Using Ontology as a Decision Support System for Manage Risks in Medicines Supply Chain: Case of Public Hospitals in Morocco

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Abstract

The existence of different vocabularies in the pharmaceuticals supply chain hinders collaboration and information sharing between partners (suppliers, delegations, hospitals ...). Also, it generates risks and errors that can prevent the access to pharmaceutical products in hospital facilities. For the supply system of medicines in public hospitals in Morocco, ontology is a solution that will improve understanding between actors, promoting information dissemination and their exploitation and promote a new approach to designing information systems. However, implementation of such an approach requires close collaboration between the various partners and requires an intensive exchange of data between them. These technical data must be transmitted, interpreted, managed, reused and stored in a consistent and standardized way. In this work, we developed an ontology using the OWLGRed tool from a UML model whose objective is risk management in the medicines supply chain in Morocco, principally in the public hospitals that supply itself in a centralized way through the supply division which handles the purchase, storage and distribution of pharmaceuticals in these institutions.

Keywords
Ontology, supply chain, risk, supply, medicines, hospital.

1. Introduction

Pharmaceuticals save lives and improve health and play a vital role in many aspects of health care. For this, they should beings available in hospital establishments at all times in sufficient quantities, in appropriate form, with assured quality and adequate information and at an accessible price (OMS, 2002).
However, achieving this objective requires close collaboration among supply chain partners and requires an intensive exchange of data between them. Indeed, each partner contributes to the availability of pharmaceutical products at the hospitals, needs access to a set of information and knowledge distributed in several information systems (internal or external to its organization) to make effective choices while taking into consideration all the required constraints and risks that may disrupt the smooth functioning of the chain. The partners also need to share decisions and data with other partners that need it. However, each partner in the pharmaceuticals supply chain has its own domain of expertise and each speaks its own language.
With the emergence of ontologies as a new paradigm of information modeling, sharing and exchange of data between the different actors of a supply chain has become possible. Thus, a new integration and interoperability track has become promising. In effect, ontologies allow not only to exchange information between systems without loss of semantics but they also offer the ability to infer new information from existing ones (Fortineau, 2013).

Our aim in this paper is to use ontologies as integrator element and as efficient support for the identification of risks related to the medicines supply chain at the hospital centers in Morocco (excluding Universities Hospital Centers) to facilitate management and make explicit the common understanding of risks between the different actors of this chain.
To do this, in the 2nd section, we present a literature review of risks associated with the pharmaceuticals supply chain. Then, in the third section, we define some concept related to ontologies. The fourth section will include an analysis of the various risks associated with the medicines supply in public hospitals in Morocco and a description of the ontology developed for manage these risks. Finally, in Section 5 we conclude and present some future works.

2. Risks in pharmaceuticals supply chain

2.1 What is a risk?

The issues related to risks in supply chains have become an important research topic. It is therefore necessary initially to define the concept of risk in this context. (Harland and al., 2003) define risk as the probability of loss and the importance of this loss for the organization or individual. It is characterized by the combination of the probability that a program or project will experience an adverse event and the consequences, the impact or gravity of this event (NASA, 2002).

These definitions specify that the risk has always negative consequences, while others said that the risk can be as a source of opportunities: the risk is an event causes a disturbance of the system state that has a negative or positive impact on its performance (Gourc, 2006). Also, the uncertainty in the achievement of objectives is a common element between these definitions but they differ in how they characterize the results and application domains.
The risks management can be represented by the procedures and measures series made by some organizations to face all kinds of the risk's exposure. It usually includes the identification, measurement, control and risk monitoring. The risk management process is focusing on the risks understanding and the reduction of their effects. The steps of the risk management process may vary the risk identification/analysis (or estimate), by the intermediary of risk measure (or of the evaluation) (Culp, 2001). This work focuses on the risk identification and analysis step because without a good knowledge of the risks, it is difficult to implement adequate measures to prevent their occurrence.

