A BPMN GENERAL FRAMEWORK FOR MANAGING TRACEABILITY IN A FOOD SUPPLY CHAIN

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ABSTRACT

In the research area of the supply chain, traceability is the result of many developments aimed at improving food quality and safety management. This paper presents the results of the first phase of elaboration of a Global Track&Trace (T&T) System for Food. A general framework is obtained through the definition of a T&T Information System. The development of an information system requires modeling of business processes and associated data results. In this research work, the whole supply chain has been modeled according to a Business Process Modeling Notation (BPMN). A general data model is proposed enough flexible and variable for developing the strategy of traceability and open the door to incorporate new future features to be taken into account. Processes and data management are achieved through the creation of a web-based system. The final model permits the supply chain optimization and the food quality management.

Keywords: Food Supply Chain, Tracking and Tracing, Information Systems, BPMN, ER model

1. INTRODUCTION

Traceability is a newer policy that is used to improve supply management, increase safety and quality, and differentiate finished goods on the basis of credence attributes (E. Golan, B. Krissoff, and F. Kuchler, 2004a). The increasing interest in food traceability directly interfaces with the introduction of new regulations and customer demands on food quality and safety.

In many developing countries, traceability initiatives have been started in the last decade and, within the European Union, it has been enshrined in a number of regulatory initiatives such as the Regulation of the European Community n.178/2002 (European Commission, 2002) . As a consequence, different types of traceability systems are emerging as a result of regulatory interventions, at an industry-wide level or as a competitive strategy at the level of individual supply chain. Moreover, the key issue frustrating the job of food safety agents are (i) the inability to link food chains records, (ii) the inaccuracy and the errors in the records and (iii) the delays in obtaining essential data. The recent cases of E.Choli in Germany are one example of the strong reaction of the market to a food outbreak disease. The E.Choli diffusion highlighted that when a food crisis occurs, rather than leaving potentially contaminated food in the market, authorities recommend the recall and removal from the market of all suspected food or recommend that consumers stop consuming the food products. This creates a huge amount of financial problems for companies which were not involved with the production or manipulation of the contaminated food.

In such a context, a traceability system may serve many purposes. Essentially, it functions as a tool for communication, making information available along the food supply chain. In order to maintain food safety, the information can be used to trace back and to find what the source and the cause of a problem is, to stop the problem or prevent it from happening again.

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; European Commission, 2004). Notwithstanding, other requirements should be satisfied to ensure food security and to improve food quality (Food Standard Agency, 2002). Additional information should be collected in each stage of the Supply Chain to ensure the availability of data for the production analysis and optimization (Thompson et al., 2005).

The paper is structured as follows. Section 2 describes the food chain traceability and presents a brief review of the state of the art about traceability systems developed. Section 3 describes the main issues which deal with the implementation of a traceability system. Section 4 describes the track and trace information system proposed. Finally in Section the conclusions are discussed.

2. TRACEABILITY IN THE FOOD SECTOR

This section provides an overview on food supply chain traceability and food supply chain and presents the problem statement in order to provide some background and highlights the main goal of this research work.

2.1. Food Supply Chain Traceability: Current State and Future Work

The European Commission defined food chain traceability as "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 Food Supply Chain (FSC) is a complex structure formed by several actors that contribute to the production, distribution, marketing and supply of food products. On the basis of the definition provided by the Food Traceability Handbook (Revision Committee on the Hanbook for Introduction of Food Traceability Systems, 2007) in a typical FSC are involved five basic entities: the primary producer, the processing company, the distributor, the retailer and the transporter or third part carrier. Each actor performs a specific task. The primary producer, such as the fisherman, the grower or the farmer, is devoted to the production of raw material and ingredient that are successively transformed by the processing companies; the transporter moves the products from one actor to another; the distributor handles the food commodities; the retailer sells food directly to the consumer. The presence of these actors highlights that the concept of food chain is extended both to the individuals upstream and downstream in the supply chain. In order to maintain the traceability, each actor must collaborate and share information in a coherent and shared form. In such a way it is possible to trace the path followed by a food product from "farm to fork".

Food Supply Chain (FSC) differs from the other supply chain because of the perishability which characterizes food product. As specified by Nishantha, Wanniarachchige, and Jehan 2010 the time windows in which food products moves from the from the raw material producer until the consumer remains relatively shorter in FSC. Food products, in fact, are extremely time critical and, by their nature, they are 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)

Traceability is obtained through the combination of two different processes: tracking and tracing. These terms are often used in an interchangeably way even though they have different meanings. Tracking is the process by which the product is followed by upstream to downstream in the supply chain by recording date in each production stage. Tracing is the reverse process. Through tracking systems it is possible to trace the global history of the product and the responsibilities at different processing stages.

