Traceability information system for freight transportation chain

S. Bendriss, A. Benabdellatif, J. Boukachour, D. Boudebous

CERENE Laboratory: [Integrated Logistic Information System (I.L.I.S)]
Le Havre University, 25 Rue Philippe Lebon BP 1123, 76063 Le Havre Cedex, France
ben_sabri2003@yahoo.fr; {benabdellatif; boukachour; boudebous}@univ-lehavre.fr

ABSTRACT
In this paper we present our research works centered on a problematic which attract the attention of many researchers and decision maker, which is the traceability of the product.

we are interested more precisely to the traceability in the field of goods transportation, by proposing a modeling approach of the relative data to freight, the result of this modeling, was used in the form of a centralized database for the whole of the actors implied in the transport of freight, the base represents the hard core of an information system for the management of the traceability. To ensure the good performance of system and in order to feed our data base with the relative data with the goods transport chain, we propose a solution according to an architecture SOA, based on an exchange of message between the various actors of the freight transport chain.

Keywords: Traceability, Information Systems, freight transportation, Service Oriented Architecture,

1. INTRODUCTION
Currently, the professional sector of the conveyers and logisticians knows deep changes and sees growing the criticality of the information control for controlling the global supply chain. Moreover it should be noted than of the requirements of the just in time type for the provisioning of the line production involved an irreversible bringing together of the trades of conveyer and logistician, which is prolonged more and more in a true integration of the transport chain in logistics.

In order to meet this need for integration, adapted logistic services with a strong added value can be the key solution. Be able to guarantee the traceability of the transported goods is one of them [6]. Nevertheless, the task will not be as easy as that in the air, considering the current situation of the main actors of the goods transportation, in complete dissociation, not realizing, as part of the transport of the freight of the point of loading at the point of delivery. Whereas, an effective system of follow-up of the goods cannot be installation without guaranteeing a continuity of physical and informational flows relating to freight [1].

The objective would be thus, to implement an intermodal transportation system, goshawks of an information system for the management of freight traceability, in the shape of a community platform, in order to inter-connect the various physical networks of the means of transport.

The notion of the traceability which draws the attention of many decision makers, applied for the follow-up of the goods, consists in constantly knowing in “real-time” the position of the vehicles transporting the goods and/or the position of these goods themselves or their containers and, possibly, the conditions of transport (means of transport, duration, conveyer responsible, times envisaged for the delivery, conditioning…) [6]. Thus, the follow-up of the goods could enable us to reconstitute the route borrowed by the goods and the conditions of their transport, as it could also make it possible to identify the responsibilities for the various speakers, if a rupture is noted in the security of the chain of transport. Conversely it could also guarantee the continuity and the integrity of the goods if each speaker of transport is equipped with adapted procedures of safety.

In what follows we present the broad outlines of our research tasks, for the installation of an information system for the traceability of the goods through the stages of the freight transport of the point of loading until its final destination at the customer.

2. TRACEABILITY NEW AREA OF RESEARCH
Born in the middle of the 80's, the traceability, declined in multiple forms, will become in the coming years, a tool unavoidable for all the companies. Today, it concerns every branches of industry and either certain sectors such as the agroalimentary one, the pharmaceutical one, aeronautics...it proves to be essential for reasons other than purely logistic: confidence relation towards the consumer, lawful constraints and legal, standardization, recall of defective products etc. [3].

In this context, new currents research integrating the traceability emergent, in an implicit way in the subjects concerning the intelligent product and more explicitly within the communities centred on the product life-cycle management (PLM).

2.1 The traceability in a vision of intelligent product
Today the traceability of the products can be seen under a new angle centred on the concept of intelligent product [12]. In this part we will seek which relation exists between intelligent product and traceability.

In its work [12], McFarlane mentions, often, the supply chain is disturbed by problems caused by the not-synchronization of the matter flow and the information flow. One of the approaches to mitigate such problems is to establish a direct connection in network between a physical product and its data recording. With through this connection network, a product can interact indirectly with the operations which it undergoes. In this manner, the product becomes “intelligent” or more precisely “communicating”, and becomes able to support the information which is necessary to him to the good moment .

Thus, McFarlane states the characteristics of an intelligent product in the following way:

1. To have a single identification;
2. To communicate with its environment;
3. To memorize and manage clean information;
4. To have a language of dialogue and exchange of its information and states;
5. To take part in the decision-making processes during its evolution;
6. To supervise and control its environment.

