DATA MODELING AND INTEGRATION APPROACH FOR ENABLING MULTIMODAL GOODS TRACEABILITY

by

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ABSTRACT

One of the main keys to ensure optimization of the multimodal transport chain of goods is to succeed to synchronize material and information flow throughout the various links constituting the whole of the transport chain. To achieve this objective, the implementation of a solution of goods tracking and tracing throughout their lifecycle remains inescapable. In this paper we present our modeling and integration point of view, through a generic data modeling of goods lifecycle and the adoption of the concept of the semantic web services by proposing new semantic ontology for the discovery of our traceability web services. The results have allowed us to propose a new approach to designing an effective traceability solution.

KEYWORDS
Goods Traceability, Information System, Data Modeling, Multimodal Transport, Service Oriented Architecture, Web Services, Ontology, Semantic Web

INTRODUCTION

Over time, the performance model on which confront the international supply chains becomes increasingly complex. In this context, the objective of minimizing operational and structural costs remains fundamental, and especially that the management conditions of the global supply chain have been strongly complicated. To this requirement is added the fluidity of goods movement through the various links of the international supply chain, occasioning to a research for the optimization of the physical displacement of goods since the preparation of the forwarding until the arrival towards the final destination (Artous and Salini, 2005). In this end, the establishment of a goods traceability solution covering all stages of the multimodal transport chain can help to a better control of the physical and informational flows relating to the goods and thus contribute to the control of the global supply chain (Janin and Vankemmel, 2008).

In order to do this, in this paper, we present two research contributions offering foundations for the designing of an effective traceability solution allowing intelligent transportation. Through the first one, we present our data modeling approach for the traceability of transported goods by leaning both on innovative research approaches (Intelligent product (Kärkkäinen et al., 2003b), Product-centered system (Kärkkäinen et al., 2003a), PLM (Garetti et al., 2003)...) and on new opportunities offered by the usage of ICT (geolocation, RFID, web services...) in terms of location, auto-identification, sharing and exchange of data relating to traceability objects. The data model proposed takes into account the various elements indispensable for merchandise traceability in its various states, the various transport operations performed on the freight, human and material resources used and its spatiotemporal location.

The second contribution concerns our research works related to IS integration approaches. Indeed, to allow the merchandise to contribute to its own destiny by managing its evolution in cooperation with the different actors implicated in its lifecycle, but also to response to the needs of integrability, interoperability, implementability and the mobility of the informational solutions dedicated for goods transportation, we have exploited the advantages offered by the usage of the approach based on semantic web service technologies for building ontologies dedicated to our application domain, thus facilitating the search, the access, sharing and reuse of data from heterogeneous data sources.
INFORMATION SYSTEM FOR GOODS TRACEABILITY

Doubly motivated by the socio-economic context of the city of Le Havre, 1st French container port (Nov@log, 2009) and the relevance of the problematic of the management of traceability data relating to the transported goods in a multimodal transport context, in what follows, we present our design approach for building an information system dedicated to goods traceability.

In actual fact, our case of study represented by a multimodal transport chain of goods, involves various actors filled with responsibility at different involvement levels, causing a considerable exchange of information and documents throughout the goods lifecycle since its expedition until its delivery to the final customer (Savy, 2006).

In this context of a system completely heterogeneous from information, systems and actors point of view, we have tried to optimize the goods transportation chain by providing solutions for modeling and data integration.

Data Modeling Approach for Goods Traceability

Through this step our objective was to propose an approach taking into account, since the modeling stage, the problematic of product oriented interoperability between systems referring to different views of goods lifecycle. We have thus opted for the choice of a reference representation of goods data, facilitating the coherence setting of the different goods representations belonging to each stage of its transport cycle. At the same time, in our approach we have tried to adapt and combine different currents research cited above, namely, PLM (Garetti et al., 2003), intelligent product (Kärkkäinen et al., 2003b), and the product-centered system (Kärkkäinen et al., 2003a).

