Product Traceability Information: An Approach for Information Linking

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Abstract

Traceability is a concept relating to all types of products and it is strictly linked to supply chain management, aiming to keep trace of the products along their entire lifecycle. In this work a new methodological approach to realize a traceability system is presented. The system developed has been structured with the aim to give a model that can be applied to the most common production realities. The information needful to reconstruct a product history have been represented in the way of *information linking* and organized through the well known Entity-Relationship (*ER*) models. The approach presented can be considered as the evolution of the actual ISO9001 Quality Management Systems that at present are not able to give practical tools and/or methodologies to realize a traceability system.

Keywords: Product Traceability, Supply Chain, Entity Relationship Model

1. Introduction on Traceability Requirements

Quality certification according to ISO9001 standards requires that firms for their products have to be able to track every jobs, assembling steps, and equipments needful to realize it (internal traceability). In addition to that, for each type of product the same firm has to be able to locate every delivered ones on which analysis and/or corrective actions has to be made, due to an unconformity found on a certain component or on a certain job (external traceability). Nevertheless the same norms, even giving a precise traceability definition and well defined tasks for a traceability system, do not give any indication related to a guideline to realize it, both in order to parts identification and in order to the fundamental information related to the product and their correct linking.

With the aim to cover this fault we have realized a traceability model, named Traceability Link System – TLS - which main steps can be structured as follows (Figure 1):

- **identification** of the product;
- **data linking**
- **information storing**
- **development** of product history.

It is notoriously known that to identify a workpiece different tools can be used, both to group classification and to piece-by-piece identification.

We have classified them as follows:

- ***Workpiece Serial number (S/Nc)***, for piece-by-piece identification;
- ***Part Number (P/N),*** notoriously used to identify a group of components homogeneous with respect to their production process and/or their final role on the finished product;
- ***GT codes,*** for manufacturing systems organized with Group Technology criteria, in this case code generation can be realized and managed through different systems such as Opitz, Miclass, Code, etc;
- ***Lot number (L/Nc)***, related to a group of component which shares a production period or a date.

In addition to the above classification we will name as **Product Serial number – *S/Np* –** the specific code which is generally utilized to identify a finished product during its entire life-cycle, while with ***L/Np*** we will notice the lot number of the same product.

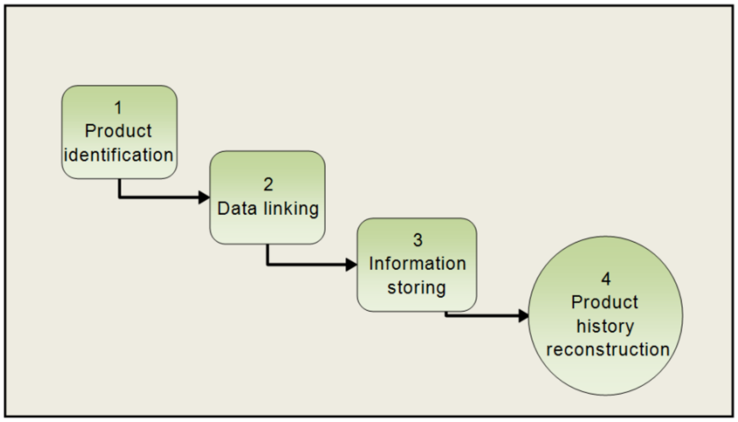


Figure 1: The main steps of a TLS

The present work aims to define a traceability model that can be applied to the most common production realities in order to follow and manage all the information embracing the processes of a product lifecycle. These information are organized according to the Entity Relationship models.
The remainder of this paper is structured as follows: Section 2 provides a literature review about traceability definition and developed approaches in IT field to manage the topic. In section 3, a deeper description of the proposed Traceability Link System is provided, by fronting product location problem in section 4. In section 5, the application to a case study is described while last section deals with conclusions.