A basic level of intelligence corresponds to a product which has only the first three characteristics mentioned above, while the level of intelligence highest requires totality of it. In the characteristics mentioned by McFarlane, one notes indeed whom the three first give a base sufficient for saying that an intelligent product is able to develop the basic functions of the traceability: identification, localization, the recording, the historization of the activities and the access to this history (defined by the standard ISO 8402)[7].

The more complex functions of the intelligent
products will result in improving each level which composes the logistic chain to reach a complete control of the product life cycle. In short, we can say that the traceability is one of the functions of an intelligent product.

2.2 The traceability in a product-centred system

Always in the vision of intelligent product, [4] mentions, the rigidity of certain companies structures can handicap them to answer the personalization of the products mass. Integration in the company is made by the information, whereas the element which is central in a production system having to ensure a personalized production on a large scale rather seems to be the product, while placing it in the system main part of the company as preaches it the international initiative of research and development IMS (Intelligent Manufacturing system) particularly by paradigm HMS (Holonic Manufacturing System) [11], [4].

According to Kärkkäinen [8], if it is considered, the intelligence and the decision-making must be distributed to the extreme (working station, transport resources, products...); the product becomes able to control his evolution, to say in which state it is and to collaborate with its environment. This system is described as “system controlled by the product”.

2.3 The traceability in the product life cycle

According to Garetti [2], the management paradigm of the product life cycle or PLM is the capacity to manage, to coordinate and to execute all the management and the engineering activities throughout product life cycle, until the delivery to the ultimate consumer, with acceptable use and acquisition costs. So the PLM integrates a large variety of disciplines, methods, tools, environments throughout product life cycle: the product development (PD), manufacture systems engineering activities (MSE), tools (CAD, CAPP, CAM, PDM)[7], and the enterprise engineering, activities and management tools (ERP, MRP, CRM, SCM)[7].

If we join the concepts of intelligent product, the PLM and the product-centered systems, we can say that through an intelligent product and adapted identification and communication technologies, it would be possible for us to find the history, the use and the localization of the product; this represents the very principle of traceability (ISO 8402).

We have could understand with what was evoked above that a reliable traceability cannot be concretized only by the construction of a coherent model for the representation of the product data and who represents one of the most crucial and complex activities, because if the model is not good, the applications will not answer initial waiting.

3. FIELD STUDIES INCLUDING TRACEABILITY

In what follows we present the literature on the various manners to integrate the traceability in a model or a representation. However, it should be mentioned that if the state of the art on the traceability is constantly update, the information systems integrating the traceability are poorly developed in literature. Moreover, none of found models shows how to link the product to information, nor how traceability is obtained.

In [5], it is mentioned that the traceability can be seen as a tree structure of genealogical type, graphically represented in the form of a tree. Thus, one of the tasks of traceability is to break down repeatedly nodes of the tree, until we find the final nodes. In the same way, Shinghal [16] indicates, a decomposition of a problem illustrated by a graph AND/OR can be used to represent the traceability problem.

One of the first theoretical approaches of the traceability is realized by [9], he proposes an ontology of traceability in project TOVE (Toronto Virtual Enterprise).This ontology introduces two concepts having to be traced: the TRU (Traced Resource Unit) and the primitive activity. The TRU is a single entity i.e., there is no other similar unit from the viewpoint of traceability. Practically, a TRU corresponds to an identifiable production batch. The primitive activity as for it is an activity not consisting of under activities. By their ontology the authors affirm that in an ideal traceability system, the capacity to trace the activities and the products is fundamental. The products and the activities are called the "central entities" and they exist only when they are described and considered individually. The principal contribution of Kim model is the assumption explicit on the single identification of each item.

Moe [13] uses the model created by Kim [9] and applies it to food industry. It provides a model more operational than the theoretical model of Kim. To do so, it defines for each central entity a series of essential descriptors which can be included in order to ensure an ideal traceability of products and activities.

The most recent work on the traceability modeling have been made by van Dorp [19] and Terzi [18]. Van Dorp, mentions for its part that the development of the traceability systems requires a precise representation of the system in question. For that, it is necessary to take into account a representation with the following elements [19]:

- The present objects in the system;
- Types of objects to locate or/and to trace;
- The interesting information on these objects;
- Relations between the objects;
- Integrity of representations and objects.

Thus, van Dorp shows an approach of design of an information system for the traceability of the goods flow.

He employs a modeling through graphs Gozinto, with represent a graphic list of the raw materials, parts, sets and subsets, transformed into finished products through a sequence of operations (or process). The representation of the data structure by Gozinto is indicated under acronym BOM (Bill Of Material). Then this graphic list is translated in a reference data model which is the base for the design of the traceability information system.