This stage has allowed us to construct a data model centered on the goods, where the object to be traced, uniquely identified, through inter alia, the use of RFID tags. The freight model is set in the heart of our data models in order to represent the various elements necessary to the traceability according to the concept of intelligent product and product-centered vision. In same optics, we have held account, through our data models, of the vision of PLM by modeling the different phases by which the goods passes in its lifecycle and by integrating all necessary information for goods tracking (Bendriss, 2009).

Through our generic modeling of data traceability, the optimization of the synchronization of different freight representations is ensured, according to whether it is a question of the physical view which can undergo actions such as the transformation or displacement, or informational view which implements treatments for the creation of new information or updating pre-existent information (Bendriss and Benabdelhafid, 2010a).

In accordance the step of the establishment of an effective traceability solution defined by GS1 (GS1, 2007), four steps are considered. They are: (1) Identify what we must to trace, (2) Ensuring the continuity of physical flow by managing the links between the various traceability, (3) Ensuring synchronization between the physical and informational flows by recording data relating to different phases of the objects traceability lifecycle, (4) Ensuring the continuity of informational flow by communicating traceability data of between the different partners involved.

For the question relating to the identification on what we must to trace, for this we are inspired by the traceability ontology of TOVE project, which defines two central entities to be traced, namely the pair “TRU & Primitive activity” (Kim et al. 1995).

In our approach, the “TRU” is represented by any merchandise intended to be transported. Then, for the choice of the “Primitive Activity”, we have adopted the SCOR model logic (Supply Chain Operations Reference), which subdivides the supply chain into five major processes: (1) Plan, (2) Source, (3) Make, (4) Deliver and (5) Return (S.C.C, 2008).

From these five basic processes, we have kept only three: The "Source" which represents a goods expedition operation, "Make" representing a transformation operation, and "Deliver" which represents a goods reception operation. "Plan" was excluded from our model, owing to the fact that traceability always rests on what was achieved without really worrying about what was envisaged. Likewise we thought that it is not necessary to represent the operation of returns management. Because we have considered it as a transformation operation where the object or the goods returned constitutes a new object in entry (Bendriss and Benabdelhafid, 2010b).

Thereafter, in our approach, so that it can be in conformity with the stages of traceability defined by (GS1, 2007) and so that our data modeling can as well as possible reflect the reality of goods transport chain, we have modeled around the central entity “Freight” all information and objects necessary to cover the global merchandise lifecycle. As shown in class diagram below, the model represents the skeleton of our generic modeling. The model takes into account of the research approaches announced previously, and this by representing the different freight transportation operations,
human and material resources used and their spatio-temporal localization, the description of the transport chain. In concordance with the “intelligent product” concept (Kärkkäinen et al., 2003b), the “service” class formalize the interaction between the merchandise and its environment, which are realized on the basis of a set of web services available through our data exchange platform (Cf. title 2.2) (Bendriss and Benabdellahfied, 2010b).

FIGURE 1
UML CLASS DIAGRAM OF THE TRACEABILITY REFERENCE MODEL

As shown in the diagram, in our approach we considered that a transport operation can be a producer or consumer of freight. For example, a "Reception" is seen as a consumer transaction, producer for "Expedition" for the transformation according to whether it is a question of a consolidation or a deconsolidation of a container, from where the double links between classes "Freight" and "Operation". On the diagram, the class of "Transformation" operation is grayed, because our traceability system deals only with the follow-up of freight (its transport), without be preoccupied with transformation operations (e.g. consolidation / deconsolidation). Indeed, we found, particularly in the port of Le Havre, that only 12 to 15% of containers are deconsolidated in the port's warehouse. For that, according to the 80/20 rule, our work focuses initially on the 85% of containers which correspond to the mode of multimodal transport, called (door to door) (Bendriss and Benabdellahfied, 2010a).

Behind each class of the diagram above hides a set of UML packages representing one or more functions of our traceability IS and will be modeled by a class diagram. Baptized "STTM" for (Système de Traçabilité pour le Transport des Marchandises), an overview of the different components of our data models will presented in the section below through the class diagrams of “Freight” package, and a brief description of the remaining package models (Bendriss, 2009). Given that this paper does not allow us to present all the detail of our data models, we limit ourselves to the presentation of our data model in the form of class diagrams little documented.

