Chapter 20
Enabling Traceability in the Wine Supply Chain

Mario G.C.A. Cimino and Francesco Marcelloni

Abstract. In the last decade, several factors have determined an increasing demand for wine supply chain transparency. Indeed, amalgamation, fraud, counterfeiting, use of hazardous treatment products and pollution are affecting the trust of consumers, who are more and more oriented to consider the so-called "credence attributes" rather than price. Thus, consumers demand detailed information on the overall process from the grape to the bottle. In this chapter, we present a system for traceability in the wine supply chain. The system is able to systematically store information about products and processes throughout the entire supply chain, from grape growers to retailers. Also, the system manages quality information, thus enabling an effective analysis of the supply chain processes.

20.1 Introduction

Winemaking has a very long tradition in Italy: Etruscans and Greek settlers produced wine in the country long before the Romans started developing their own vineyards in the 2nd century BC. Until the mid-1980s, wine production was not generally of a high standard and, indeed, much table wine was cheap and of very poor quality. In the last years, however, consumers have become to consider traditional determining factors such as price less important than other qualities, called credence attributes. This has lead the Italian wine industry to go through a series of reforms aimed at introducing strict quality controls. Thus, the standard of the production has risen to a level whereby Italian wines can now compete at international level with French wines. Consumers however request certifications for these credence attributes and for this reason traceability is gaining more and more importance in characterizing

---

Mario G.C.A. Cimino · Francesco Marcelloni
Dipartimento di Ingegneria dell'Informazione: Elettronica, Informatica, Telecomunicazioni, University of Pisa, Largo Lucio Lazzarino 1, 56122 Pisa, Italy
e-mail: `{m.cimino,f.marcelloni}@iet.unipi.it`

production quality [7, 10]. Further, food traceability became a legal obligation within the European Union [22]; similar requirements for traceability systems are present in the United States and Japan [26, 18]. On the other hand, traceability is becoming an essential management tool for improving production efficiency. Indeed, traceability enables an effective process control and allows generating reliable risk assessment models, for identifying various factors that cause quality and safety problems [27]. Finally, traceability can play important roles in promotion management and dynamic pricing, with more dynamic and agile planning approaches. Traceability data can also provide instantaneous decision-making responses to variations in the supply chain. Nonetheless, enabling traceability in complex supply chain is not trivial, due to the high number of activities and actors. Further, companies generally outsource operations and leverage global sourcing.

Traceability is defined as the ability to follow a product batch and its history through the whole, or part, of a production chain from raw materials through transport, storage, processing, distribution and sales (called chain traceability) or internally in one of the steps of the chain, for example the production step (called internal traceability) [19]. Traceability of products has been introduced since the 1990s [13, 6] and is still under investigation by scientific and industrial bodies [4, 7, 10, 15]. A number of traceability systems, technologies and standards have been developed to carry out supply chain traceability and internal traceability, with different business objectives [2, 3, 9, 12, 17, 20, 25]. Nevertheless, only large enterprises, which are characterized by a tightly aligned supply chain and supported by a considerable use of information and communication technology, employ very efficient and fully automated traceability systems [10]. On the contrary, small enterprises only rarely implement traceability and, when they do, they add the traceability management to their normal operation, decreasing the efficiency and increasing the costs. Thus, today, a considerable challenge is to develop agile and automated traceability platforms for communities of small-scale enterprises [21]. On the other hand, just these enterprises are typically involved in the different activities of a wine supply chain.

In the automation of supply chain traceability, some standards and technologies gained a leading role [2]. In particular, radio-frequency identification (RFID) [24] and Electronic Product Code (EPC) global (EPCglobal) [9] are considered to be the most appealing sensing technologies and paradigms, respectively, for supply chain traceability. Further, in the vision of "The Internet of Things" [16], promoted by the Auto-ID Labs network [1], a global application of RFID allows all goods (bottles, casks, kegs, etc.) to be equipped with tiny identifying devices. Also, a globally distributed information system, made of networked databases and discovery services, allows managing an "Internet of Physical Objects" to automatically identify "any good anywhere".

The need to share data in this globally distributed information system requires the adoption of some coding standard which is agreed by all parties and allows them to communicate with each other, so as to ensure the continuity of the traceability throughout the chain. To this aim, the most promising coding system is certainly the GS1 (formerly EAN.UCC) system [12], a specification compliant with the EPCglobal Architecture Framework (EPC-AF) [9]. The EPC-AF is a collection of interrelated standards for hardware, software, and data interfaces (EPCglobal Standards), together with core services (EPCglobal Core Services).

Although standardized identification technologies and data carrier middleware are today mature, tracing items in a production chain, across different-scaled enterprises and through the full process scope, is an inherently expensive design task. Indeed, the various approaches proposed in the literature are often designed for specific good categories, and are characterized by the need of a top-down design approach for each supply chain. This approach usually produces some specific form of application middleware. However, general enterprise solutions are more difficult and more costly to develop, because they often need to be tailored to different applications. On the other hand, the wine supply chain is complex and fragmented, with distant suppliers and different demanding customers. Further, only the largest companies have significant technology requirements. Finally, there is also a myriad of other support companies that provide materials, transportation, storage and other services that are also impacted by traceability [11].