2. Literature Review

Traceability is a concept relating to all products and all types of supply chain. Nowadays, in an economic system in which companies compete against each other in an environment largely founded on customer satisfaction, traceability is an indispensable instrument in obtaining the market consensus. Direct benefits are supply chain optimization, product safety, and market advantages (Regattieri et al., 2007).
Product traceability allows to maintain records of all materials and parts from purchasing to finished goods where a unique number identify a part, batch or a finished product; it provides the ability to identify and track a product or a component along its lifecycle facilitating product identification in case of possible defects. Product tracing can be conducted from various perspectives. Component, production, and distribution perspectives are the three major perspectives. Product tracing can also be conducted according to different levels of details, either by lot or by piece (Yuan et al., 2011). Rábade and Alfaro (2006) showed the reasons why a firm decides to implement a traceability system, and described how the use of a traceability system has provided it with many qualitative and quantitative advantages along the different stages of the supply chain, manufacturing operations and inventory and logistics activities.
A traceability system can be classified into two typical phases: tracking back and tracking forward (Moriyama et al., 2004; Taniguchi and Sagawa, 2005). A typical example of tracking back is tracking when, where and by whom were the materials of a certain product processed; on the other hand a typical example of tracking forward would be to track where and by whom products made of certain parts are stored or used (Taniguchi and Kobayashi, 2005).
To provide traceability, a system must be able to identify products item by item and, in addition it must be able to record product data per item (Wakayama et al., 2006). Rábade and Alfaro (2006) analysed buyer–supplier relationship's influence on traceability implementation in the vegetable industry, and showed the way traceability helps to reinforce the degree of coordination in the supply chain.
In the specific case of product traceability, it should be necessary not only to focus on the design behind the development process, but also on components and raw materials used to fabricate the product. Furthermore,

the history of all processes involved in product development cycle and delivery should be retained (Ouertani et al., 2011). Several researches have applied traceability to food products in order to front at least the consequences of possible food safety crises (Saltini and Akkerman, 2012). In fact, the better and more accurate a traceability system is, the faster a firm can identify a food safety problem, resolve it by withdrawing or recalling the implicated products and effectively investigate what caused the problem (Karlsen et al., 2011; Regattieri et al., 2007; Ruiz-Garcia et al., 2010).
In addition, due to the rapid development in management and information technologies, traceability has become a consumer requirement for products together with on-time delivery, multiple functions, high quality. Yuan et al. (2011) developed a product tracing module (TRC) for enterprise resource planning system (ERP) in order to trace product problems efficiently and in time offering to industries a solution for products traceability. Shengping et al. (2010) designed and built a traceability platform as well as developed data acquisition system for bee products based on agent technology and multi-agent system; on this basis, PDA-based and PC-based data acquisition systems are developed as well as key control points are provided in bee product traceability. Thakur et al. (2011) introduced a new methodology for modeling traceability information using the EPCIS framework and UML state-charts. The method follows the approach of defining states and transitions in food production by providing illustrations from two supply chains; frozen mackerel production and corn wet milling processes. All states and transitions for these processes as well as the information that needs to be captured for each state are indentified in order to provide improved description and integration of traceability information. Information exchange technologies such as EPCIS are used for monitoring events based on logistic processes. Thakur and Donnelly (2010) conducted in-depth analyses for a soybean value chain to determine the importance of traceability information by developing a UML class diagram to model the product, process, quality and transformation information at any link in the chain.

3. The TLS fundamental information and Entity Relationship models

The information needful to reconstruct a product history, i.e. the whole data that are to be stored inside databases able to manage a traceability process, have been represented in the way of *information linking* and organized through the well known Entity-Relationship (*ER*) models. With this kind of link representation we are able to specify and define the logical properties of the data to be stored and their informative contents, allowing us to realize a conceptual database oriented to define the data architecture of the archives which support the TLS.
The Traceability procedures developed, and related data links realized with ER models, have been characterized both in order to the presence or the absence of the S/Nc on each component and in order to the production policy used by the firm, i.e. **Lot-for-Lot** policy (for production systems scheduled according to *Just in Time* concepts) and **EOQ** policy, that can be regarded as the most general instance case. For each type of policy we have assumed that a certain unconformity found on a component can be reasonably limited to those products that are in the same purchasing lot, whatever be the production phase which has caused that unconformity.