2.2 Risks and Medicines Supply Chain

The pharmaceuticals supply chain is defined as a set of processes, operations and organizations involved in the discovery, development and manufacturing of pharmaceuticals, which aims to provide medicines with the good quality at the right time and the right place and customers with optimal cost to be consistent with the objectives of the health system (Kaufmann, 2005). Then, there are risks in a supply chain when unexpected events might disrupt the flow of materials on their journey from initial suppliers through to final customers (Waters, 2007).
Several studies propose a risk classification and modelization through medicines supply chain ((Breen, 2008) and (Mehralian, 2012)). The majority of identified risks are similar to those prevailing in industrial supply chains despite the pharmaceutical products particularities. We synthesized the results into 6 categories and 3 levels as detailed in the Table1. There’re many levels of risk management that could be organized along standard company structure. We use three structure approaches: strategic, tactical and operational

Table 1. The risk categories related to the medication supply chain in the literature.

				Strategic	Tactical	Operational
Risk Categories	Process Risks	1.1	Inventory management			*
		1.2	Workers skills			*
		1.3	Information flow			*
		1.4	Production and acquisition			*
		1.5	Transport			*
		1.6	Planning and Control			*
		1.7	Outsourcing		*	
		1.8	Strategy	*		
	Demand-related risks		Customer Needs	*		
	Supply-related risks	3.1	Partnership with supplier	*		
		3.2	Supply and Supplier Outcome	*		
		3.3	Raw material quality			*
		3.4	Contract & Agreements	*		
		3.5	Flexibility of supplier		*	
		3.6	Delivery reliability		*	
		3.7	Information systems			*
		3.8	Flexibility in product variety		*	
		3.9	Quality Management System		*	
		3.10	Timely delivery			*
		3.11	Counterfeit	*		
	Environmental Risks	4.1	Natural disasters & terrorism	*		
		4.2	Political issues	*		
		4.3	Waste management for suppliers	*		
	Market					*
	Financial risks				*	

We classified risks related to the medicines supply chain in the literature into 6 categories:

- Process Risks includes 6 risks at operational level related to inventory management, workers skills, information flow, production and acquisition, transport and planning and control. Outsourcing and strategy are associated to the tactical and strategic levels.
- Demand-related Risks includes risk of customer demand not matching organization's forecast
- Supply-related Risks: At the strategic level, supply-related risks can be associated with partnership with supplier, contract and agreements and counterfeit. At the operational level, these risks can be associated with raw material, information systems or timely delivery.

- Environmental Risks: Natural disasters and terrorism, political issues and waste management for suppliers ; can also prevent proper operation of supply chain
- Market risks encompass the risk of financial loss resulting from movements in market prices
- Financial risks generally arise due to instability and losses in the financial market caused by movements in stock prices, currencies, interest rates and more.

3 Ontologies: General concepts

3.1 Definition of Ontology

The ontology is a new modeling paradigm of knowledge borrowed from philosophy and developed as part of the semantic web. They define the concepts, relationships between concepts, choices and constraints that must be respected. In effect, an ontology defines an organized whole (often in the form of taxonomy or semantic network) of usable concepts for formulating knowledge. (ElKadiri and Kiritsis, 2015). Ontologies specify explicitly the conceptual knowledge using a formal or semi-formal language. In the community of Knowledge Engineering, the Ontology term is often associated with a meta-model that describes the contents of a database, its properties, how it can be used and the vocabulary and syntax provided by the representation language.
Then, ontology is a powerful tool for eliminate ambiguities in trade by giving an explicit representation of the domain to improve communication, which in turn allows greater reuse, wider sharing and an interoperability more extensive.

3.2 Types and construction methods of ontology

There are several types of ontologies and its applications are diverse. We suggest in this context the classification proposed by (Guarino, 1998) which proposes four types of ontologies:

- Generic ontologies or upper ontologies : are an independent conceptualization of a problem or a particular area, for example: space, time, objective and event
- Domain ontologies: describe the vocabulary related to an area such as health, industry and education. Also, it can describe the vocabulary associated with a task such as planning, diagnosis or purchase. This type of ontology defines the necessary knowledge to solving a particular type of work.
- Application ontologies : provide concepts based on a specific task and a particular area.
- Representation ontologies: specify conceptualizations that underlie knowledge representation formalisms.

In the literature, there are several works that have proposed the construction methods of these ontologies including the work of (Gruber, 1993), (Uschold and Gruninger, 1998), (Guarino, 1998) and (Grubic and Fan, 2010). The following table (Table 2) summarizes the definitions of these methods.