The composition of certain finished products is represented through the modeling of all the constituting materials and their various intermediate relations. When the sequence supplements assembly for the manufacture a finished product is ended, a multilevel list of batch called BOL (Bill Of Lots) is compiled. This list provides necessary information to determine the composition of an articles batch.

In the work of Terzi [18], are presented the preliminary results of the holonic approach for the product traceability. The authors propose a model in which the product supports the informational part for the traceability (Holon-product) throughout its life cycle. This model re-uses existing concepts around the enterprise standards like PLCS, MANIDATE, ANSI/ISA-95 and PLM@XML.[18] formalizes, under UML, the structure of the information system associated with the traceability product data. This model is still conceptual and it must be validated.

Starting from these observations and in order to add a brick in these problematic which attract the interest of many scientific, we present in the following an approach of modeling for the traceability management of the goods transported through their stages of transport as of the loading until their final destination.

4. TRACEABILITY INFORMATION SYSTEM FOR FREIGHT TRANSPORT

For set-up of our step based on the research tasks quoted previously, in fact, If we join the concepts of intelligent product,
the PLM and the systems controlled by the product we can say that through an intelligent product and adapted technologies of identification and communication, it would be possible for us to find the history, the use or the localization of the product which represents the principle even traceability (according to the standard ISO 8402).

It has to note that our traceability system of freight covers the stages upstream and downstream of the harbor and customs stages operations, and of the maritime transport generally realized in the harbor and customs information systems already existing.

Our system wants to be interoperable, compatible with a use in bosom SME, the system supports a whole of functions making it possible to ensure the traceability of the goods apart from the zones already covered by existing systems of follow-up.

Indeed, the system allows:

- To trace the transported product, whatever the number of links and successive actors of the corresponding transport chain, being understood that a product “traceable” is a product which has a single identification has been made possible thanks to the advent of the NTIC notably the RFID technology.
- To manage the processes related to goods transport
- To provide to the system users the forms necessary for the information exchanges and the execution of the transport tasks
- To manage the essential data to execution of these processes
- To ensure the transmission of the relative information to traced product (ex: resources human and material used, spatiotemporal localization…), between the various actors of the transport chain.

4.1 Multimodal transport chain

In a multimodal environment, the principal stages of placement of goods transport are the following ones:

![Fig.1 Multimodal transport chain](Image)

(The zone framed in dotted line represents the stages already covered).

In this chain of multimodal transport, various actors are implied. They are divided into three categories according to their responsibility [6]:

1. The shipper (the salesman or the purchaser)
2. Organizers of transport (transport commissioner, transit agent, etc)
3. Logistic operators (transport, managers of platform, ship-owners)

From a modeling view point of the necessary data, to cover the useful data for the products traceability management throughout their life cycle. The construction of a representation of reference facilitates the consistency of the various representations of the product pertaining to each stage of its life cycle [10]. Indeed, thanks to the reference conception of the synchronization of various representations is optimal.

4.2 Data modeling of the freight transport chain

In what follows, we present our step of modeling for the construction of our data model for the product to layout like its environment, a data model which takes into account the various critical components for the traceability of freight in its various states, the various operations of transport realized on the goods, the resources used (human and machines), its localization. The interactions between the product and its environment are carried out on the basis of whole of web service, in the objective to obtain information about goods, for the exchange of the messages between the chain actors in order to upgrade the advance statute of transport, or to place at the disposal of the users necessary forms to the execution of the transport tasks.

The diagram below schematizes the fields of our data model centered on a central entity “Product” representing the heart of our model:

![Fig.2 Data model centered on the product](Image)

So that the model can as well as possible reflect reality and so that it can meet our aim of traceability, we started with to put us the question about identification of what we must trace, for that we are inspired of the work of Kim et al. [12], by adopting the central entities of their ontology, which are the couple “TRU and the activity”. As we have mentioned previously the TRU is a single unit from the traceability from the point of view, and the elementary activity is an indecomposable primitive activity in under-activities. It is thus a basic operation: for example a planning, provisioning, manufacture, delivery.

So and since our modeling is based on an approach process, we have adopted for the choice of the primitive activities of the ontology of project TOVE, the logic of the model SCOR (Supply Chain Operations Refers) [13], which subdivides the supply chain in five great processes: Plan, Source, Make, Deliver and Return for the returns management.