3.1. Lot for Lot policy

With this policy we have a direct correspondence between the number of purchasing lot (**L/Nc**) and the number of the production one (**L/Np**); so the ER link (Figure 2) to realize will be of the type:

$$\mathbf{L/Nc} \rightarrow \mathbf{L/Np} \qquad [\text{ER1}] \qquad (1)$$

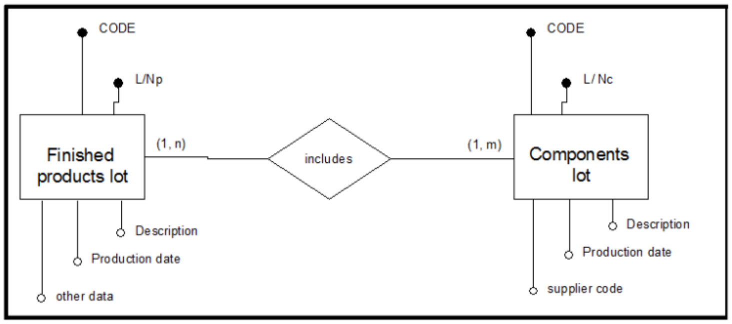


Figure 2: ER1 model for lots linking

When the component is identified with S/Nc this link can be made during each production step because it is always possible to identify the single component with its S/Nc and the related L/Nc. While when the S/Nc is not present, in addition to realize the ER1 link every time the parts are taken out from their packages (where the lot number is written), we will need also the following relation that allows to link the L/Np with the S/Np (Figure 3) of each product included in that lot:

$$\boldsymbol{L/Np \rightarrow S/Np \ \ included\ into\ L/Np} \qquad \text{[ER2]} \tag{2}$$

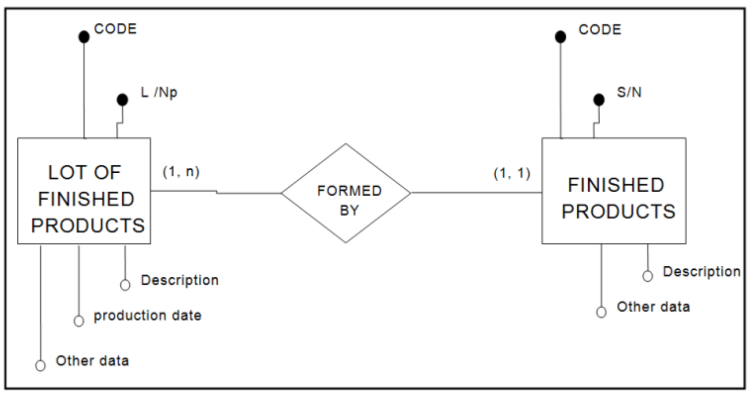


Figure 3: ER2 Model for lot formation

ER1and ER2 allows to realize a data structure that, in case of Lot-for-Lot production, is able to link the S/Np and its related information to the L/Nc of the component; infact if with ER2 we are able to link the S/Np of the product to its L/Np, the ER1 makes us able to link the before mentioned L/Np to the L/Nc of the component that has to be checked.

3.2. EOQ policy

This kind of production/purchasing policy can be regarded as the most general instance, in which a part of the lot of components purchased or produced is put into the warehouse (to be used for one of the next L/Np) and another one, after incoming analysis, could have to be sent back to the supplier or subjected to corrective treatments.

In spite of that, information related to the finished products shall be no more of global behavior (i.e. linked to the L/Nc) but are to be related to each single component (i.e. linked to its S/Nc).

Nevertheless the component could have or could not have the S/Nc; so when the S/Nc is present the system implements the following link:

$$\boldsymbol{S/Np \rightarrow S/Nc} \qquad \text{[ER3]} \tag{3}$$

while, for those components with **S/Nc**, we have provided the system of the additional ER4 link:

$$\boldsymbol{S/Np \rightarrow L/Nc} \qquad \text{[ER4]} \tag{4}$$

Now we have to point out that in this case the ER4 link is univocal when we link a finished product to a lot of components, while it is a one-to-many relation in the contrary case because, as we told before, a lot of components can be found on more than one lot of finished products. In this way, also with this management policy, the last two relations, ER3 and ER4, are able to link the first information available for a product (S/Np) to those related to its components (S/Nc or L/Nc). In Figure 4 we show the flow chart of the entire procedure, as it has been implemented on our prototype software. This procedure is executed by the system each time a part is assembled on one of the finished products that has been planned in production mix.