Companies vary greatly in their technical capabilities: from phone, fax and paper based transactions, through robust e-commerce, bar code, and other internal systems. Thus, their ability to identify products, and perform tracking and tracing activities is directly related to their technical skills [8].

To overcome these issues, a wine supply chain traceability system with a high level of automation is discussed in this chapter. In particular, the chapter is organized as follows. Section 20.2 presents a set of traceability requirements for the wine supply chain. Section 20.3 is devoted to the representation and the management of traceability information, whereas Section 20.4 details the behavioral model of the system in terms of transactions. The architecture is discussed in Section 20.5. Finally, Section 20.6 draws some conclusions.

20.2 Traceability Requirements in Wine Supply Chain

In 2003, GS1 co-established the Wine Traceability Working Group, joining representatives of international wine trading companies from France, Germany, South Africa, United Kingdom and United States. Further, industry peers in Argentina, Australia, Chile, New Zealand, Spain, and other wine regions, have collaborated with the Working Group on building a traceability model that has global applicability. In particular the Working Group defined a reference wine supply chain [11], which has been employed as reference in our framework to assess the fundamental requirements of wine traceability. Fig. 20.1 shows this scenario by highlighting the main actors of the supply chain. Each actor is responsible for specific activities which have to be traced so as to enable supply chain traceability. In the following, for each actor, we describe these activities and the corresponding data which have to be collected to make traceability effective.

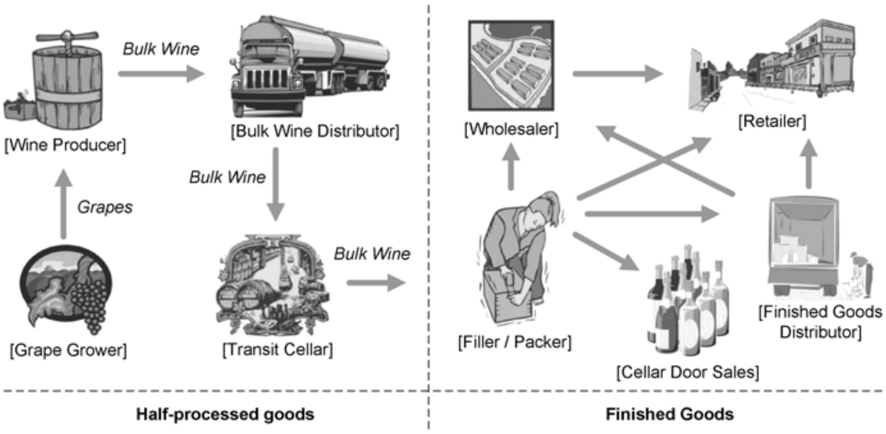


Fig. 20.1 A representative scenario of wine supply chain

Grape Growers are responsible for the production, harvest and delivery of grapes. Growers should record, for each plot of vines, details about the location, type and care of the vines, annual production record, origin and chemical content of water used for cleaning and irrigation, and the annual treatment [11]. Further, for each receipt of treatment products from suppliers, growers should record the supplier's details, a description of the product received, as well as applicable batch numbers. Each plot of vines is identified with a location number, which is allocated by the grape growers. The growers supply, with each delivery, the location number of the plot from which it comes and the date of picking, so that the receiving wine producers can link the related details to the wine made from these grapes.

Wine Producers are responsible for the production, manufacture and/or blending of wine products. Wine producers should record where, in the winery, grapes or juice were stored and must keep accurate records for the large number of procedures and operations performed to transform juice into wine. The wine producer is responsible for identifying each production run with a batch number. Further, for each receipt of additives from suppliers, the wine producers should record supplier's details, receiving date, a description of the product received, as well as applicable batch numbers.

The *Bulk Distributor* is responsible for receipt, storage, dispatch, processing, sampling and analysis of bulk wine. The wine is usually pumped into transport containers such as road tankers or barrels. When the wine arrives at the "tank farm", the bulk distributor checks the receiving documents, records all the information including the amount of received wine and takes samples for tasting and analysis. If the wine is rejected, the wine returns to the source, otherwise, two distinct processes are performed: (i) storage and dispatch of bulk wine without any blending or any other processing; (ii) storage, blending of different wines and dispatch of the new bulk blend. The bulk distributor sends batches of wine to the transit cellar. Identification is handled for the bulk distributor and the bulk wine container. To ensure forward tracking, it is essential to record references of the delivery items and to link these to the recipient.

The *Transit Cellar* is responsible for the receipt, storage, dispatch, processing, sampling and analysis of bulk wine. The transit cellar receives bulk wine from bulk distributors in different kinds of containers. Each of these containers is identified with a proper code. The transit cellar sends batches of bulk wine to the filler/packer. Each container sent is identified with a unique number, and with the associated quantity of wine (litres). In order to maintain accurate traceability throughout the chain, it is necessary that the transit cellar records the item and batch numbers, as well as the identifier of each dispatched item. To ensure forward tracking, it is necessary to record the global identifiers of the shipped items and link these to the location of the recipient.