Of the five basic processes of model SCOR, we have kept only three: provisioning which represents an operation of reception, manufacture, and the delivery which represents an operation of forwarding. Planning was isolated of our model. Indeed, the traceability always rests on what was carried out without being concerned with what was envisaged. It also did not seem necessary to us to create in our generic model an operation of the management of the returns. Indeed, we consider the management of the returns as a manufacturing process to whole share where the turned over batch constitutes a new batch in entry.

Now so that the model can take into account the various elements necessary for the traceability, we supplemented it by allotting human, material resources and the spatiotemporal localization to him. The Service class represents the interactions between the product and its environment, which are carried out on the basis of whole of web services available through a platform of exchange of the data.

In our approach the goods are seen like a material object, characterized and identified by an unique identifier, with the physical object can be associated a unit with additional details such as information of intrinsic nature such as size, weight, volume, marks,… or of the specifications of the product like: the place and conditions of storage… constituting an extension of the product thus. This extension constitutes an artifact of the product represented by an information system, resources distributed between the physical product itself and of the distant resources (the centralized database of our platform).

For the link between the product and the operation which holds it, let us note that there are two types of treatment, an operation can produce or to consume a product for example a
reception is a consuming, production operation for forwarding and both for the transformation according to whether it is a question of loading or unloading of a container, from where double association between the classes product and operation in the UML class diagram below which formalizes the classes and the objects of the model, constituting the heart of our traceability system centered on the product.

Fig 3 UML class diagram of the traceability model:
On the diagram, the class of the task of the Transformation is grayed, owing to the fact that our system of traceability is occupied to follow-up of the freight (its transport), without concerned about the operations of transformation (ex: loading/unloading) during the transport chain.
To adapt our data model for our case of study, in fact the freight transport, we modeled around the model "Product" the whole of information and the objects necessary for the follow-up and the course of the tasks of freight transport by the models below:

« Transportation_resource » package:
In the diagram TR indicate “Transportation Resource”
This diagram describes the units of loading (container, container cistern, vehicle, and mobile vehicle), the means of transport used, as well as the type of transport (road, rail, inland waterway, sea or compound). "TR charged for delivery" indicates the Unit of loading or means of transport placed on another means of transport, while "TR charged for delivery", it indicates a loading of transport facilities for a given delivery. "TR_Assignment" as for it, represents the assumption of responsibility of transport facilities for the realization of a task of transport.

« Actor » package:
This diagram of class describes the various actors of the transport chain according to whether it is a question of a shipper, forwarding agent, transport commissioner, shipping agent, responsible of a logistic platform or a recipient.

« Site »package:
The classes of this diagram describe the characteristics of a site of loading or unloading.

« Delivery » package:
The class below described the delivery of whole or a part of an order.

« Expedition » package:
The class Expedition indicates a distinct quantity from goods transported of a shipper to a recipient, the link between the classes Expedition and TR_Assignment associates an expedition with means of transport assigned with the transport of the latter

« Message » package:
These classes describe a message between two actors (message content, message support, type of message…).

« Transport journey » package:
This diagram describes a voyage, segmented in journey and defined by departures and arrivals in various sites.

Now returning to the central element of our system, the goods with its extension informational, schematized in the diagram below which describes the goods through a whole of information being in a database centralized for the whole of the actors implied in the transport of freight, association between the physical product and its information are carried out through a single ID of the traced product.
The link between classes Product and Transportation_resource_type associates goods with a unit of loading or means of transport.
4.3 Data exchange platform for freight traceability:

To ensure the good performance of system of traceability and in order to feed our database with the relative data with goods transport chain, the solution consist in establishing an exchange of message between the various actors of the platform.

Through these messages, the upgrade of data of the base will be carried out in real-time, in a centralized and completely automated manner.

The various messages available on our platform associated with each stage of the chain of transport are the following:

**A. Stage of the preparation of expedition:**
1. The request for reservation (pre-booking), between the shipper or the transport organizer and the conveyer;
2. The confirmation of reservation (booking), between the conveyer and the shipper or the transport organizer;

**Stage of the loading:**
3. The opinion of provision of the goods, between the shipper or the transport organizer and the conveyer;
4. The opinion of assumption of responsibility of the goods, between the conveyer and the shipper or the transport organizer;
5. The opinion of goods expedition, between the shipper / the transport organizer and the forwarding agent;

**1st stage of the terrestrial transportation:**
6. Announcement of delivery, between the conveyer and the manager of the logistic platform;

**Stage logistic platform Storage:**
7. The acknowledgment of reception of delivery, between the manager of the logistic platform and the conveyer;
8. Provision of goods, between the manager of the logistic platform and the conveyer;
9. The opinion of assumption of responsibility of the goods, between the conveyer and the manager of the logistic platform;

**2nd Stage of the terrestrial transportation:**
10. Announcement of delivery, between the conveyer and the forwarding agent;
To arrive finally at the **stage at the borders of the harbor operations:**
11. The acknowledgment of reception of delivery, between the forwarding agent and the conveyer.