The operations required by a traceability management system can be divided into two main activities which refer to internal traceability and supply chain traceability. The internal traceability is realized by internal procedures, different for each business, that allow tracing the origin of materials used, the process operations and the food destination. The food supply chain traceability or external traceability is guaranteed by the integration and coordination of the tracking procedure adopted by each operator of the chain, and represents the ability to follow the path of a specific unit of product along the production chain.

The definition and implementation of a FSC traceability system depends on both the supply chain 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 supply chain is able to adopt a system of internal control and recording (internal traceability) information and if transitions between actors are regulated and managed in a coherent and shared form (De Cindio et al., 2011).

2.2 Problem Statement

Traceability systems are emerging proposing different approaches, as result of both regulatory and industry initiatives. Three key functions of a traceability systems have been identified (Hobbs et al., 2002; Sanderson and Hobbs, 2006;E. Golan, B. Krissoff, and F. Kuchler, 2004b). The firs key function is to allow efficient trace-back of products and inputs when a food safety or herd health problem occurs. In such a case, efficient and timely trace-back could limit the size of product recalls and the number of people exposed to tainted food, thereby limiting human-health impacts, minimizing productivity losses from illness, etc. The second key function is that traceability can be used to reduce information costs for consumers by identifying credence attributes through the labeling of environmentally-friendly production practices, or assurances about feed, other ingredients or production practices. In this case the traceability system is directly connected with the quality system of the company. The third function of traceability may be as a means of strengthening liability incentives to produce safe food.

Potential of traceability systems and the numerous advantages that can be obtained through its implementation have been well documented in literature (Moe, 1998; Lo Bello et al., 2004).

Despite multifaceted potential benefits, nowadays the operational conditions of current traceability systems are kept at bare minimum merely to fulfill legal requirements. Particularly Small and Medium Enterprises (SMEs) are either do not use traceability systems or use non-digital systems due to the limited scale of their operations, necessity of heavy investment and nature of their manufacturing process (Nishantha et al., 2010). Many barriers, in fact, hinder the successful implementation of traceability, the most important are: necessity of costly investments, reluctance to change, lack of skilled staff to handle advanced systems and limitation of existing traceability systems. Meeting the traceability standard set by an industry organization or by government regulation, affects the cost of production per unit of food. Nevertheless, tracing and tracking capabilities are crucial to confine the reaction to possible hazards and reduce the recovery cost (Bechini et al., 2005).

The issue of food recall, and the consequently issue of money loss, can be easily solved through the introduction of a global traceability systems capable of enabling more targeted recalls, of identifying more strategically the product origin and consequently constraining the product recall only to the products actually affected by contamination (Pouliot and Sumner, 2009). In this way, in case of emergency, the outbreak of a disease can be immediately identified.

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 (European Commission, 2002); 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.

Moreover, currently consumers have no access to the information on the real origin of products, the activities in which the products were involved and the operators who manipulated it. Many initiatives have been started in the area of food traceability in the last decade and several authors have been interested in the development of food traceability systems (Jansen-Vullers et al., 2003) ;Regattieri, Gamberi, and Manzini (2007); Bechini et al. (2008); Thakur and Hurburgh (2009); Thakur and Donnelly (2010); Thakur, Martens, and Hurburgh (2011), (Thakur, Martens, et al., 2011b; Thakur, Sørensen, et al., 2011); Bevilacqua, Ciarapica, and Giacchetta (2009); Ruiz-Garcia, Steinberger, and Rothmund (2010); Verdouw et al. (2010)). Despite the numerous efforts for developing effective traceability systems, current results obtained reveal some critical limitation of existing traceability systems (Bechini et al., 2005). Successful implementation of traceability systems requires elevate investment costs, staff training and global legal requirements.

2.3 Research Objective

The research objective of this work is the development of a new general framework for the traceability of food products able to support quality and safety control. The solution adopted for the information management to support traceability is generally applicable, which means that it meets requirements from various kinds of industries. This model can be applied in real-life situations that might benefits from traceability solutions.

