrated or organic) and processing operations (sowing date, treatments, packaging and shipping).
- *Plant Batch*. It identifies the "production of a crop species with similar characteristics by period of sowing/transplanting, cultivation and plant-health control" at the agricultural company. All the information about the treatments suffered by each batch of plants is generally recorded in the logbook. In the logbook are contained additional information about the cultivation company and the place in which the batch is located.

In the transformation phase the following types of batch are identified:

- *Batch of raw material*. It identifies raw material delivered from the cultivation company and is characterized by the amount of bins supplied in a defined date or time, containing a fixed quantity of vegetables divided by caliber, as well as all the characteristics of the plant batch of origin.
- *Stored Bin*. It identifies a batch of raw material for input at the transformation process and stored in the internal warehouse. Each bin is uniquely identified by a label that contains the information on the product, the supplier and the destination.
- *Batch of semi-finished/finished products*. It is defines at the time of production process, characterizes the products processed and contains information about actors involved in the production phase, batch destination, quantity, time and date of treatments.
- *Stored Batch* It is defined for each type of batch stored in the internal warehouse. For each Stored Batch, such as a Stored batch of incoming raw material or a Stored batch of semi-finished/finished products, are defined the parameters which characterize the environment in which is stored, the storage cell and the correct location in the storage cell.

A series of business objects define business objects containing all the basic information required traceability have been generated starting from the composition of each batch. The data present in the model have been classified. A data classification was carried out in order to distinguish the data required for the internal traceability from those required for the external traceability. The information which refers to the internal traceability is only available for the actors present in the company object of interest or for the Control Authority which expressly request them.

4. Methodology

The web application generated to support the traceability system has been developed following a methodological procedure which requires the execution of four basic steps:

- Analysis and modeling of the business process specification;
- Modeling of the data structure;
- Creation of the complete BPMN model through the enrichment of the process model with the addition of information needed for traceability;
- Transformation of the process model in an application model in WebML and creation of the executable Web application.

Figure 2 shows a simple representation of these steps. In the first step of the proposed methodology the business requirements have been initially conceptualized in a business process model with a high level of abstraction. The processes and actors involved in the SC and relationships between them can be modeled using different techniques such as Petri nets, IDEF diagram, Event-driven process chain (EPC), UML Activity Diagram. In the present research the authors have modeled the food SC using the standard Business Process Modeling and Notation (BPMN). BPMN allows for reconstructing patterns of process or the Business Process Diagram (BPD) by means of graphs or networks of objects. These objects represent the activities of the process and they are

connected by control flows that define logical relationships, dependencies, and the execution order. In general, BPMN is used for two different operating configurations. The first refers to processes that take place entirely in a company. In this case, the processes are private and internal activities of the company are not directly visible to other actors in the SC. This configuration, called internal traceability, allows for maintaining traceability of the products internally to the companies... The second refers to the collaboration of processes between two or more business entities (corporations, organizations, groups, etc.).This collaboration permits to keep external traceability or SC traceability. Each entity develops its own process and exchange information with other professionals. These exchanges take place, especially when a product moves from one operator to another in the SC and it is necessary to keep track of this transition. The needs of the different actors involved in the chain were modeled in a first draft represented in BPMN. Then, the data model was created using the Entity-Relationship Model (ERM). Successively the data model is integrated with the process model in order to assign the required data to each process. The BPMN model was subsequently enhanced introducing process parameters and at this stage the complete BPMN model was been created.

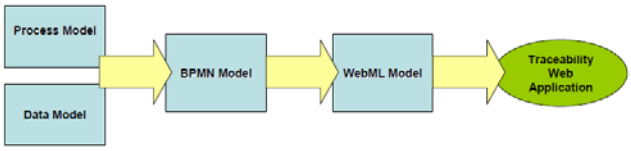

Figure 2: Methodological approach for the generation of the web application for the frozen vegetables traceability

The process flow enriched with the data flow (BPMN Model) led successively to the generation of the Application Model and the Process Metadata Model. These models are the main elements of the WebML Application Model (Ceri et al., 2002). The Application Model specifies the characteristic features of the executable application in the WebML language. It is composed by the Hypertext Model and the Presentation Model. The Hypertext Model defines the composition and the navigation of the web application. The composition describes which pages form the hypertext and which information is contained in each page. The Presentation Model is needed to define the pages appearance. On the other hand, the Process Model Metadata offers a visual representation of the operating logic of the process, defining the data model to structuring data in a format compatible with the Entity-Relationship (ER) model.