Table 2. Construction methods of the ontologies

Methods	Definitions
"Enterprise Ontology" (Uschold and King, 1995)	It is a method which aims: to improve communication between human beings, provide a basis for the specification of user applications and support interoperability.
"TOVE" (Grüninger and Fox, 1995)	A method that necessary to construct of a logical model of knowledge.
METHONTOLOGY (Fernandez-Lopez and al., 1999)	This method is developed by the Artificial Intelligence Laboratory for building ontologies in knowledge level.
La TERMINAE (Biébow and Szulman, 1999)	This method proposes the construction of ontologies from texts.

Unified process for ontology building (Nicola and al., 2005)	This method based on the Unified Process (UP) and UML. UPON is guided by diagrams of use because it aims to build user-oriented ontologies.

3.3 Ontology Development Tools

There are various ontology languages like XML, RDF(S), DAML+OIL and OWL. Many ontology tools have been developed for implementing metadata of ontology using these languages as:

- The Ontolingua server (Farquhar and al, 1997) located at Stanford University allows a user or group of users to view existing ontologies and cooperatively build new ontologies. Access to the server is affected by a standard Web browser.
- WebOnto (Domingue, 1998) developed at Knowledge Media Institute at the Open University. It is a web-based tool and mainly graphic to build ontologies cooperatively.
- ProtégéWin (Eriksson and al., 1999) was designed for the Department of Informatics Medical University of Stanford, especially for building ontologies. Once the ontology built, ProtégéWin automatically generates a knowledge acquisition tool for ontology instances.
- ODE (Blazquez and al., 1998) ODE (Ontology Design Environment) is a construction support tool for ontology in "knowledge level", which is independent of any formal language. It includes verification tools coherence of ontology.
- OWLGred (Barzdins and al., 2010) allows creating, editing and viewing ontology. It offers a comprehensive overview of OWL based on UML. OWLGred shows classes as UML classes, properties such as class attributes, objects such as associations and cardinality restrictions and associations between classes as multiplicities of UML.

We aim in this work to use domain ontologies as efficient support risk management in the medicines supply chain in Morocco to facilitate integration, internal and external, of the different partners in this chain. The developed ontology will be built using a UML model. Indeed, we have interest in using the "Unified Process for ontology building" method to identify different risk which may prevent access to medicines and also describe the supply process and partners of this chain. OWLGred tool was chosen to automatically pass our conceptual model expressed as a UML class diagram to a formal semantic ontology represented by OWL.

4 Domain ontology for risks management in the medicines supply chain in morocco

Domain ontology consists of a shared vocabulary between different partners of the medicines supply chain in Morocco. A first job is to build a corpus, which includes the definition and classification of risk and the relationship between partners. From the vocabulary contained in the corpus, we will extract the constituent primitive concepts of this ontology.

4.1 Risks in medicines supply chain in Morocco

In Morocco, the medicines supply chain (Figure 1) is characterized by a context with large disturbances, a high uncertainty in supplying of medicine and medical devices and particularly by the significant risks which can decrease the coverage of patients needs and generate dangerous consequences for the Health Ministry, the patient, the hospital (reputation, decrease in performance) and for the care team.

In effect, the CESE report in 2013 emphasized that in level the hospital establishments (HE), the needs determination for medicines for the year n+1 is made on the basis of the average consumption of the previous years and not from the real needs and medical prescriptions. This low involvement of prescribers at the time of the needs expression generally produces overestimates and contributes to the accumulation of the medicines stocks and to their expiry.

Also, the CCMPS report (2012) stated that the medicines storage poses problems, with large quantities of expired medicines, for delays in deliveries, rupture of frequent stocks and the insufficient of the logistical means at central and local level. The medicines distribution suffers from a lack of coordination within the

distribution network and the absence of an integrated information system for control the activities in medicines supply chain (CESE, 2013). In addition, the supply division (SD) as responsible for the consolidation of requirements, the tenders' launch, the reception, the storage and distribution of pharmaceutical products, the administrative management as well as the supply monitoring, doesn't have an information system to allow for effective traceability between the various links in the chain which makes the access to the information difficult and generates a set of risk at all levels (Yafout, 2015).

Figure 1. Medicines supply process for public hospitals in Morocco.