This paper aims to contribute to the development of a reference model in food traceability and it presents the result of the first part of a complex research work. At this step, a new Traceability Information System is developed. The system is obtained through the modeling of business processes and the development of a data model which contains all the information required for traceability. In order to ensure traceability and to implement an effective traceability system, the supply chain has been modelled using the Business Process Modelling Notation (BPMN) (Object Management Group, 2010), a common language understandable by analysts and developers. On the basis of the FSC model, data has been modeled following the Entity-Relationship (E-R) model (Hoffer et al., 2010). The integration of the process model with the data model has led to the generation of a web application that can be used for traceability purposes and supply chain management and optimization.

3. MODEL DEFINITION

In this section the food Track&Trace general framework is described and a short introduction to Business Process Modeling Notation is provided.

3.1 Business Process Modelling Notation

The Business Process Modelling Notation (BPMN) is a new standard to model business process flows and web services. It is a graphical notation that depicts the steps in a business process. BPMN depicts the end to end flow of a business process. The notation has been specifically designed to coordinate the sequence of processes and the messages that flow between different process participants in a related set of activities (Object Management Group, 2011). A business process currently spans multiple participants and coordination can be complex. Until BPMN, there has not been a standard modelling technique developed that addresses these issues. BPMN has been approved to provide users with a royalty free notation.

The primary goal of BPMN is to provide a notation that is readily understandable by all business users, from the business analysts that create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and finally, to the business people who will manage and monitor those processes.

BPMN aims at bridging the gap between business process design and process implementation. It allows the automatic translation from a graphical process diagram to a BPEL process representation that may be then executed using a Web services technology. Another goal, but no less important, is to ensure that the XML language designed for the execution of business processes, such as WSBPEL (Web Services Business Process Execution Language), can be visualized with a business-oriented notation.

The Business Process Modelling Notation is especially used in Service Oriented Architecture (Object Management Group, 2011). In a Service Oriented Architecture (SOA) approach, business processes models are leading in routing event data among multiple software components that are packaged as interoperable services (Erl, 2005; Papazoglou et al., 2007). The main elements of the BPMN are showed in Figure 1.

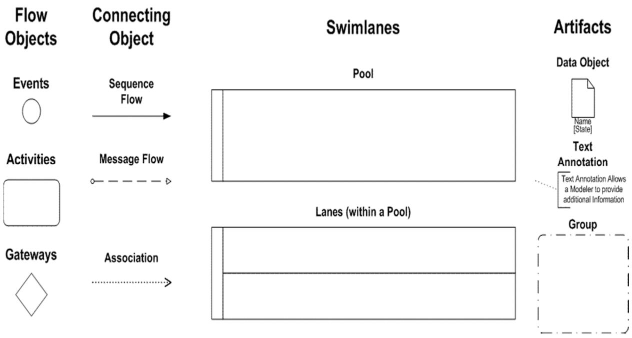

Figure 1-Core elements of the BPMN

BPMN allows 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 are connected by control flows that define logical relationships, dependencies, and the execution order. The advantage of using BPMN concerns with the model dynamicity: in fact, the transition from one version to another one permits to add or cancel some elements of the model without the necessity of reprogramming the application using a specific language. According with BPMN, the actors involved in the supply chain have been classified into pools and external traceability is obtained through the flow of messages. 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. The flow of products lots along the supply chain is associated with information exchanges among responsible actors and possibly third-party organizations.

3.2 Food Track&Trace General Architecture

In this paragraph, the general framework of the proposed Food Track&Trace System is described. The development of efficient traceability information systems in food chains has assumed considerable importance in recent years. The ability to trace and track every single unit of product depends on the supply chain traceability system which in turn depends on the internal data management system and the information exchanged between the actors.

Generally, an information system is formed by the business process models and associated data resources. In the proposed research work traceability is obtained through the development of a SOA application. Process and actors involved in the supply chain and the relationships between them have been modeled using BPMN. As mentioned in the previous paragraph, the BPMN is the new standard for modelling business processes and web service processes, as put forth by the Business Process Management Initiative (BPMI – www.BPMI.org) that makes web services work in a four-stage process, as follows (Owen et al., 2003):

1. Design the processes using BPMN.
2. Simulate the processes and modify them for efficiency.
3. Make the services available by publishing them using a Business Process Execution language.
4. Orchestrate the web services into end-to-end business flows by assembling them and coordinating their behavior. Business Process Management Systems (BPMS) are employed for this stage.

Process models represent specific ordering of work activities across time and place, including clearly identified inputs and outputs (Davenport, 1993). They represent the sequence of activities, events and control decisions.