5. Results

The first model of traceability for the analyzed company has been obtained describing for each pool the business logic along with the responsibility logic using the BPMN standard. At this stage detailed information are absent.

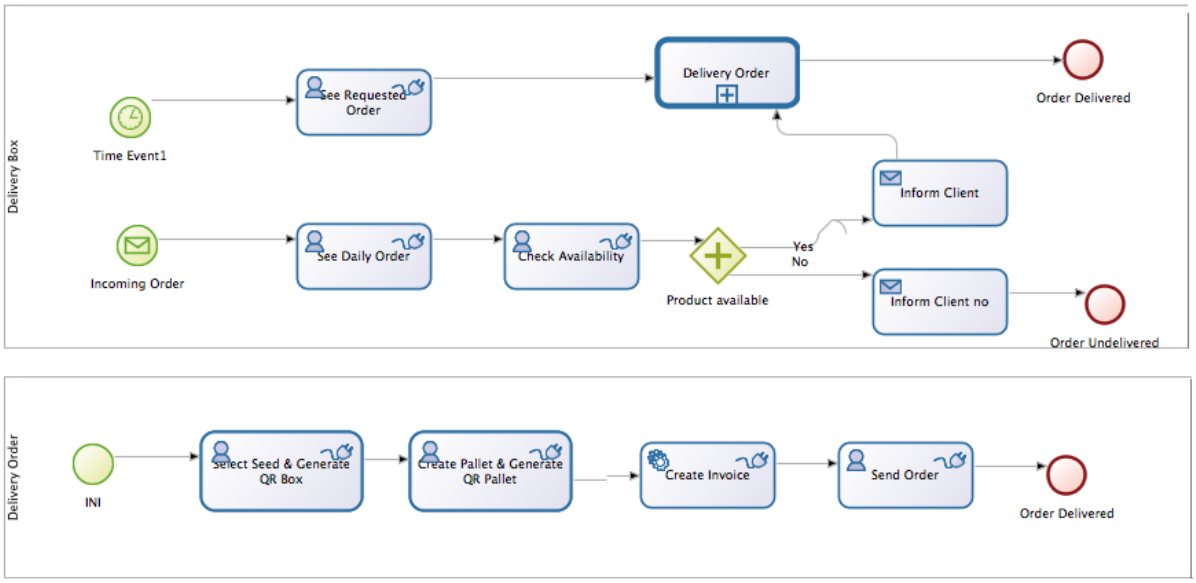

Figure 3: BPMN Process Diagram

A first draft of the traceability model in BPMN was initially created. Then, a deep analysis was conducted for each task and data were recorded. Thus, the first BPMN model was extended with the creation of

choreography through the introduction data in input and data in outputs. At this time the BPMN model was completed with the addition of parameters and the definition of sub-processes. In such a context, the final version of the BPMN model was obtained by several iterations over the first model. The advantage of using the BPMN concerns with the model dynamicity: the transition from one version to another one, in fact, it permits to add or cancel some elements of the model without the necessity of reprogramming the application using a specific language. In the BPMN process model elaborated external traceability is maintained through the flow of messages between the different lanes. Figure 3 shows the delivery process for the Seed Order in BPMN. The choice of the BPMN as standard to model the process flow is directly connected with the advantage of integrating actors, tasks and data in a single model. This BPMN model, in fact, represents in a single model the process flow chart diagram, the Data Flow Diagram (DFD) and the ERM. In other words it is the translation of the elements represented in Figure 3 in the same model.

The main elements of the data model are entities, or containers of data elements, and relationships, defined as semantic connections between entities. Entities are characterized by attributes such as name and type. Entities can be organized into hierarchies, and relationships are governed by cardinality constraints. A streamlined data model is showed in Figure 4. In the model each batch is identified by an ID (batchID), which is unique within the SC. Each actor is uniquely identified by an identifier actor (actorID). The batchID contains the actorID. Typically batchID is attached as a bar code on the batch of seed, batch of seedling and batch of package.

