A Conceptual and UML models of procurement process for simulation framework

Abdessamad Douraid, Saâd Lissane Elhaq and Hamid Ech-cheikh

Laboratoire d'Informatique des Systèmes Industriels et Energies Renouvelables
Ecole Nationale Supérieure d'Electricité et de Mécanique, Université Hassan II, Casablanca, Morocco

Abstract

This paper presents a set of conceptual and UML models that can be used to construct a simulation framework of procurement process. Whereas the good control of this process is crucial as well it composes an interesting ratio of costs along the whole chain. For this purpose, we took into account the information and the material flows of the upstream supply chain that linking the manufacturer and its suppliers. Our contribution is to make a reusable and a modular pattern of procurement process, which is able to be configured and used for several manufacturer industries. In order to benchmark the different scenarios of each configuration and to furnish a decision aids' tool, for the sake of the decision makers to obtain the right choices.

Keywords: *Procurement process; Conceptual model; UML Models; Simulation framework; Decision aids' tool.*

1. Introduction

In today's global marketplace, the existing economy and the globalization have encouraged not only the emergence of an unstable industrial environment but also a fierce competitiveness. This instability is reflected in particular by the varied demands from customers, which makes it essential for companies to be agile and flexible; means to be adapted quickly to these changes while preserving their global economic performance. However, only one integrated organization ensures overall performance in an uncertain environment. Thereby, companies fit well into supply chains in which they will develop relationships with their partners. The deployment of these supply chains has led to an evolution on how to coordinate businesses; it has risen from business groups where each member worked for his own benefit favoring a local vision along networks of partners, to manage the flow of information and materials throughout the chain. It therefore becomes imperative to establish effective organization mechanisms in order to achieve the global targets and improve the performances of the entire supply chain.

A common dilemma to those who deal with supply chain management is the so-called bullwhip effect or Forester effect. According to Lee et al, [11], this effect arises when there is a lack of coordination among the elements of the supply chain at the moment when there is a variation in the quantity demanded by the final client, with the reactions of suppliers tending to be amplified at each passage upstream through the chain. All of them react increasing or diminishing the orders differently from what is really necessary, seeking to protect themselves. For long chains, the results may be extremely negative, for distortions, in the client to supplier direction accumulate, amplifying in a non-linear way. This effect is caused by the lack of an adequate and coherent supply chain management as a whole.

Therefore, the coordination is considered the most powerful issue in supply chain management. For this, Modeling and analysis of such highly complex systems are crucial for performance evaluation and for comparing competing supply chain because the developed modeling tools in enterprise modeling field are mostly used for representing logistic networks [7].

Figure 1 shows the structure of a typical supply chain. It consists of several organizations; beginning with suppliers, who provide raw materials to manufacturers, which produce products and keep those manufactured goods in the warehouses. Then, they send them to distribution centers or to wholesalers where they ship the goods to retailers. The customers then buy products from retailers. Different industries have somewhat different structures of the supply chain networks. Our research focuses on the upstream side of this supply chain, which is procurement. This process faces various difficulties such as the dynamic demand which is characterized by a stochastic aspect, supplier management, multiplicity of ordered items, etc. Thomas and Tyworth have analyzed suppliers' tactics with random delivery's deadlines [22]. Also Arda has studied procurement policies within organizations of multi suppliers [1]. Villeminot et al. have treated the modeling and simulation of supply chain (procurement process) in automotive manufacturer framework of a great European constructor [23]; their aim was to answer the just inventory security level while keeping the quality of service. The

literature reveals some works regarding modeling and analysis of the discrete event dynamic systems such as procurement process. Yet, most of them are specified for a particular company in a particular industry sector.

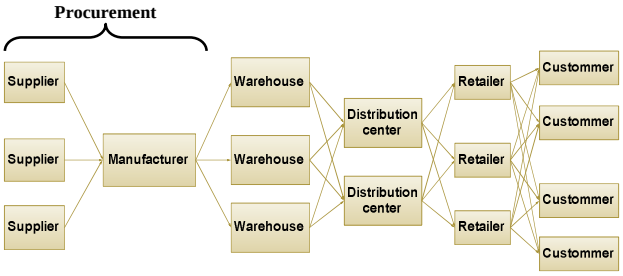

Fig. 1 Supply chain stages.