The *filler/packer* is responsible for the receipt, storage, processing, sampling, analysis, filling, packing and dispatch of finished goods. The filler/packer receives containers of bulk wine from the transit cellar, and also "dry goods" in contact with wine (bottles, caps, corks, etc). Each of the containers of bulk wine and logistic units of dry goods are identified with a proper batch number. During this stage, the wine is poured into different kinds of containers, such as bottles, bags, kegs or barrels, and a lot number is allocated to them. A link between these components (bulk wine, finished product) should be maintained. The next step is the packaging into cartons and pallets and the dispatch of these cartons and pallets (identified with a lot number) to the finished goods distributor. The lot number must be linked to the batch(es) of bulk wine used to fill the bottles. To ensure forward tracking, it is necessary to record the global lot number of the shipped items and link these to the location number of the recipient.

The *finished goods distributor* is responsible for the receipt, storage, inventory management and dispatch of finished goods. The finished goods distributor receives pallets and cartons from the filler/packer and dispatches them to the retailer. These trade items are identified with lot numbers. To ensure forward tracking, it is necessary to record the global lot number of the shipped items and link these to the location number of the recipient.

The *retailer* receives pallets and cartons from the finished goods distributor and picks and dispatches goods to the retail stores. The container number of an incoming pallet is recorded and linked to the location number of the supplier. The retailers keep a record of the container number and the lot numbers of the components of the pallets and cartons they receive. The retailers sell consumer items (bottles, cartons) to the final consumer. These items are identified with a number allocated by the brand owner.

This brief description of the wine supply chain has highlighted that all the processes from the grape grower to the consumer can be traced by associating appropriate identifiers with the traceability entities managed by the single supply chain actors and, for each identifier, creating a record with all the information required about the entity. Each actor of the supply chain is therefore responsible for recording traceability data corresponding to specific entities. Further, each actor has to create the links between identifiers which identify correlated entities. For instance, the filler/packer has to link the lot number of the bottles to the batch number which identifies the bulk wine used to fill the bottles. This link enables forward and backward traceability. The identifiers are physically associated with the traceability entities. To this aim, we can use both RFID tags and bar codes. Typically, RFID tags are used in the first stages of the wine supply chains for speeding up the logistics operation. Currently, in the last stage, which involves bottle traceability, bar code is still preferred to RFID tag. However, in the next future, it is likely that also in this stage RFID tags will replace bar codes.

In the next section, we will introduce a simple data model which allows enabling traceability in the wine supply chain.

20.3 Traceability Information Representation and Management

The data model must be general enough to represent the variety of traceability items which are managed within a wine supply chain (for instance, grapes, vines, tanks, bottles) and also the activities which have been performed on these items at different stages of the supply chain. Thus, the data model has to provide a means to univocally identify traceability items and activities, and to record information about items and activities, and their relations. Further, a traceability system for the wine supply chain has to take additional data on quality features explicitly into account. For example, during the storage of the wine in the bulk distributor it is important to monitor temperature and humidity.

Each item is identified by a *global identifier*, which has to be unique within the supply chain. To avoid a centralized administration of the identifiers, we adopt a solution inspired to the approach used in the GS1 [12] standard. Each actor is assumed to be uniquely identified in the supply chain by an *actor identifier*. Moreover, an actor is allowed to freely associate an identifier (*traceable entity identifier*) with each traceable entity (i.e. either an activity or an item) the actor is responsible for. If an actor manages several distinct items, the item identifier may consist of the item type identifier and one progressive number. The only constraint we impose is that the identifier is unique within the amount of items managed by the actor. The global identifier is composed of the *actor identifier* and the *traceable entity identifier*.

We adopt the data model we introduced in [2]. Fig. 20.2 shows this data model. Here, classes are grouped into two distinct UML packages: *Traceability* and *Quality*. The former contains the entities that allow tracing and tracking the product path. The latter contains the components related to item quality. The *TraceableEntity* is an abstract class that models the basic characteristics of the two entity types involved in traceability: items and activities. The field *TraceableEntity.id* implements the traceable entity identifier. The association *is managed by* enforces a traceable entity to be always associated with a responsible actor. This constraint guarantees the univocal identification of the traceable entity, as described above. Further, *TraceableEntity* is also associated with *Site*, which holds its own unique identifier: i.e., each item is placed in one site. Thus, at each stage of the supply chain, the traceability system is

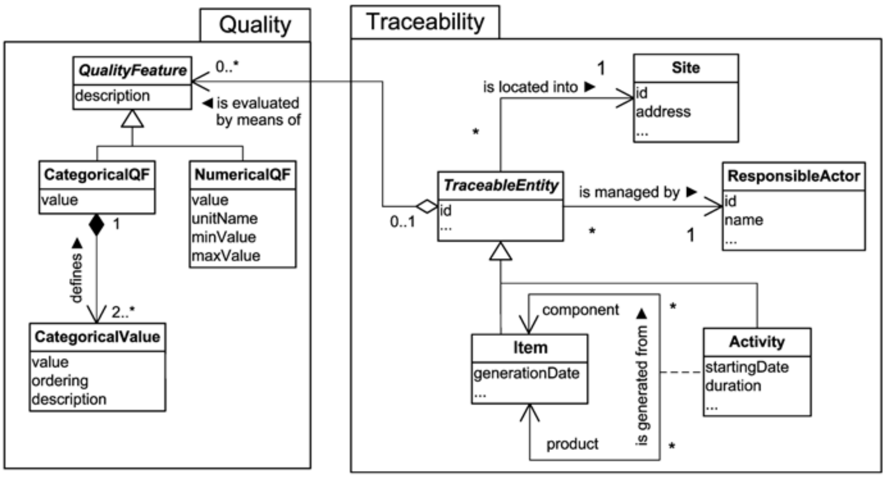


Fig. 20.2 UML class diagram of the traceability data model

able to retrieve the information about the site where the item has been processed or stored. Both *Site* and *ResponsibleActor* are characterized by a number of attributes that summarize all the information required for traceability. The association *is generated from* states that each item may be generated from zero or more items (zero in the case of an initial item). The generation is ruled by an activity.