With the help of the exchange of these messages, the actors users of the platform will be able to follow the advance of the transport of the goods and thus to have relative informations with the goods transported like:

- State on the loadings of goods
- State on unloading of goods
- States on the gaps
- States on the deliveries
- States of the incompatibilities for a given site
- States on the messages exchanged during transport...

Now, to be able to exchange messages between the various actors of the chain of transport, knowing that one lays out of a rather significant number of actors, geographically distant, a multitude of information to be exchanged throughout the transport chain, the objective is to propose a solution entirely interoperable, compatible with a use within SME equipped with an internet connection.

For these reasons we propose a solution according to architecture SOA “Service Oriented Architecture”, because it to be seems the most adapted solution to ensure the functionalities quoted previously.

**B. Communication platform architecture:**

The platform offers a mechanism of deployment of service and facilitates their exploitation. To recover and manage web services coming from several suppliers, the provided platform of the means of adapted exchange. This platform is made up of a back-up XML file, XML server, SOAP server, supplier server, UDDI directory and an identification module.

![Fig.4 Communication platform architecture](image)

**C. Base unit of the communication platform:**

**Back-up XML file:** is used for the storage of the relative informations to the descriptors of services and the actors;

**XML server of treatment:** it constitutes the core of the platform of communication[15].

It with the responsibility to treat the XML (eXtensible Markup Language) documents, to carry out the requests of the users and to take care of the coherence of the exchanges between waiter SOAP (Simple Object Access Protocol) and the management system of the web services. It consists of [14] :

- **Manager of the web services:** allows the administrator of the system to manage the web services (Creation, suppression, activation, deactivation and launching), by using a XML document to store them.
- **Manager of accounts actors:** allows the administrator of the system to manage the accounts of the actors of the web services activated on the waiter, by using a XML document to store the relative informations with actors.

**Identification module:** he plays the part of relay between the XML server of treatment and the SOAP server. He ensures connections between the various servers: XML, SOAP and Supplier [14].

**SOAP server:** allows to activate, to deactivate and to execute the descriptors of services recorded by the administrator [14].

**Supplier server:** Represent the class or the system which encapsulates the methods and objects to be called upon. The supplier server must be accessible by the SOAP server in order to ensure the good performance of the platform of communication.

**UDDI (Universal Description Discovery and Integration):** Directory for the referencing of the web services.

In this section we present a simplified scenario representing the case of an exchange between three actors of the transport chain of freight: a **shipping agent or trustee** "is employed by a ship-owner or a shipper to represent it in a port at the time of the stopover of a ship", a **forwarding agent**: “is an intermediary ensuring the connection between two means of transport”, and a **shipper**: “it can be owner or not of the goods, it concludes the contract of carriage and often, he give the goods to the conveyer, it can be the shipper, the recipient or an trustee”.

We can enumerate the stages of the exchange in the following way:

1. The shipper addresses a request for reservation near a forwarding agent;
2. The forwarding agent confirms the reception of the request for reservation;
3. Then, the forwarding agent addresses a request for reservation near the shipping agent;
4. The shipping agent confirms the reception of the request and addresses a list of the offers available;
5. The forwarding agent chooses the offer which is appropriate to him and informs the shipper;
6. If the shipper accepts the offer, a confirmation of acceptance will be transmitted to the forwarding agent, who confirms in his turn the request for reservation near the shipping agent.

Below, an example of sequence of the messages exchange between the three actors after a request for reservation, implying the invocation of a whole of web services.

![UML collaboration diagram](https://example.com/uml_diagram.png)

**Fig.5 UML collaboration diagram for an exchange scenario**

**5. CONCLUSION**

In this paper we presented, our approach of modeling for products traceability management applied for the goods follow-up in a context of multimodal transport, the data models suggested were implemented in the form of a centralized database gathering the whole of the actors of the transport chain, for the food of data base and to providing the data necessary for the freight traceability, with the whole of the actors users of the platform, a web services solution according to an architecture SOA was proposed;

In a following phase, the objective is to integrate the information system developed in a real situation (experimental platform), or on a process of simulation, this to evaluate the real capacity of the system to be integrated in a corporate real case and thus to fix its limits.

**REFERENCE**