FIGURE 2
UML CLASS DIAGRAM OF “FREIGHT” PACKAGE
The class diagram above presents the central heart of our data models; we mean by freight any set of goods intended to be transported, identified in a unique way by, in particular, a RFID tag. The classes of this package describe the constituents and characteristics of a goods defined by a set of information which characterize them. As illustrated above, a "Merchandise" is made up of "package" themselves composed of "Product". The "Batch" enables to identify the production batch which product is part of, as for the "Stock", it enables to inform about places of goods storage and its components. In the same optics, goods classified according to its nature through "Goods_class", is linked to "Load_unit_loaded" to refer to loading units used for transport (container or swap body).

In accordance with the entities presented in our reference model (Cf. Figure. 1), we have modeled the remainder of the data necessary to meet our requirements in terms of goods traceability. To do this, data models were presented, namely, for example, the package "Transportation resource". Indeed, through this package, the objective is to describe all the material resources implicated in goods transportation. In our modeling approach, we have specified two resource categories. The first one "Transport_mean" allows to describe the means used to accomplish the displacement and the movement of goods, this includes light and heavy trucks for road, ships or barges for maritime or the inland waterways and trains for railway (Bendriss and Benabdellahafid, 2010b).

In our approach we have formalized through a class “Transport_mean loaded”, the possibility to loading a transport means on (in) another transport means, it is for example the case where transport means as the trucks are directly loaded with their goods in ships or on barges to be transported. This transport situation exists, for instance, for the RORO ships in the transport roll-on/roll-off (Savy, 2006). The model also enable to formalize means transport classification by type through a class "Type_transport_mean", and this according to the transport mode adopted.

For the second category of transport resources, formalized by a class “Load unit”, it allows describing the whole of load units used in the transport of goods; it is mainly question of containers or, to a lesser degree, the swap bodies. The localization, in the chain of transport, of a load unit is formalized through a link between this last and a class “Localization”. A “Load_unit_loaded” class allows describing the phases of loading and unloading (stuffing/stripping) and of the removal of merchandise in a given loading unit.

In the same way, through a package “Actor”, we have described the human resources involved in goods transportation according to whether it is a question of a legal entity or a private individual representing an individual specifically identified whose role is to represent the legal entity or to be affected by it to accomplish a given task of transport. Similarly, for to the localization which was used to identify the various places by which the goods pass through its evolution in the transportation chain. In our model, localization can be performed with NICT tools for geopositioning such as GPS which informs automatically about longitude and the latitude of a place (Bendriss, 2009). As for the transport, the model, we have identified and described it with its various stages represented by journeys, rounds or visits. Indeed, for each one of them, the beginning, the status and the end are identified and described so as to allow the update of transport chain evolution. The various phases by which transport passes were been related with the location and transportation mode adopted in order to establish a link between the triptych places, modes and means of transport. In the same optics, we have associated to the transportation chain a transport order which is a precondition to any transport service; it allows describing the engagement of the different chain actors for the achievement of all or part of the goods transportation. For transport operations, three generic transportation operations have been identified, "Expedition", "Reception" and "Transformation" (Cf. Figure. 1). The "Expedition" describes any operation of goods preparation intended to be transported from a point to another of the multimodal transportation chain. Where the goods changes hand during its movement from its origin to its final destination, a new expedition is considered, and this, as many times as is necessary to use a new carrier. It should be noted that if this operation is mainly dedicated to the description of goods expedition, it can also refer to the expedition of transportation means. As for the "Reception", it describes any operation of delivery at the time of ownership change, successively between the different transportation chain actors, and that until a final delivery to the ultimate consignee of goods. For the same reasons quoted previously the "Transformation" has been neglected in our modeling (Bendriss and Benabdellahafid, 2010a).