Fig. 20.3 shows an example of the objects used to record an activity: a filler/packer purchases a red wine cask from a transit cellar, and carries it to her/his storehouse by a truck. The input and the output items of the activity are definitely the same cask. However, transit cellar and filler/packer typically identify the cask in a different way. Further, transit cellar and filler/packer are, respectively, responsible for the output and the input items. Therefore, for traceability purposes, input and output items are different. Thus, several different instances of class *Item* can correspond to a unique physical item (the same cask in the example).

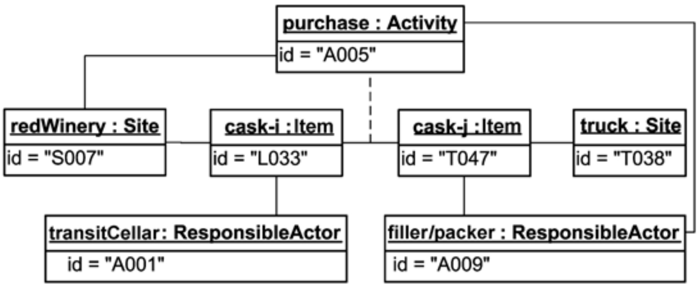


Fig. 20.3 Objects involved in recording the actual execution of a simple activity

In Fig. 20.4, a UML sequence diagram describes a possible message exchange within a purchase activity. We refer to a distributed model with no central tracking management. Here, the actor responsible for an activity is also responsible for recording and managing the relation between input and output items. The transit cellar communicates the global identifier of the input item to the filler/packer, who is in charge of binding such an identifier to the other corresponding identifier for the output item. This association allows both item tracing and item tracking. Typically, the global identifier is attached as barcode or RFID tag to the item. Thus, part of the communication consists of reading item identifiers (by means of appropriate devices) at successive supply chain actors.

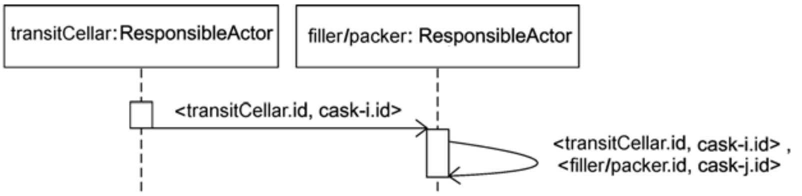


Fig. 20.4 Sequence diagram of a purchase activity, in a distributed model

In order to retrieve the history of an item, each actor of the supply chain has to communicate with its trading partners. In fact, legally, the requirement [22, 26, 18] for traceability is limited to ensure that businesses are at least able to identify the immediate supplier of the item and the immediate subsequent recipient (one step back-one step forward principle), with the exemption of retailers to final consumers. The data exchange must of course be carried out in a secure and reliable way.

Quality requirements often play a crucial role in modern business process management, and thus they deserve particular attention in the corresponding traceability systems as well [23]. The ISO 9000 standard [14] defines quality as the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs. To meet quality requirements, we introduced the *Quality* package shown in Fig. 20.2. This package contains the abstract class *QualityFeature* (QF), which includes a description of the feature itself and a collection of methods to set and retrieve feature values. Values can be either categorical or numerical. *CategoricalQF* and *NumericalQF* concrete classes implement features that can assume, respectively, categorical and numerical values. *CategoricalQF* contains a set of *CategoricalValue* objects, which define the possible values. A *CategoricalValue* is characterized by the value, a description, and an ordering value. This last item can be used whenever ordered categorical values are needed. *NumericalQF* is qualified by the value, the unit name (for instance, “Kg” for “weight” quality factor), and the minimum and maximum values. This class organization allows dealing uniformly with different quality features. Fig. 20.5 shows an example of object diagram that describes the quality features “color intensity” and “rating” associated with item cask-i of wine. Color intensity can assume numerical values in the interval 1-10. Rating