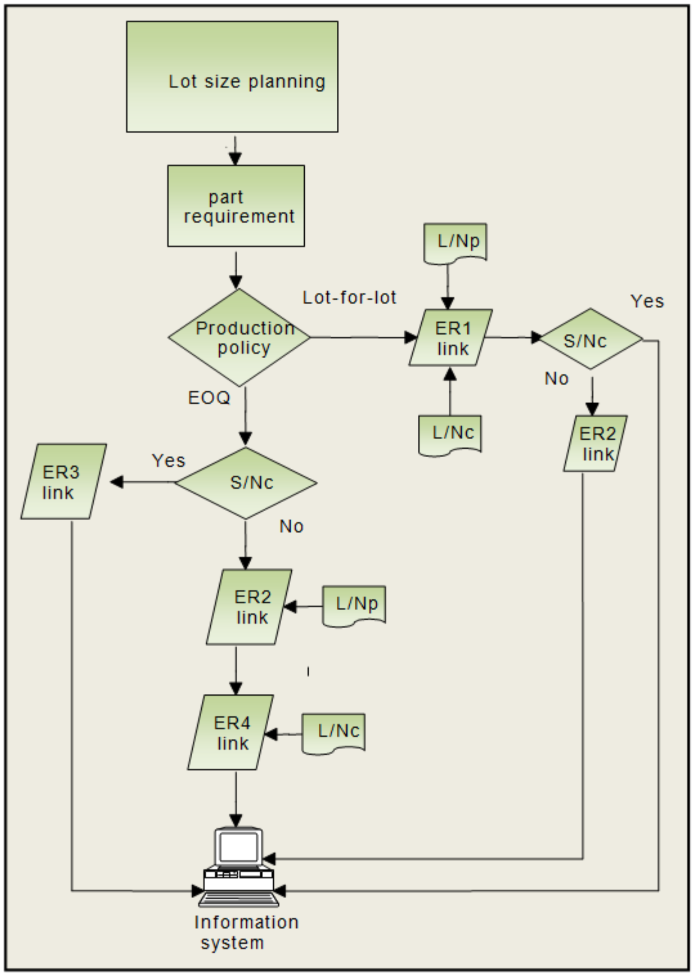


Figure 4: Flow chart of the information storing step

4. Location of the products

The final step is to define the informative flow and the logic sequence of every information for the model in this way structured.

With this aim, also in this step, we have realized the C*onceptual Flow Charts* of Figure 5 and 6, which have been distinguished with respect to the purchasing system utilized by the firm. The peculiarity of these flow charts consists of the presence of the *ER Events* that allow, by the before mentioned links, to define the correspondence between the input of an event and its output.

So, in case of Lot for Lot policy, the software works as shown in Figure 5, where it is possible to point out that the presence of a S/Nc on a component, in spite of the one-to-one link, allows a faster product location with respect to the case in which the S/Nc is absent (one to many link). A product unconformity forces a phase of faults analysis with the aim to identify the cause and the component which generated the unconformity; once this step is fully completed, the use of ER relations shown in the previous sections allow to establish the serial number of the delivered component.