In the general framework proposed, the whole food supply chain where initially modeled in order to visualize the basic processes, the actors involved and the related product and information flows. Taking into account the Supply Chain Operations Reference (SCOR) model of the Supply Chain Council (Supply Chain Council, 2010), for each actor present in the model, have been defined the most important operations.

A simple schema of the BPMN model is described in Figure 2. The general model shows the different processes operated by each actor along with the information flow. Actors involved in the supply chain have been classified into pools and information has been organized in the form of business objects. 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 main agents modeled in the General Framework are the primary producer, the processor, the transporter, the wholesaler and the retailer. Because of the different features characterizing each primary producer, this agent has been successively modeled and dived into three other actors: primary raw material producer, secondary raw material producer and third raw material producer. For example, when referring to the vegetable field, these actors represent respectively the seeder, the nursery and the grower.

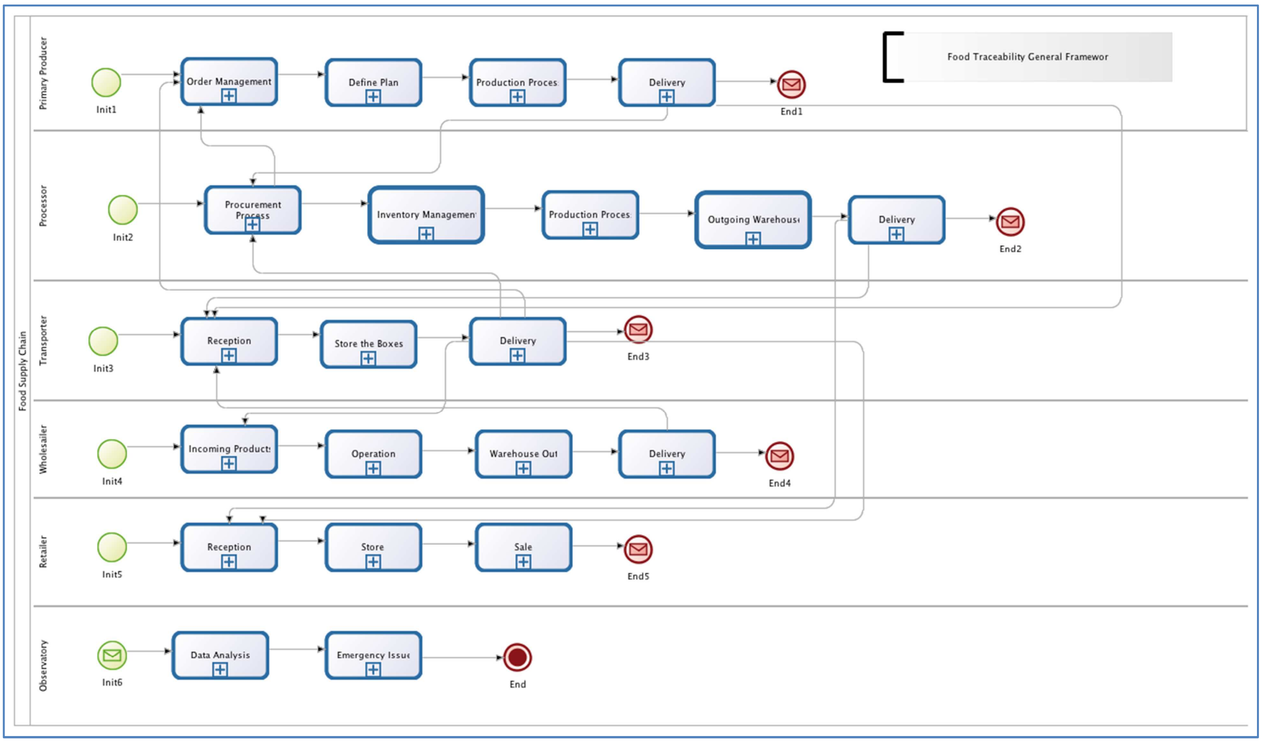

Figure 2- General Model

Transformations and logistics operation such as sourcing and delivering have been considered for each actor. An operation of transformation is operated each time that a lot is manipulated and each time that it leads to the definition of new lots. In these cases, according to Bechini et al. 2008 the lot behavior has been modeled by the following activity pattern: lot integration, lot division, lot alteration, lot movement.

The General BPMN Model of Figure 2 shows common processes for some actor, such as "production process" for primary producer and processor, "delivery" or "sale" for all the actors, "Reception for transporter and retailer and similar to this "incoming products", "procurement process" and "order management" respectively in wholesaler, processor and primary producer.