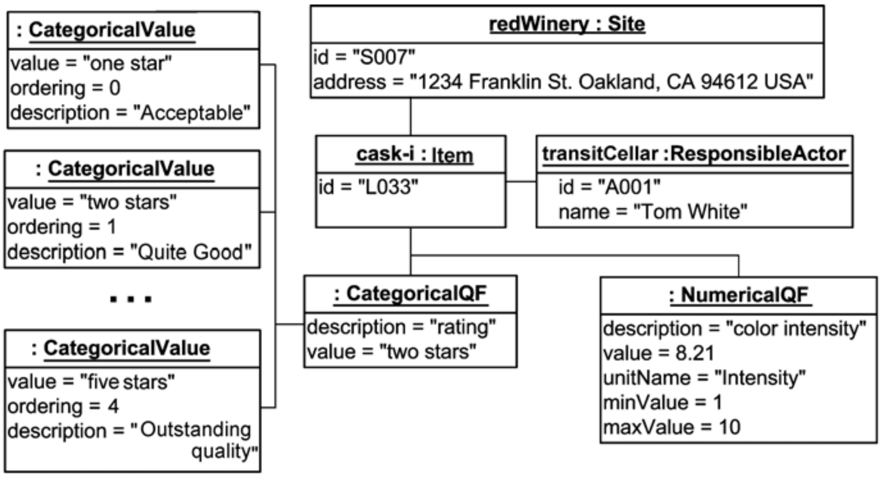


Fig. 20.5 Example of objects related to quality features

takes the wine excellence into account. Here, excellence is evaluated by employing a 1- to 5-star rating system [5].

20.4 A Transactional Model for Process Tracking

The full comprehension and monitoring of what actually happens along the supply chain requires not only a precise data model for the involved assets, but also a clear understanding of the item temporal progression towards successive stages in the supply chain. In a nutshell, a simple formal characterization of the item "history" is needed for the investigation on the actual requirements of the overall traceability system. The key observation is that the item progression is determined by *activities over it*, and thus its behavior can be described recording the activities that a generic item may undergo.

A transactional model describes the way in which the system can use transactions in message flows to accomplish certain tracking tasks and tracing results. From a tracking perspective, each activity that terminates correctly generates some item, and for each generated item a proper business transaction is recorded by the traceability information system. A business transaction is an atomic part of work that can be associated with the activity. For instance, from an activity with N output items, a set of N independent transactions can be tracked. A single transaction cannot be decomposed into lower level independent tracking pieces of information. A business transaction is a very specialized and very constrained semantics designed to achieve product state alignment when needed by third parties. As a transaction, it must succeed or fail, from both a technical and business protocol perspective. If it succeeds from both perspectives, it can be designated as a piece of the item history. If it fails from any perspective, it should not leave any trace of its existence.

In the following, an exact specification of the content of a transaction is provided. Let us suppose that an *item* is globally identified by the responsible actor ID (*Axx*), the site ID (*Sxx*), the item ID (*Ixx*), and the generation date-time (*Dxx*). Similarly, an activity is globally identified by the responsible actor ID, the site ID, and the activity ID (*Txx*). Indeed, considering further constraints, it could be possible to identify an item with a subset of this data. For instance, let us consider a product with a simple production process consisting of a number of serial transformations, with no fork and join of activities, such as *fermentation*, *aging*, *packing* and *transport* of home-made wine. If a unique RFID tag is used for each transformation, then the item ID is enough to identify the item at each production stage. However, this requirement is very expensive in terms of tags. If a unique tag is used for the entire item history, then date-time is needed to distinguish the item at different processing stages. Hence, in each transaction, the item ID and the date-time are supposed to be necessarily known. The pair (*Ixx*,*Dxx*) allows identifying an item in a specific stage of the supply chain, even if the RFID tag is re-used after the item has been sold. To follow the production path, when a new tag is applied to the output item, it is important to keep track of the input item ID [2].

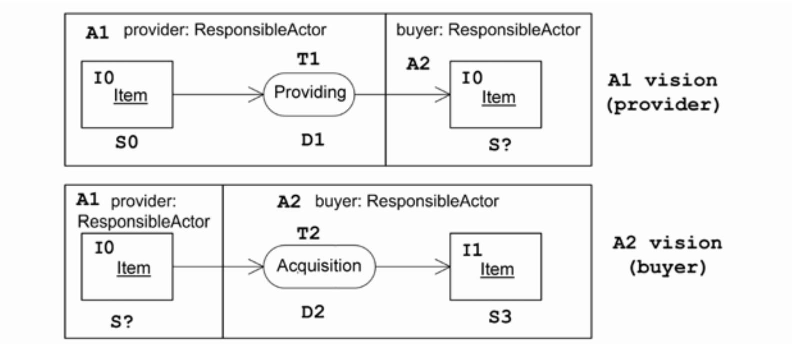
It is worth noting that the times recorded in transactions can play a crucial role in the tracking of items. For this reason, a clock synchronization mechanism among the distributed units has been realized. More specifically, each *SU* is periodically synchronized with a global Internet time clock service, whereas each *TU* is automatically synchronized with the related *SU* during the daily start-up. This two-level synchronization process allows a sufficient precision. Indeed, the actual precision needed to determine an ordering between production activities is very coarse with respect to the clock technology available on digital devices.

Together with the item, some contextual information is fundamental to support a series of tracing processes, which need to be connected with the real world at a business level. For instance, when some contamination event occurs, it is important to know *who* and *where* to investigate, and also further features of the item itself. Hence, in a general traceability model transactions have to contain at least the input/output items, their site and their responsible actor.