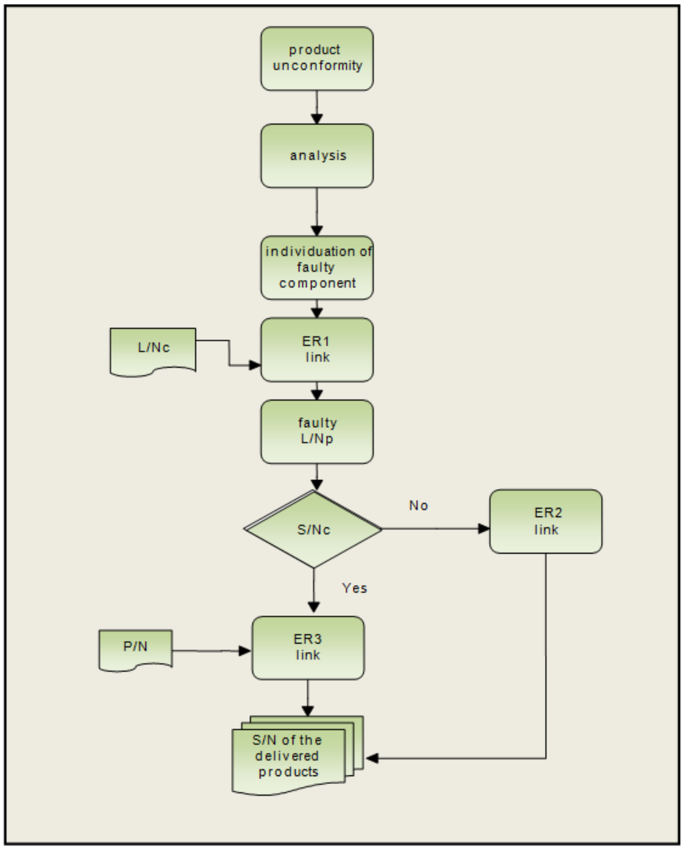


Figure 5: Information flow with lot-for-lot policy

When purchasing and/or production policy needs the adoption of lot-single-components link, the flow chart of the traceability process becomes that one showed in Figure 6.
As for the previous case, a faults analysis procedure allows to define the faulty component in case of a product unconformity. According to the presence of the S/Nc, different ER relations are used to determine the S/N of the delivered products.
Now it is possible to see that in this last case the informative flow is more complex in spite of the impossibility to establish an univocal correspondence between the lot of finished products and its components.
We have to point out that the system in this way structured is able to operate both when the traceability process starts from the market (*Feedback Traceability*), and when the firm find by itself an unconformity on a product or a lot of it (*Direct Traceability*).

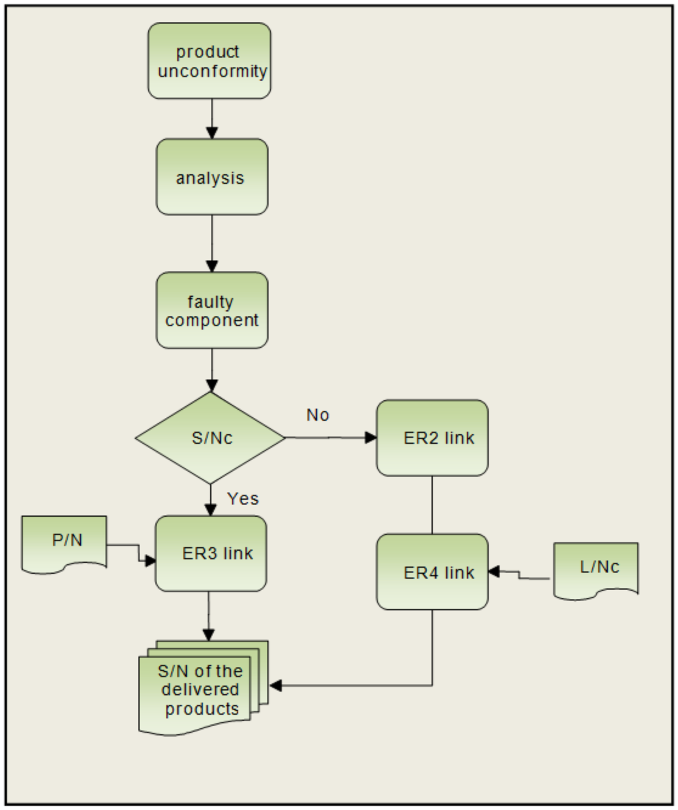


Figure 6:Information flow with EOQ policy

In this way with any purchasing policy and any kind of part identification, after having found an unconformity on a component of a product, our TLS is able to locate on the market every products (S/Np) in which that component has been assembled on, identifying production processes to correct, equipment used and every related information. That can be regarded as the most important and final task of a traceability system.

5. A Case Study

The system proposed has been applied in an electromechanical company, operating in telecommunication networks area, where there was an internal traceability system realized marking components with S/Nc made by barcode labels.