Each activity showed in Figure 2 represents a call activity which connects with another BPMN process.
A QR code is generated each time that a Traceability Resource Unit is formed. Different units of aggregation are defined according to the GS1 Global Traceability Standard (GS1 Standards Document, 2010). In particular:

- A Consumer Unit (CU) represents a single products, bags, and packages with a certain amount, volume or weight of goods.
- A Trade Unit (TU) is represented by cartons, boxes, pallets or bulk lots (in weight or volume).
- A Logistic Unit (LU) is generally represented by pallets and containers.

Each time that products are moved from one actor to another, the transporter generates a QR for each Shipping Unit (SU) and for each Logistic Unit (LU) manipulated. A Shipping Unit represent a truck or vessels loads.

Transportation can be done in different ways and using several means of transportation and different carries can be involved in the process of movement. The carries can refer to different companies. The general idea adopted in the Food Track&Trace System is that each carrier read the QR code of the product to move and generate a new QR code with the information on the carrier, the mean of transportation, the route, the date time of manipulation and delivery. The unit of transportation is manipulated each time that it is operated and activity of division or merge.

A central role in case of food accidents is played also by the Observatory. The Observatory is responsible for the management of the traceability system and recall activities in case of food outbreak disease. Each actor communicates with other actors of the supply chain and it constantly provides the Observatory with the information required for the traceability management. The Observatory contains a repository with all the information of the products produced in a particular location. The Observatory BPMN model is formed by two different lanes: the Data Analysis Department and the Emergency Task Department. In case of food accident or outbreak disease, with infected or dead people, the Emergency Task introduces in the System all the information about person, location and products eaten. For each food eaten the system generates a new table with all the ingredients and raw material used for transforming and producing the food in all the supply

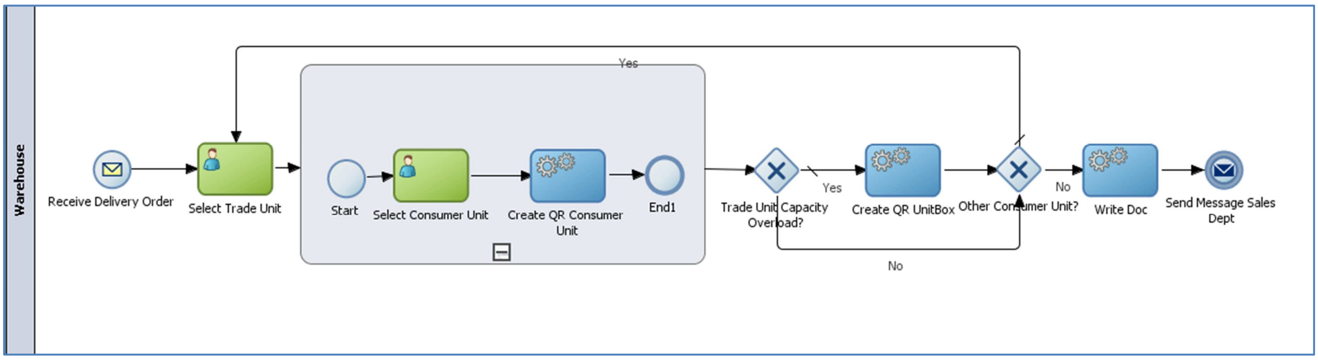

Figure 3- Process of Packaging and Labeling

chain stages. The system will show the maps relating to the introduced information and the probable location in which the infection has been generated.

One of the most important operations in the traceability maintenance is represented by the process of packaging and labelling. Figure 3 shows an example of the packaging process in which a QR Code is generated for each Consumer Unit and Trade Unit.

The core of the proposed process modeling is to identify common data and parameters and to construct a data model enough flexible to be adapted to different supply chains. The main objective of our work was to make available all the information at the final consumer. The tracking system is based on a service-oriented architecture (SOA) and the communication is based on messages in XML.