All the possible transactions can be represented by using the following two patterns.

a) providing-acquisition. Fig. 20.6 represents a scenario of providing-acquisition of an item. At the instant *D1*, the actor *A1* provides the actor *A2* with the item *I0*, which was stored at the site *S0*. At that moment, *A1* could not know the site in which *A2* will store the item, and then, in her/his vision, that site is denoted by *S?* (unknown site). This is usual, for instance, if the two actors belong to different companies, or if some module has not been properly configured. In this case, the transaction will have an undefined output site (transaction *TR1* in Fig. 20.6).

Similarly, at the instant *D2*, the actor *A2* acquires the item *I0* and stores it in its own site *S3*. However, he cannot know where the item was previously stored. Again, in this case the acquisition transaction will have an undefined input site (transaction



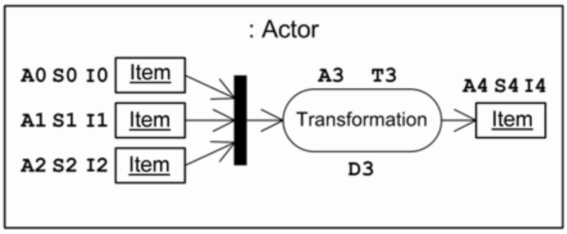
```
TR1: [A1,S0,I0] -> providing   (T1,A1,D1) -> [A2,S?,I0]
TR2: [A1,S?,I0] -> acquisition (T2,A2,D2) -> [A2,S3,I1]
```

Fig. 20.6 A scenario of the *providing-acquisition* transactions

TR2 in Fig. 20.6). Note that, in Fig. 20.6, the item is identified by two different RFID tags before and after the acquisition, i.e., *I0* and *I1*, respectively. On the other hand, if the RFID tag is kept, *I0* will be equal to *I1*. Note how, starting from the input item of the transaction *TR2* (i.e., [*A1*, *S?*, *I0*]), and replacing its actor (i.e., *A1*) with the actor in the output item (i.e., *A2*), it is possible to derive the output item of the transaction *TR1* (i.e., [*A2*, *S?*, *I0*]). This means to identify the transaction *TR1* with some data available in the transaction *TR2*, i.e. a step backward in the tracing back. If more than a transaction with the same output item is available, the transaction *TR1* closest in time to *TR2* is considered (i.e., with *D1* such that *D1* is closest to *D2*). Vice versa is also valid for a step forward (tracing forward).

b) transformation. In the case of processing activities that are internal to a company, a group of *N* items can be transformed into a group of *M* items, via splitting, merging, moving, processing, etc. This activity can be represented as a series of *M* transformations of *N* items into an item, having the same items as input. Fig. 20.7 describes a scenario with three input items. Here, at the instant *D3*, the actor *A3* performs the activity *T3*, taking as inputs the three items, *I0*, *I1* and *I2*, and giving as output the item *I4*. The input items were stored at the sites *S0*, *S1* and *S2*, respectively, and owned by the actors *A0*, *A1* and *A2*, respectively. The output item is stored at the site *S4*, and owned by the actor *A4*. Note that, in this transaction, tracing back and forward are simpler to perform with respect to the providing-acquisition transaction, because sites are known.

As an example, let us consider a simplified wine supply chain. The starting point of the supply chain is the harvesting of wine grapes (from nature, in our simplified setting). In the first place, this can be accomplished using mechanical harvesting or traditional hand picking one. Subsequently, during fermentation, yeast interacts with sugars in the juice to create ethyl alcohol. Fermentation may be done in stainless steel tanks, in an open wooden vat, in a wine barrel and even in the wine bottle itself. Hence, during the aging of wine, complex chemical reactions involving sugars, acids



```
TR: {[A0,S0,I0], [A1,S1,I1], [A2,S2,I2]}
    -> transformation (T3,A3,D3) -> [A4,S4,I4]
```

Fig. 20.7 A scenario of the *transformation* transaction

and tannins can alter the aroma, color, mouth feel and taste of the wine, in a way that may be more pleasing to the taster.

This simple supply chain can be modeled as depicted in the UML communication diagram shown in Fig. 20.8. For simplicity, we have supposed that harvesting, fermentation, aging, packing and transport are performed by the same supply chain actor. Actually, this is typically the case especially for high quality productions. We have denoted this actor as *wine maker*. In the figure, *nature*, *wine maker*, *shop* and *customer* are the different *ResponsibleActors*, and they interact according to given activities, possibly producing new items. The activity ordering is specified by the numbers associated with the shown procedures.

At the beginning, the *wine maker* performs an acquisition from the *nature* (harvesting) and creates a new item. Then the *wine maker* performs two transformations (fermentation and aging): each transformation produces a new item. Finally, the *wine maker* provides (transport) the shop with the wine and generates a new item. The *shop* performs an acquisition (buying), which produces a new item. When the *shop* provides (sale) the wine to the customer, it creates a new item. The *customer* comes after the last responsible actor of the supply chain: he/she does not create any item because his/her acquisition has not to be traced.

As highlighted in the last example, the tracking process along the chain production possibly generates and manages a huge amount of data records. In order to allow tracing procedures to remotely retrieve such data, a pervasive architecture is needed. This aspect is detailed in next section.