Through these models, we have tried to answer for all criteria proposed by the Moody evaluation framework (Moody and Shanks, 2003), however, our model as it is does not answer for the criterion of integration and implementability. This led us to conduct a reflection by proposing an exchanging and an integrating data solution fully interoperable. To do this, the solution should allow us to update goods data traceability in an automated way, in order to be able thereafter to restore the lifecycle of transported goods in its entirety, but also to facilitate the accomplishment of the various transport tasks. For all these reasons we propose a solution according to a SOA architecture "Service Oriented Architecture" (Fournier-Morel et al., 2008), from where the utility of the service's package (Cf. Figure. 1).
**Semantic Web Services for Goods Traceability**

In order to bring intelligence to the merchandise, and thus to allow it to contribute to its own destiny by managing its evolution in cooperation with the different actors implicated in its lifecycle, but also to response to the needs of integrability, interoperability, implementability and the mobility of the informational solutions dedicated for goods transportation, we have adopted the logic of the web-based services. We have thus associated a set of web services at given merchandise according to its statute or of its evolution in its lifecycle. This was set up in order to ensure an automation of interoperability between the various chain actors by offering them customized services, facilitating to them the achievement of the various tasks of transport in conformity with the reality of the multimodal transportation chain, among the implemented web services we quote: Transport order, Freight quotation, Freight booking, Transport instruction, Loading plan, Goods manifest, Delivery Confirmation...etc (Bendriss, 2009).

Similarly, to allow the tracing and the tracking of goods, we have implemented a set of web services for traceability data retrieval in order to explore the totality of transported merchandise lifecycle and that of the entities present in its environment; like human and material used resources, its spatio-temporal localization...etc (Bendriss, 2009).

As known, a basic web service architecture is based on the triptych WSDL, SOAP and UDDI. Indeed, a web service that is an autonomous program running on the web is described by a WSDL (*Web Services Description Language*), which is registered in UDDI registries (*Universal Description, Discovery and Integration*) to facilitate research (discovery) thereafter. The task of transport and exchange of data between systems is done through SOAP protocol (*Simple Object Access Protocol*) (Fournier-Morel et al., 2008).

However, web services according to this basic architecture applied to our multimodal transport chain, with an environment of extreme complexity in terms of geographical distance between actors, the heterogeneity of systems and data and the mobility of the different sources of data makes the task of discovering and locating web services very difficult (Bendriss, 2009). Indeed, contrary to the standards WSDL and UDDI which provide only a syntactic description of services, the concept of semantic web service allows bringing intelligence to the mechanism of services discovery by offering semantic information on the operation of services and thus improving the quality of the discovery (Chris, 2005). In this optic, we have adopted the concept of semantic web services in order to increase the efficiency of the discovery of our web services in terms of timeliness and relevance of results.

Among the various solutions dedicated to semantic Web services, DAML-S ontology has been proposed for the semantic description of web services and helping to the automation of tasks such as discovery, invocation, composition and monitoring of web services (Gautier, 2004). This ontology is used to describe the properties of a "WebService" and his or her services available to the users. The main classes of the ontology described by DAML-S are illustrated in Figure below (Ankolenkar et al., 2002).

![Figure 3: Main Classes of DAML-S Ontology](image)

At the heart of this ontology, we can find the "Service" class which recuperates the general properties of a "WebService". This class has a "ServiceProfile", is described by a "ServiceModel" and supports a "ServiceGrounding". The "ServiceProfile" explains what the service do and what it requires of the other agents, the "ServiceModel" defines the operation of the "WebService", the "ServiceGrounding" provides the necessary information to use "WebService" and the class "Resource" provides information on the used resources by the "WebService" (Gautier, 2004).

Consumers of web services of our goods traceability platform, namely the actors of the multimodal transport chain, have a lot of requirements on the business and the technological characteristics of the provided web services, namely, the
business rules of the transport chain actors, the geographical proximity between supplier and consumer of the service, response time, the dependability level, resource management functionalities, collaboration level, data security, etc.