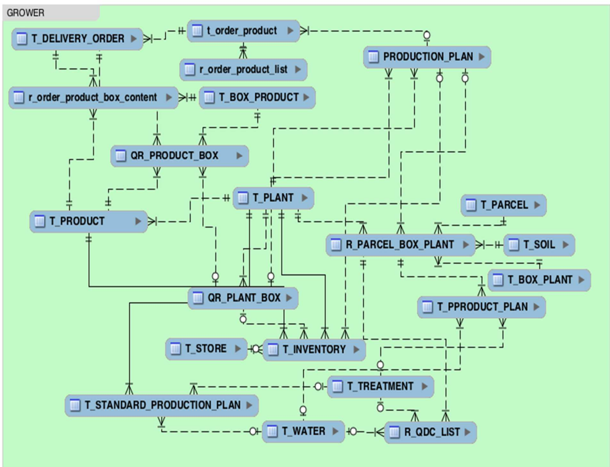

Figure 3- E-R Diagram of the Grower

It is required data to be recorded for the modeling and the analysis of product processes in the chain. An extended data model has been created following the Entity-Relationship (E-R) diagram (Hoffert et al., 2006) to support the whole architecture. 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. A general data model is proposed enough flexible for developing the strategy of traceability and open to incorporate new future features to be taken into account. The data modelling and management approach is achieved through the creation of a web based system. A MySQL database has been generated for each actor involved in the supply chain.

Figure 4 shows the database diagram that has been generated for a particular actor, a grower, who is responsible for seedling seeds and for the growing of a plant until a certain period or dimension. In the model all the information about treatments and location are recorded, including the geographical information of the land in which the parcel is located.

By using information from the production environment it is possible to provide relevant details on local environmental conditions which contribute to the particular uniqueness of the products, as soil, landscapes and climatic conditions, and to certify the origin of a particular product. In addition, the indication of origin (soil, region, country) becomes objective data with special regards to the new requirements of food safety and environmental protection.

A general problem of the previous traceability systems is that actors positioned downstream in the supply chain generally have no information about operations and treatments operated by the previous actor in the chain. In order to solve this problem, it was important to consider that all the information on a product is directly included in a QRcode. The QR-code, which was developed by Denso Wave (http://www.qrcode.com), is known as a kind of 2D barcode. The features of this code symbol are large capacity, small printout size and high speed scanning etc. A QR code is generated each time that a traceability unit is generate, moved, or manipulated.

4. CONCLUSIONS

The outbreak food diseases of the past years show as more information is necessary, and that a global traceability system is fundamental in a global market. In addition to systematically storing information that must be made available to inspection authorities on demand, a traceability system should take also food safety and quality improvement into account. To take into account the current requirements on food quality for health care into consideration, additional data that is not strictly necessary for traceability must be stored. For instance, for a cooking activity, oven temperature and humidity can be considered important parameters in case of hazard. For a cultivation activity, operations on the parcel are fundamental to trace the proximity of the land for cultivation to a source of pollution.

The traceability system prototype presented in this paper is designed under a flexible and open perspective in order to facilitate integration of information across the entire supply chain, ensuring consumer trust and compliance with legal and quality standard. Communication exchange, which implies information transmission in a secure and reliable way, is regarded as an e-business transaction. The software tool utilized for the process modeling directly generates a web application model that assures the connection to each operator of the supply chain.

The framework includes a set of process models that are understandable by business manager in a notation that can be interpreted by SOA-based Information System (BPMN).

The main features of the general proposed framework 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 supply chain, (vii) 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.

Through the final system, each FSC operator can: (i) guarantee the origin and the quality of a food product; (ii) assure the compliance with regulation; (iii) improve logistics; (iv) improve the inventory management; (vi) management of the whole products lifecycle.

In addition, recorded data can be used for several analyses such as the definition of: (i) type and quantity of cultivation (plant, animals or fresh) per locality or region; (ii) type and quantity of cultivation per period or year; (iii) land surface availability to be allocated to a particular product; (iv) level of activities of a particular locality/region/country; (v) previsions; (vi) recommendations.

Finally, data and time information recorded at each production step will help identifying non-compliance in the case of storage. The system, in fact, can be used in order to avoid food fraud such as off-season sales and certify the total quality of the product.

5. FURURE RESEARCH WORK

In this paper are presented the results of the first phase of elaboration of a global Track and Trace System. A new traceability framework can be defined combining the advantages of an information system for food traceability with the advantage of a geographical information system. This system can help governmental authorities in case of food outbreak disease and offer more information to the customers on the products that eat.

The integration of the Global T&T Food System with the Geographic Information system is a strategic approach that can help in the Geotraceability maintenance. Nowadays, the use of data processing applications that can process geographical information is becoming more widespread. In parallel to this development, geographical data are becoming more widespread and increasingly accessible, in particular due to the generalization of spatial data infrastructure and the diffusion of tool like Google Earth (http://earth.google.com).

ACKNOWLEDGMENTS

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

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