20.5 An Architectural View of the System

Let us consider more specifically the architectural view of the traceability system. Fig. 20.9 shows a deployment diagram containing different kinds of units. The proposed traceability system comprises different *Tracking Units (TUs)* equipped with RFID or code bar readers. A *TU* gathers data and transmits them to a *Storing Unit (SU)*. *SUs* are in charge of keeping local production data, supplied by *TUs*, according

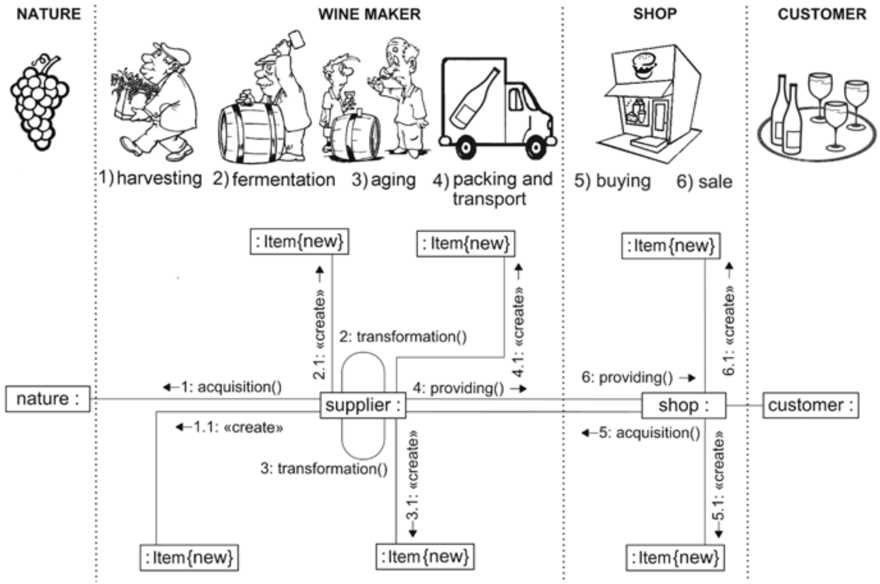


Fig. 20.8 Communication diagram for a simplified traceability system in wine production

to some criteria. *Analysis Units (AUs)* steer business process analyses and harvest data supplied by *SUs* in terms of pieces of a global tracing problem. *TUs* can be hosted by a mobile device (e.g., PDA or smart phone equipped with an RFID reader), or fixed device (e.g., bank reader, door gate reader). Further, *TUs* allow data harvesting supported by user agents, because *TUs* are self-configured on the basis of the local context. More specifically, there are some *Context Units (CUs)*, which are able to provide a local business process context. Indeed, *CUs* and *AUs* are strictly related to each other. For a given business analysis, an amount of data need to be collected, and this process can be guided configuring the *TUs* via *CUs*. Furthermore, *CUs* contain also the definitions of the quality features used by *AUs*. Thus, for instance, when quality attributes such as color intensity and rating have to be inserted, the *TU* is automatically configured by the corresponding *CU* so as to show appropriate interface widgets. Finally, there are some lookup services for *SU*, accomplished by *Registry Units (RUs)*. The traceability system is based on a distributed architecture in which data is managed according to a "pull" model [2]. In the pull model, at the *tracking stage*, data is stored at the site where it was generated. At the *tracing stage*, an *AU* actively requests a particular analysis from the system. Hence, *SUs* wait for a pull request to reconstruct an item history. When a pull request arrives, only related tracing data is collected and returned to the *AU*. According to the service-oriented paradigm, the communication between *SUs* and *AUs* relies on an asynchronous message-centric protocol, which provides a robust interaction mechanism among peers, based on the SOAP/HTTP stack. On the other hand, the communication between *TU* and the other units can be proficiently achieved using a more efficient and lightweight XML-RPC/HTTP based interaction.

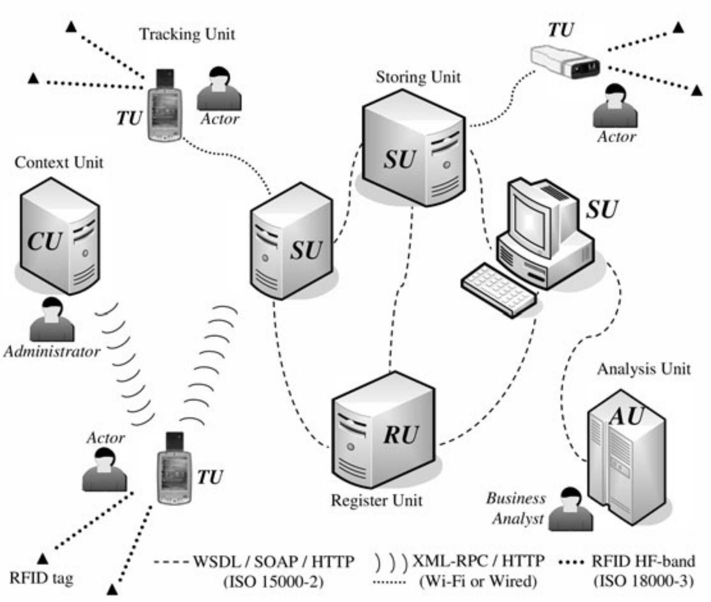


Fig. 20.9 An overall Deployment Diagram of the Traceability System

20.6 Conclusions

In this chapter, we have proposed a solution for wine chain traceability that relies on a general model and a pervasive and mobile architecture, employing RFID technologies. After a business and technological overview, encompassing wine supply chain requirements, key properties of a data representation model have been pointed out. Hence, a transactional view of process tracking has been provided, together with the discussion of the application of the system to a simplified example. Finally, the detailed architecture has been discussed.