For our case of study, the discovery of web services is closely tied to these elements. Therefore, the taking into account of these characteristics, by the service providers, during the publication of their services is essential. However, ontology DAML-S does not have this; it does not provide a perfect description of the web services for our case of study. Indeed, DAML-S is a generic ontology that can be applied everywhere (Gautier, 2004). For this reason, we have decided to enrich DAML-S and adapt it in order to support the description of web services for our multimodal transport chain.

To perform this task, we have felt that it is necessary to: (1) Define an ontology based on DAML-S for describing the Web services of our traceability platform, (2) Elaborate an ontological description of the actor profile, which allows to filter the search results to return only the most relevant results.

1. Semantic description of traceability web services

In order to take into account the business and the technological characteristics of services, in addition to the functional descriptions, ontology will be added to DAML-S, which will be named "Traceability Service for Goods Transportation" (TSGT) and which will describe the web services of our traceability platform in terms of these criteria. This ontology will have the form as illustrated in the figure below.

FIGURE 4
MAIN CLASSES OF TSGT ONTOLOGY

As shown in the figure, the class "TSGT" (Traceability Service for Goods Transportation) describes the web service for our traceability platform according to the two criteria; technological and those related to the business of the multimodal transport chain.

a. "Business Information" Class

This class of our ontology describes the web services with a business point of view. In fact, we found it necessary to incorporate into the web services descriptor information on business rules of a given actor of the transport chain through the class "Transport management". Similarly, the class "Actor_profile" will describe the different types of actors in the multimodal transport chain and which can be classified into three categories, namely, the category of shippers that gathers the consignors and the consignees of the goods, the freight forwarders and the freight brokers who forms the category of the organizers of transport and finally the class of the carriers whatever their modes and means of transport (road, rail, river or maritime). This class is linked to the class "Functionality" which gathers the features offered for actor profile as the creating or the editing of a transport electronic document or of data relating to the goods lifecycle. As for the class "Task", it allows to describe the various transport tasks that an actor of the multimodal chain can perform. The Class "Resources" describes the different electronic resources available on the platform and necessary for the accomplishment of various transport tasks as well as resources of the Auto-identification used for tracking goods. In the same way, the class "Exchange" gathers two types of tools, Asynchronous such as file transfer, EDI and email ... etc and synchronous such as real-time tools (data issued from sensors, RFID tag, GPS, etc.)
b. “Technological Information” Class

As its name suggests, it contains all technical information on the web services. For example, we have integrated in this class all the information describing the web service in its technological aspect. These include, for example, the technical administration of the platform in terms of web services management (creation, modification, activation, deactivation and deletion), management of the accounts and the rights of actors and other features needed for the operation of the platform. Similarly, the class "Security" provides information on the level and the type of security offered in terms of authentication, confidentiality, integrity, access control and non-repudiation. As for the class "Technical Particularity", it describes the web service in terms of response time, communication speed, version of software, reliability and availability of web service... etc. The "Software" and "Equipment" classes allow us to describe the software and hardware solutions needed to run this platform, and this, in the client side as in the server side. In the same way, the class "Language" describes the web services in multilingual, where each instance of this class provides information on a language of a service.

As previously announced, our ontology is based on DAML-S ontology. However, given that our goal is to develop semantic descriptors to facilitate discovery of web services by the different actors of the transport chain and not to model them in the form of process. Therefore, we have retained, from DAML-S ontology, only the classes "Service" and "ServiceProfile" that have been enriched by our new ontology "TSGT" as illustrated in figure below.

As can be seen in the figure, we have included another class in DAML-S ontology. The class "Integration" formalizes the criteria of integrability and the implementability of our platform by describing the different services and modules that can communicate together.

2. Semantic description of actor profile

After describing our point of view which allowed us to formalize our ontology dedicated to the description of traceability web services. In this section we present our actor profile ontology for filtering search results. Generally, the discovery process returns several results per query many of which are more or less appropriate to the needs of the transport chain actor. Therefore, the discovery process should filter the results according to information that characterize the actor in order to help him to search the pertinent services. To do this, the construction of an ontology describing actor profile will allow the filtering, based on data stored in the descriptor, of results of research and offer him the appropriate service to his research.