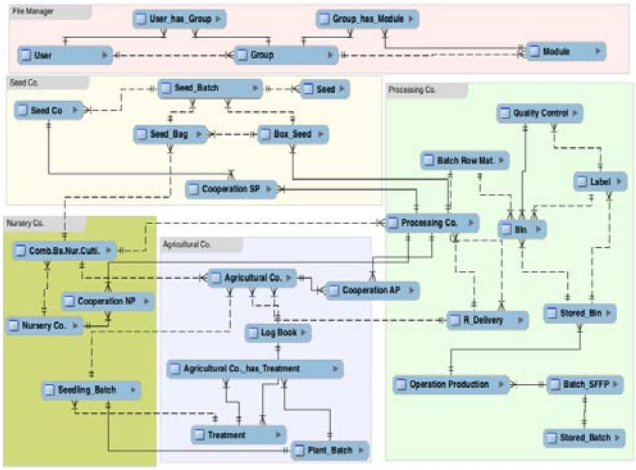

Figure 4: Data Model

The generation of the data model for the business process marks the transition from the extended BPMN Model to the Process Model Metadata in which activities and gateways are transformed into instances of logical representation of relations. In the Data Model entities are present related to documents generated as output from each process mapped in BPMN, including all the parameters that govern the workflow process. Finally, the Application Model has been generated. The instances of the business processes are generated from the WebML model according with the J2EE (Java 2 Enterprise Edition) Language. The model proposed has been compared with the other similar models mentioned in section 2. Table 1 shows that the web application model easily integrates the process model with the data model using the BPMN standard, not yet used from other authors to construct a traceability system. It represents an effective way to increase food safety and quality, build confidence and commitment to and by consumers.

The model permits the SC optimization and the food quality management. The main features of the model are: (i) high flexibility, (ii) reduced development time, (iii) reduced implementation costs, (iv) high usability, (v) management and control of actors, processes and data, (vi) easy information exchange between the different actors of the SC, (vii) appropriate level of integration with the data system.

5. Conclusions

Nowadays the Food Traceability represents one of the main issues for public authorities and industry. Governments and consumers looks at traceability as a way to improve food quality ad safety. This paper proposes a web based traceability system able to support the business processes of a food chain through: (1) the modeling of business processes, (2) the definition of the data model to support SC and (3) the generation of a Web Application that allows to record, edit and retrieve data via the web. The process model is integrated with a data model. All data were stored on a web server and made accessible via Internet. Each actor records data of products and processes and collaborates with other operators in industry by making available all the information necessary for traceability. The web application model generated integrates the business process model with the

data model and creates a front-end displayed in a Web browser that enables the retrieval of information using the Web. The SC of frozen vegetables has been modeled according with the BPMN standard. Then, data required for traceability have been classified according to their relevance to answer to the internal or external traceability and the data model has been created following the Entity-Relationship diagram. The integration of the flowchart with the data model has led to the generation of a web application. The model is characterized by high flexibility, reduced development time, reduced implementation costs, high usability, management and control of actors, processes and data, easy information exchange between the different actors of the SC, appropriate level of integration with the data system. However, there are critical issues to be addressed, such as the tightness of a mandatory standard for all companies in the food sector for the encoding of information.

Table 1. Comparison of the proposed model with other models

	Analyzed models							
ASPECTS	Bevilacqua	Thakur	Jeansen-Vullers	Bechini	Verdouw	Ruiz-García	Regattieri	Proposed Model
Customer Internet access	Yes	No	No	No	No	Yes	Yes	**Yes**
Modelling by production lots	Yes	Yes	Yes	Yes	Yes	Yes	No	**Yes**
Correlation between information and production flow	Yes	Yes	Yes	Yes	Yes	N/A	Yes	**Yes**
Rapid access to archives and documents	Yes	Yes	No	Yes	N/A	Yes	Yes	**Yes**
Consideration of single ingredients	No	N/A	N/A	No	N/A	N/A	Yes	**Yes**
Data Modelling	ER	ER	ER	UML	N/A	UML	No	**ER**
Process modelling	EPC	Flowchart	No	UML	BPMN		No	**BPMN**
Data Base Centralized	N/A	yes	si	Yes	N/A	Yes	Yes	**No**
Rapid configuration	No	No	No	Yes	Yes	N/A	No	**Yes**
Common process understandable for business managers and IT	SI	No	No	No	Yes	No	No	**Yes**

Acknowledgements

This paper is co-funded with the support of the European Commission, European Social Fund and Regione Calabria (Italy).

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