In spite of the complexity of the final product the purchasing policy was of Just in Time type for those highly complex and expensive components, while for the most common parts an EOQ policy was adopted. With this kind of mixed purchasing policy the external traceability was obtained only for those components purchased with Lot-for-Lot policy, for which it was possible to relate the L/Nc of a faulty component to the L/Np of its related product.

In this way our prototype system has been applied to those components purchased with EOQ policy, defining the information that are to be related to finished products and those for components to be assembled on. In addition to that the traceability system has been provided of the data related to the dies used to realize some of the components, implementing the following data structure (table 1):

Table 1: The information provided for the system

Finished product	Component	Die
S/Np	L/Nc	Id. Number
Product name/description	Drawing number	User
Technical specification	Name/description	Weight
Customer destination	Materials used	Production year
Test document	Production cycle	Owner
Production cycle	Test document	Cycle time
	Supplier name	

One of the logical flows related to a query, and its related interactions between databases, can be represented in Figure 7, where with dashed line we have identified the informative flows, while with continuous line we have represented the actions made on the system.

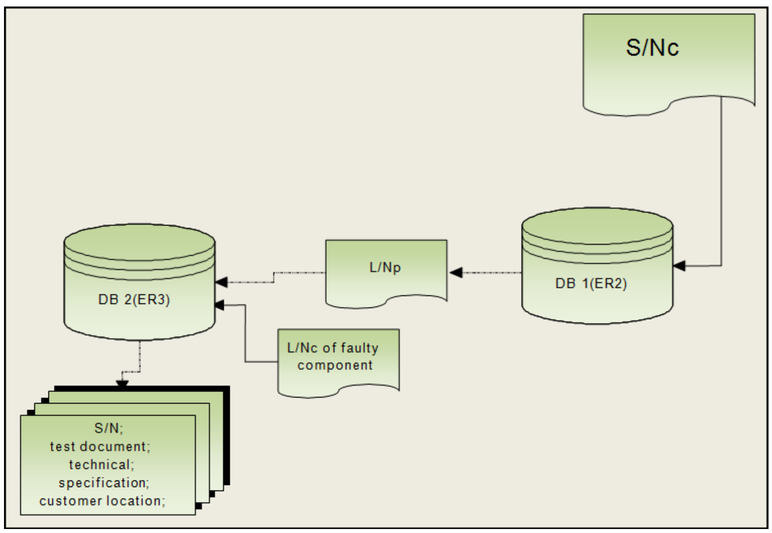
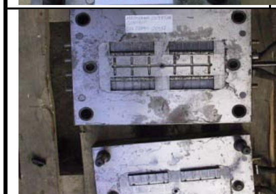
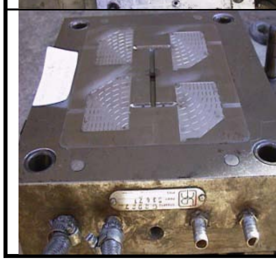


Figure 7: Information flow during product location

For some of the most critical products we have measured times needful to locate every products delivered, their technical information and final users, before and after the implementation of our prototype system (Table 2). The measurement has been made in the most unfavourable case of *Feedback Traceability*, in which the firm has to track a product on the basis of few information coming from the customer. As we can see, in addition to a drastic reduction of location times in case of JiT policy, we have obtained good results also for those components purchased with EOQ policy for which, beforehand, product spotting and history reconstruction was impossible. In this sense, the approach guarantees product traceability and offers good functionalities for what concerns the traceability time. TLS offer to the firm the possibility to identify additional products in case of EOQ policy and to perform this task sooner than before.

Table 2: some results obtained with TLS

Product	Purchasing policy	Traceability time (days)	
		Before	Actual
	**Just in Time**	5	0,2
	**EOQ**	Impossible	1
	**EOQ**	Impossible	1,5

6. Conclusions

The present paper has been realized within a research for a big firm operating in telecommunication appliances sector. The main purpose has been to provide a practical tool to allow the firm to trace products along their logistic chain with the aim to allow a fast product location for failures and defectiveness management. The software obtained from the developed methodology allows to trace product with respect to their stock and purchasing policy and allowed to the firm a high level of service with respect to the possibility to shorten product location during their working life and to make faster maintenance activities.
The research is now in progress with the aim to define a method for product traceability criticalities. Its results maybe the further development of this work.

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