With this ontology (Cf. figure. 6) the actor is described according to several categories of properties, namely, "Personal_Info" which provides information on the identity and contact information of the actor, according to whether it is a question of a legal entity 'actor' like (shipper, freight forwarder and carrier) or a private individual (operator) representing an individual specifically identified whose role is to represent the legal entity, "Activity" and "Business_Area" classes inform, respectively, on the position and the profession domain of the actor like (driver of a transport company or a clearance agent of a forwarding company) for "Activity", and the business sector of the actor like (an importer or exporter, an organizers of transport, a maritime or road carriers... etc) for the class "Business_Area". As for the class "Preference", it describes the preferences of the actor in terms of searched information or electronic resources, and this according to the bottom and the form. The class "Geographic_Location" allows sorting the results by geographical proximity between actors. Classes "Equipment" and "Security" inform on the software and hardware resources available to the actor and the security aspect desired by the actor. As for the class "Task", it gives information on transport tasks that actor wants to accomplish. Classes "Expertise" and "Interest" inform on expertise areas of the actor and the interests of the actor in the field of multimodal transportation of goods. Similarly, the class "Language"
provides information on the most searched languages by the actor, while "Keywords" is a free class to refine the search. At last, the class "Profile_Traceability" will serve as a memory for the lifecycle of the actor on our traceability platform, and this by archiving the requests of the actor by "Request", or what the actor does at the time of connection (search a traceability data, perform a transport order, change his profile, etc.).

**FIGURE 6**

**MAIN CLASSES OF ACTOR PROFILE ONTOLOGY**

The ontology described above is managed by a web service and has been designed so that it can be invoked by any other web service, for its management we have integrated a set of features allowing the initialization, modification, consultation, deletion and the search in an actor profile.

3. Architecture operation of the traceability platform

For operation of the platform, the actors will be based on the triptych SOAP, WSDL and UDDI (Fournier-Morel et al., 2008), as well as the ontology web services and actor profile.

Indeed, a provider wishing to publish a web service register a WSDL description of the service at the UDDI and a semantic descriptions in the ontology, as well as the addition of service provider, by filing their information in the ontology.

For the process on which we focus our interest, namely the discovery process of web service. Once the services described and stored in the ontology and the UDDI registry, it becomes possible to search these services using requests performed by the service consumer. To discover a service, the user can do its research only on the name and the description of the service; otherwise he can specify research aspects on the classes of the ontology in which will be executed the research. The discovery program returns all results corresponding to the request, and then the ontology of the actor profile will be used to refine searches and to filter the results according to the profile of the actor. The figure below illustrates the process of service discovery by using the proposed ontology (Cf. figure. 7).

Then, for the services invocation, once the list of services is discovered, it is automatically sent to the consumer who chooses the service to be invoked. The chosen service will be invoked by the program by retrieving the necessary information from its WSDL description and by connecting to this service, then the consumer interacts directly with the service server by invoking its operations and its methods.
CONCLUSION

Through this paper we have presented our data modeling and integration approach for enabling multimodal goods traceability. In the first part, we have presented our data modeling approach based on innovative research approaches, the result have allowed us to construct a data model, called "STTM", which allowing us to respond both to the needs of traceability as well as for the good progress of the various tasks of transport chain.

Subsequently, for the integration of our traceability solution we have adopted the logic of web services. The solution proposed allows both to share and exchange data traceability between different transport chain actors in order to restore the product lifecycle in its integrality, but also it offers an opening of our solution towards other solution already existing in the chain of transport. To facilitate the discovery of our web tracking service, we have used the concept of semantic web services which allowed us to defining an ontology based on DAML-S for describing the web services of our traceability platform, called "TSGT", then we have elaborated an ontological description of the actor profile, which have allowed to filter the search results to return only the most relevant services.

To test the feasibility and applicability of our solution, we have developed a prototype of application which gave satisfactory results. The validation of our traceability vision on a real case of goods multimodal transport are under concretization within the framework of a research project of which we form part, accompanied by various influencing actors of the multimodal transport chain.

REFERENCES