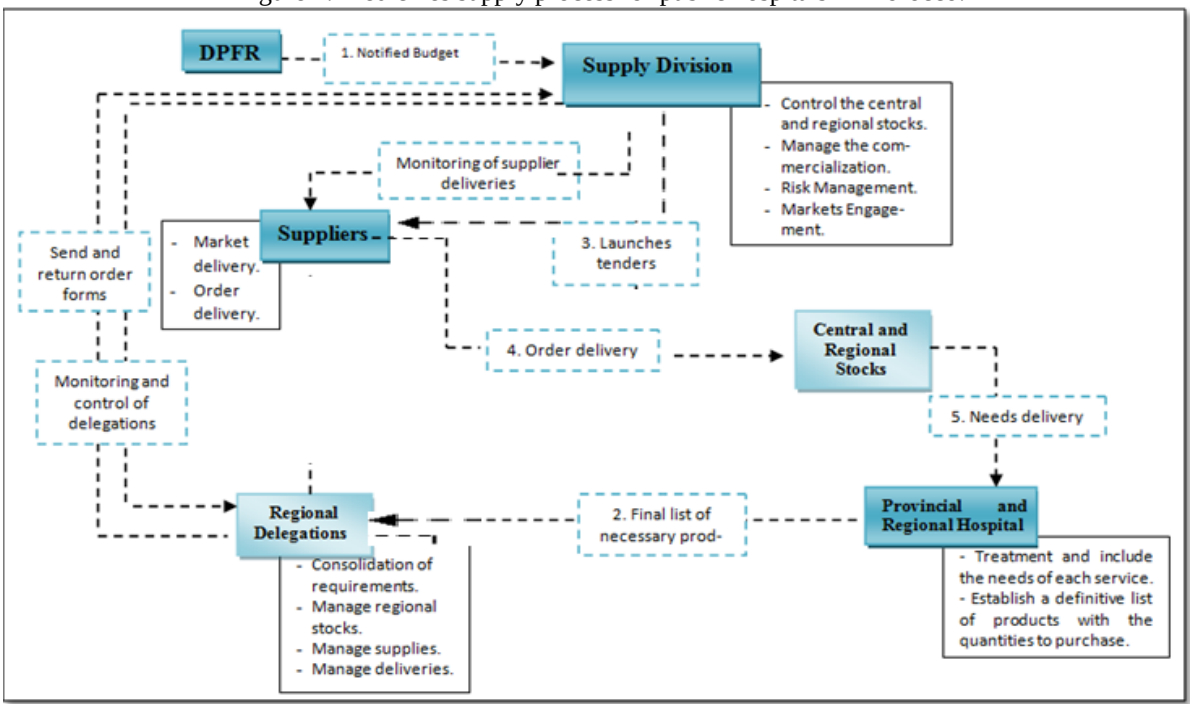


Table 3 presents a detailed description of different errors and risks that may disrupt the proper functioning of the medicines supply chain in Morocco. This description is made according to the categories and sub-categories founded in the literature (Table 1).

Table3. Risk Register in the medicines supply chain in Morocco.

Categories		**Sub-Categories**		**Description**
Process Risks	R1	1.1	Inventory management	-The rupture of stock
				- Overage
				-Limited Capacity
				-Poor storage conditions
				-Absence of a software inventory management
				- Error in the calculation of the security stock
		1.2	Workers skills	- lack skills
		1.3	Information flow	- Problem of information exchanges between the various actors
				- Problem of traceability in the different steps of the management cycle.
				- Poor data quality
		1.4	Production and acquisition	- Defect related to the manufacturer's production capacity
		1.5	Transport	- Transport doesn’t meet the standards.