The system has been realized considering a real wine supply chain in Tuscany, made of more than a hundred small (family) grape growers, four medium-large wine producers, three fillers/packers and a large wholesaler (a consortium). In terms of processes, such supply chain comprises 20 different types of production activities, 37 types of quality features and 14 types of sites. The participating enterprises are characterized by different levels in technological competence, economic resources, and human skills. In this setting, the system has been oriented to support the following goals: (i) to reduce the time and effort needed to execute every-day transactions; (ii) to significantly lower the rate of errors that are currently caused by replicated data entries and manual interventions; and (iii) to reduce the software maintenance and usability cost.

References

1. Auto-ID Labs, `http://www.autoidlabs.org` (accessed 2010)
2. Bechini, A., Cimino, M.G.C.A., Marcelloni, F., Tomasi, A.: Patterns and technologies for enabling supply chain traceability through collaborative e-business. Information and Software Technology 50(4), 342–359 (2008)
3. Bertolini, M., Bevilacqua, M., Massini, R.: FMECA approach to product traceability in the food industry. Food Control 17(2), 137–145 (2006)
4. Bevilacqua, M., Ciarapica, F.E., Giacchetta, G.: Business process reengineering of a supply chain and a traceability system: A case study. Journal of Food Eng. 93(1), 13–22 (2009)
5. Broadbent, M.: Michael Broadbent's Vintage Wine. Websters Int. Publishers, London (2002)
6. Cheng, M.L., Simmons, J.E.L.: Traceability in manufacturing systems. International Journal of Operations and Production Management 14(10), 4–16 (1994)
7. Donnelly, K.A.-M., Karlsen, K.M., Olsen, P.: The importance of transformations for traceability - A case study of lamb and lamb products. Meat Science 83, 68–73 (2009)
8. European Federation of Wine and Spirit Importers and Distributors (EFWSID), Voluntary Code of Practice for Traceability in the Wine Sector (2001)
9. EPC Global, `http://www.epcglobalinc.org` (accessed 2010)
10. Gandino, F., Montrucchio, B., Rebaudengo, M., Sanchez, E.R.: On Improving Automation by Integrating RFID in the Traceability Management of the Agri-Food Sector. IEEE Transactions on Industrial Electronics 56, 2357–2365 (2009)
11. GS1 Working Group, Wine Supply Chain Traceability, GS1 Application Guideline, Brussels, Belgium (September 2008)
12. GS1 Traceability, `http://www.gs1.org/traceability` (accessed 2010)
13. ISO, ISO 8402:1994, Quality management and quality assurance, `http://www.iso.org`
14. ISO, ISO 9000 family of standards (2006), `http://www.iso.org/iso/en/iso9000-14000/index.html`
15. ISO, ISO 9001:2000 and ISO 9001:2008, Quality management systems - Requirements, `http://www.iso.org`
16. International Telecommunication Union, The Internet of Things, ITU Internet Reports, Geneva, Switzerland (2005)
17. Jansen-Vullers, M.H., van Dorp, C.A., Beulens, A.J.M.: Managing traceability information in manufacture. Int. Journal of Information Management 23(5), 395–413 (2003)
18. Ministry of Agriculture, Forestry and Fisheries of Japan, Guidelines for Introduction of Food Traceability Systems (March 2003)
19. Moe, T.: Perspectives on traceability in food manufacture. Food Science and Technology 9, 211–214 (1998)
20. Mouseavi, A., Sarhadi, A., Lenk, A., Fawcett, S.: Tracking and traceability in the meat processing industry: a solution. British Food Journal 104(1), 7–19 (2002)
21. Opara, L.U.: Traceability in agriculture and food supply chain: A review of basic concepts, technological implications, and future prospects. Journal of Food, Agriculture and Environment 1(1), 101–106 (2003)
22. Regulation (EC) n. 178 of the European Parliament and of the Council of January 28, 2002, ch. V (2002)
23. Food Standards Agency of Actored Kingdom, Traceability in the Food Chain - A preliminary study (2002), `http://www.foodstandards.gov.uk/news/newsarchive/traceability`

24. Roussos, G.: Enabling RFID in retail. IEEE Computer 39(3), 25–30 (2006)
25. Sasazaki, S., Itoh, K., Arimitsu, S., Imada, T., Takasuga, A., Nagaishi, H., Takano, S., Mannen, H., Tsuji, S.: Development of breed identification markers derived from AFLP in beef cattle. Meat Science 67, 275–280 (2004)
26. U.S. Food and Drug Administration, regulation 21CFR820, Title 21: Food and drugs, subchapter H: Medical devices, part 820 Quality system regulation, (revised April 1, 2004), `http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=820`
27. Wang, X., Li, D.: Value Added on Food Traceability: a Supply Chain Management Approach. In: IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI 2006), Shanghai, China, June 21-23, pp. 493–498 (2006)