				- Means not adapted to the various types of pharmaceuticals.
				- Annual cost allocated to transport is very high.
				-Limited Capacity
		1.6	Planning and Control	- Planning doesn't take into account the real needs of services
				- Lack of control and use monitoring of pharmaceutical products in services
		1.7	The Outsourcing	- Outsourcing transport can cause problems at delivery
		1.8	The strategies	- The strategy adopted by SD for the purchase and storage is centralized and generates stock outs and overstocks
		1.9	Human Resources	-Lack of human resources
Demand-related risks	R2		Customer Needs	-Poor estimate of needs
Supply-related risks	R3	3.1	Partnership with the supplier	- Failure to respect specifications (Delivery)
				- Monopoly
		3.2	Supply and Supplier Outcome	-Delay in the supply
				- Poor tender management
		3.3	Raw material quality	- Poor quality of raw materials can produce defective products
		3.4	Contract & Agreements	- No contract enforcement
		3.5	Flexibility of supplier	Poor flexibility in the relations between SD-supplier and SD-hospital center
		3.6	Delivery reliability	Low capacity to deliver the quantity demanded of a product to the desired date
		3.7	Information systems	- Absence of an information system
		3.8	Flexibility in product variety	-Poor flexibility of suppliers
		3.9	Quality Management System	- Absence of a system that can manage the quality
		3.10	Quality Management System	- Failure to respect delivery times for suppliers
		3.11	Counterfeit	Diversion of products and the quality problems
		3.12	Raw materials	-Unavailability of raw materials at suppliers
		3.13	Manufacture	- Manufactured pharmaceutical products may declare non-compliant.
				-Complexity of manufacturing process
Environmental Risks	R4	4.1	Natural disasters & terrorism	
		4.2	Political issues	
		4.3	Waste management for suppliers	
Risks related to the Market	R5			Increasing the size of government procurement, which pose new risks
				Raw materials prices

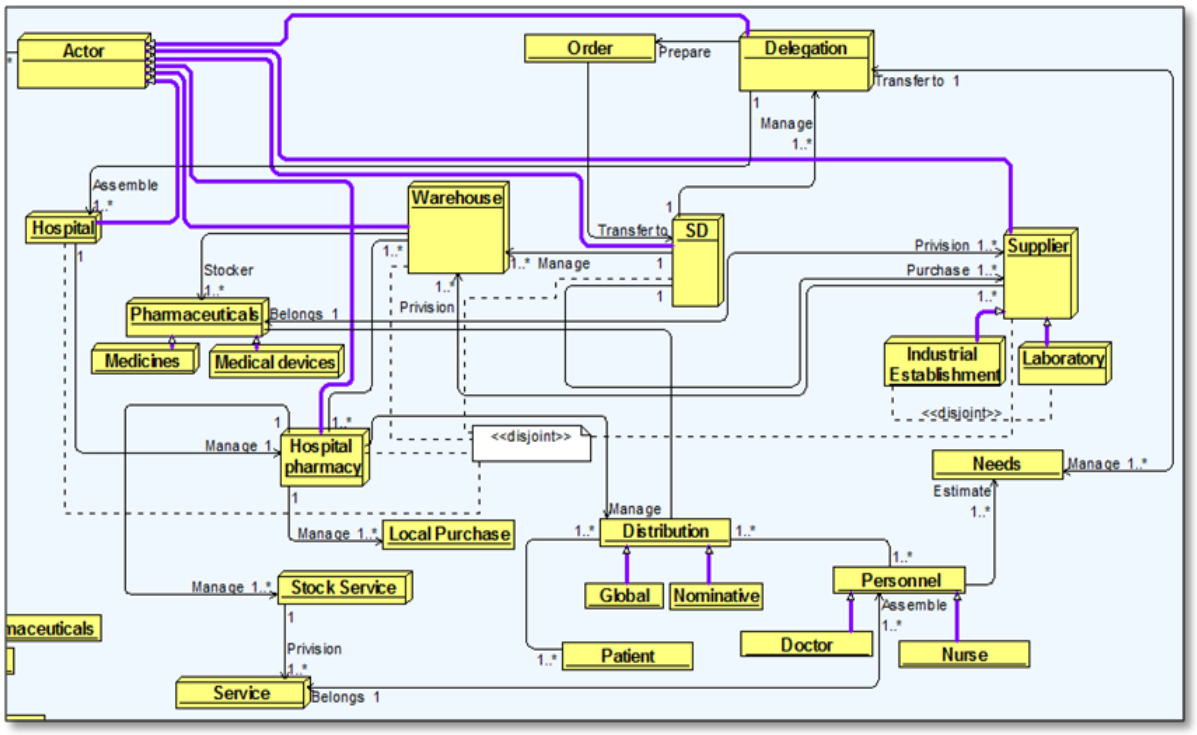
				Interest rates
Financial risks	R6			The purchase of pharmaceutical products doesn't depend on the needs expressed by the various hospital centers but depends on the notified budget

The table as a risk register who based on the literature and reports submitted by the Health Ministry in Morocco. This risk register details all identified risks, including description, category, sub-category and cause. It's a spreadsheet containing all the statements of risk identified for the medicines supply chain in Morocco.
However, several efforts were made to prevent and solve these problems, mainly: the increase in medicines budget by the Health Ministry, the establishment of regional pharmacies, standardization and upgrading of hospital pharmacies and adapting and improving methods of the hospital pharmacy management (Health Ministry, 2013). And despite all these efforts, the needs coverage of the population in medicines remains insufficient since the patient still complains of the non-availability of these products. So it isn't a question of meeting standards, procedures or standards of good practice, but to identify important concepts in the field, clarifying the relationships between objects to allow standardization of languages between partners.

4.2 Conception of the domain ontology

The domain ontology (DO), as was mentioned before, defines all concepts related to a domain of activities semantically, it concerns here the risk at the level of the medicines supply chain in Morocco. It aims primarily to "assemble and unify the terms related to risk management". Also, it provides a vocabulary of concepts used in the domain with their definition, similar concepts, related concepts, etc. The conception of this ontology was made in the Unified Modeling Language (UML). It is a simple formalism for experts in the domain that facilitates the process of the ontology constitution.
UML profiles used to specialize a UML model. They can be used in all models without modifying their structure. Moreover, it should be noted that such reasoning, although it is possible, isn't exploitable by a machine because it isn't an automatic reasoning since UML profiles don't allow any form of automatic semantic processing. In effect, the domain ontology modeling in UML must then turn into formal ontology. It can then be edited in protected and enriched environment.
Note that several research papers suggest modeling ontologies with UML, including (Crane and Purvis, 1999), (Schreiber, 2005), (IBM, 2006). In (Brockmans and al., 2006), the authors develop an approach which aims the visualization of OWL ontologies using the UML graphical notation. To create an ontology with UML (enriched) and then automatically switch to OWL (or vice versa), (Barzdins and al., 2010) suggest OWLGred tool. We chose to use the same tool to automatically switch from a conceptual model expressed as a UML class diagram to a formal semantic ontology represented by OWL.
The following figure (Figure 2) shows partners of the medicines supply chain in Morocco (Supply division, suppliers, warehouses, delegations and public hospitals) where each rectangle represents a class, and lines with a triangle represent the generalization relationship between classes.

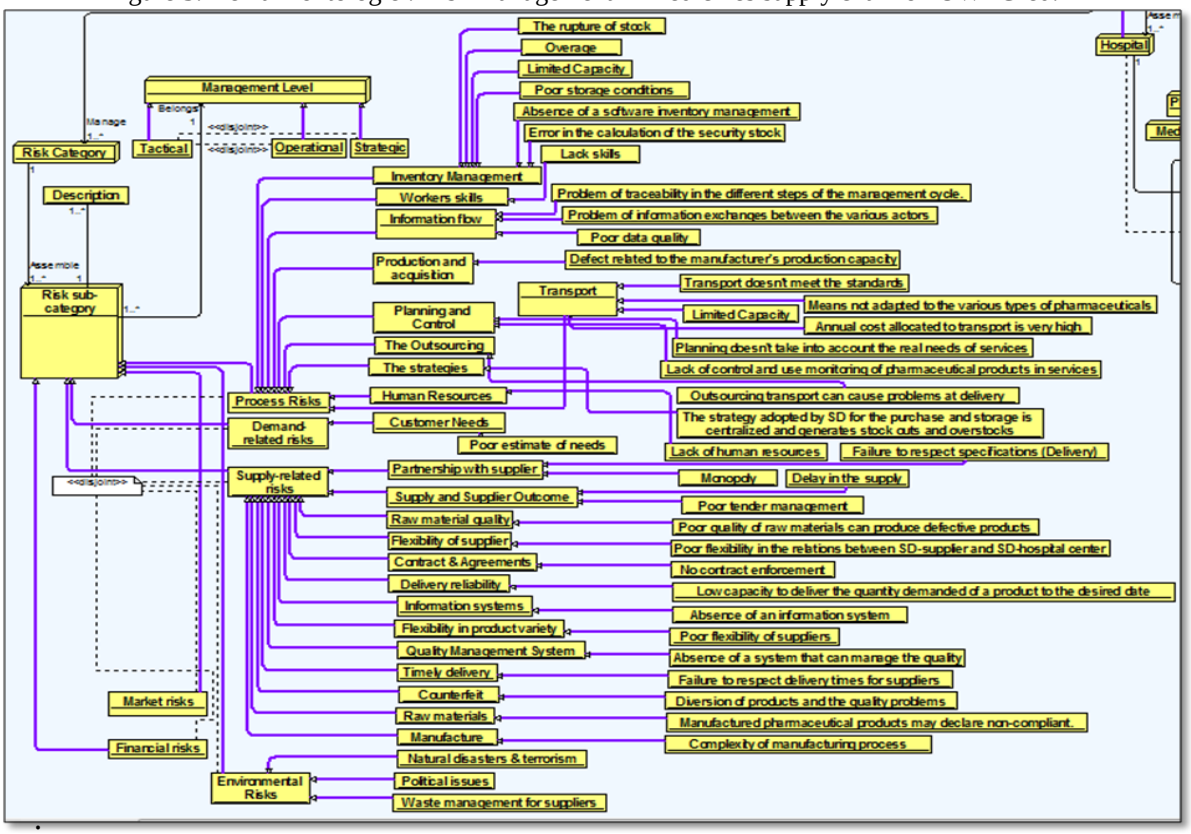
Figure 2. Demain ontologie : Partners of the medicines supply chain on OWLGred.



Identifying needs in hospitals is often left to head nurses or doctors who transfer the patient needs to the service needs (Need Class) and transmit them to the hospital pharmacy (Hospital Pharmacy Class). The Need Class also includes the programmed and non-programmed (urgent) needs for one or more services (Service Class). All these needs are then transferred to the Regional Delegations and Provincial Directorates (Delegation Class) that compile annual commands on pharmaceuticals of one or more hospitals (excluding the CHU : autonomous supply). Then, the commands elaborated send to the SD (SD Class) to begin the process of purchasing from suppliers. The Suppliers class represents laboratories and industrial establishments involved in procurement at warehouses depending on the type of products delivered. At the hospital pharmacy, the products delivered by the central warehouses (Warehouse Class) are then stored in the stock of pharmacy (Stock Class) and distributed to various services according to a schedule adapted for each hospital. The dispensation is made according to the care units type (Service Class), product type (PH Class) and resources available but generally we can distinguish between two main modalities: Global and Nominative. Indeed, the Distribution Class creates a flexibility of choice of the distribution methods (Global and Nominative Classes) of medicines and medical device (Medicines and MD Classes).

The global distribution is to deliver the products to the service (Service Class) in advance on presentation of a weekly order for ordinary commands for a period of a week or an order for pharmaceutical complement which allows the service to order the products which don't available in its stock at any time. The products are delivered just after the deposit of a delivery order signed by the service head. These products are then stored at the service and issued to healthcare personnel (Nurse Class) and (Doctor Class) who administer by a medical prescription. Concerning the nominative distribution, allows the products delivery to a patient (Patient class) and not a service which plays an intermediary role between the pharmacy and the patient, on presentation of a prescription to the nominative delivery of products. Also, the proposed domain ontology allows different partners to identify any risk can be presented in the medicines supply chain into different categories, subcategories and management level (operational, tactical and strategic) as described in Table 2 (Figure 3).

Figure 3. Demain ontologie : Risk management in medicines supply chain on OWLGred.



The diagrams presented describe the pharmaceuticals flow from the sending of commands to suppliers until receipt at the service level. Partners in this chain: the Supply Division (SD), suppliers, warehouses, hospital pharmacy and the services must manage the Risk Categories Class. This class shows the different risk categories (Risk Categories Class) that can disrupt the efficient movement of the chain. A category may include one or more sub-categories (Risk Sub-Category Class). The different risks can be managed at the strategic, tactical or operational level. The level class offers the possibility of choosing between the different levels.

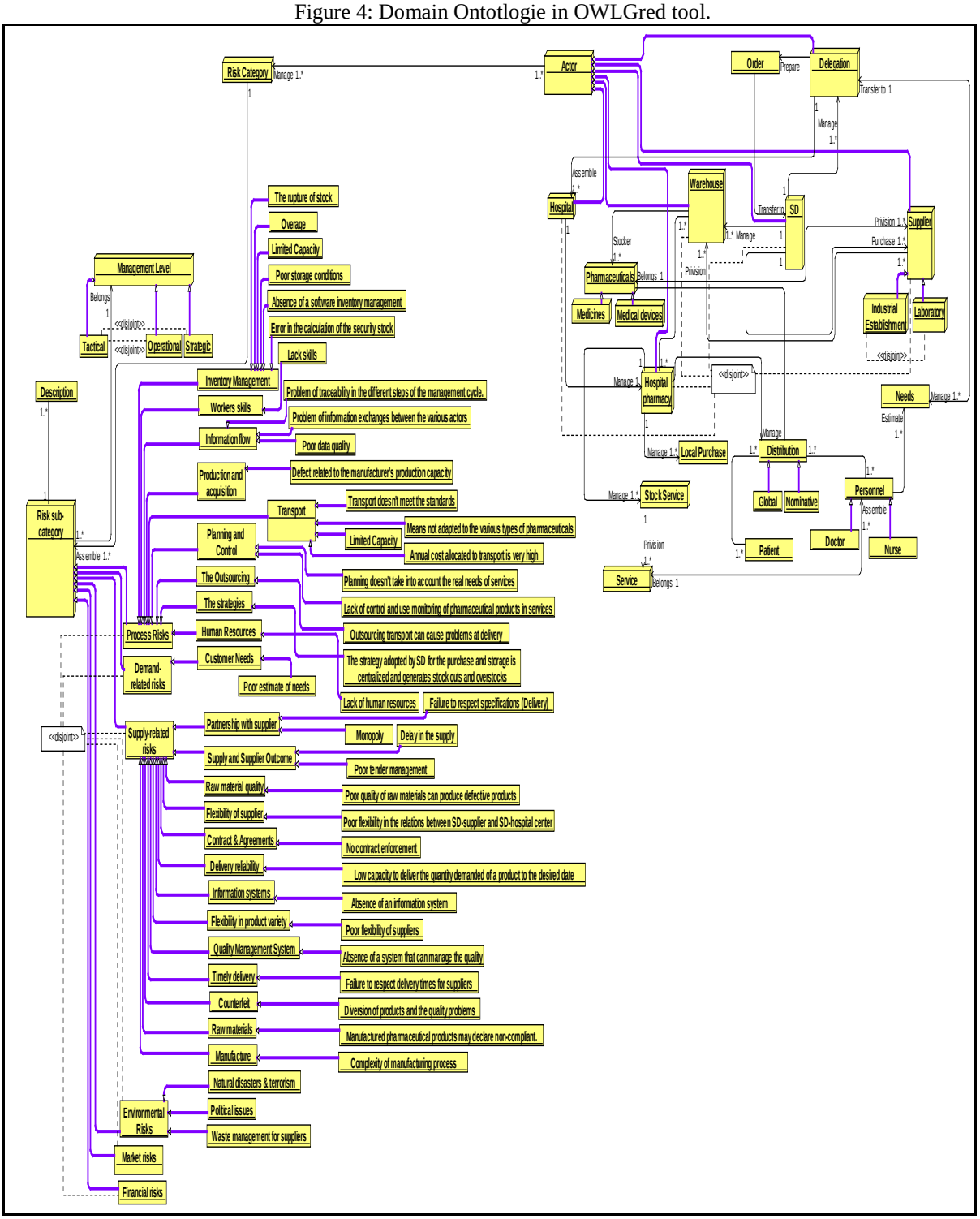
5 Conclusions

In this article we proposed domain ontology as a decision support system for the risks management in medicines supply system at the public hospitals of Morocco (Figure 4). The proposed system provides three functions: identifying risks in the medicines supply chain at the level of the public hospitals (except University Hospital Center), semantic description of each risk category and risk management by the various partners in the chain.

- The risks identification in the medicines supply chain at the level of the public hospitals: the system user can identify the different risks that may prevent access to medicines and also classify them according to three levels of management (strategic, tactical and operational).
- Semantic description of each risk category: from errors and problems descriptions in the medicines supply chain presented in the first part of section 4, the user can classify the risk according to subcategories.
- Risk management by the various partners in the medicines supply chain: to complete the identification, the user may need information about other chain partners. The reasoning by ontologies enables the sharing of different risks, information and knowledge related to the domain of medicines supply in the public hospitals.

The decision support system proposed, will be validated in a larger context with the final users and also the impact of the evolution of ontologies should be studied on this system.

Figure 4: Domain Ontotlogie in OWLGred tool.



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