In this paper we propose formalism for modeling procurement process at the operational level, based on the conceptual and UML models to be afterward employed for simulation which is a powerful tool to help the managers in decision making. Our contribution is to make a reusable and modular pattern of procurement process. More precisely, the static and the dynamic behavior of the system are described by the UML. This model is considered as the first part of global supply chain model for manufacturing sector, which will be combined with some others to complete an integrated platform for modeling and simulation within our laboratory.

The structure of this paper is organized as follows. Section 2 affords an overview of supply chain modeling and simulation, according to the literature review. Section 3and section 4 present our approach based on the conceptualization and UML modeling, where use case diagram, class diagram, activity diagram and state diagram used to furnish both static and dynamic views of the interactions among entities of the system. Finally, section 5 summarizes our contribution and gives outlooks on future researches.

2. An Overview of Supply Chain Modeling and Simulation

This section presents a brief review of the principle matters concerning the procurement and the supply chain modeling and simulation according to the literature review.

2.1 Procurement and Supply Chain

Procurement, also known as purchasing and supply, is amongst the key links in the supply chain and as such can have a significant influence on the overall success of the organization. Ensuring that there are sufficient supplies of raw materials at the right price, with the required quantity, in the right place and at the right time is obviously vital to any manufacturing plant. Procurement is basically part of the logistics process [5]; Logistics is defined by the council of Logistics Management, as the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption for the purpose of conforming to customer's requirement Procurement or purchasing is responsible for acquiring all the material needed by an organization [16].

According to Wheel [25]: Procurement includes all activities required in order to get the product from the supplier to its final destination. It encompasses the purchasing function, stores, traffic and transportation, incoming inspection, and quality control and assurance. And according to Saad and Kadirkamanathan [21], procurement in a supply chain is managing the flow of materials and products from the source to the user. This flow typically includes aspects of purchasing, manufacturing, capacity planning, operations management, production scheduling, manufacturing requirements planning, distribution system planning, transportation systems, warehousing and inventory systems, and demand input from sales and marketing activities.

2.2 Modeling and Simulation of Supply Chain

Modeling and simulation of systems have been identified as the two great discoveries that will accelerate the resolution of great challenges to be found by manufacture industries in 2020 [2]. The reason of generating a supply chain simulation model is to provide a valuable insights and well understanding about different flows involved in supply chain. The mainly models are developed to address particular issues, such as: optimization, risk management, decision analysis and diagnostic evaluation.

In literature, several tools and approaches have been used for supply chain modeling [3] [13]. Generally, we can distinguish two main categories:

Analytical models: Describe the system entities and their relationships using a function of mathematical analysis. In the dynamic modeling of supply chain, control theory and operational research are two analytical methods which are well known in the scientific community [15]. The uncertainties and disturbances are not easily represented in the analytical approaches, which lead to the use of approximations (e.g. probability distribution), as well as some analytical approaches are limited in consideration of time and the interactions of the system are not always modeled [12].

Simulation models: Simulation is the process of designing a model from real system by means of abstract objects to reproduce the behavior of the system [10]. Recently, simulation studies are increasingly used in supply chain (procurement). Furthermore, it is estimated that the overall behavior of a supply chain cannot be evaluated only by using simulation [17].

Furthermore, the simulation offers an alternative method for detailed analysis of the complex real world systems such as the procurement process. Given that a simulation model is well-suited for evaluating dynamic decision rules under "what-if" scenarios, a few attempts have been made to develop simulation models to improve procurement performances. According to Chwif et al. [4]; Discrete-event systems (DES) simulation models are also a very popular approach for procurement process related problems. This simulation approach allows different combinations of decision strategies to be evaluated and thus provide adaptively necessary for efficient use in dynamic, on-line environments.

3. The Proposed Conceptual Model of Procurement Process

In literature, the usage of conceptual models for the documentation and construction of real world events is broadly accepted [19]. Thus, using such models and modeling methods for an interorganizational supply chain information management seems to be reasonable. Information systems engineering is a process of change in order to achieve certain goals in information systems design [9]. In this section, we will present certain representation forms of the systems that are necessary for the systematic and exact conceptual modeling of procurement process. Showing the information and the material flows that linking a particular manufacturer to a single supplier.

3.1 Procurement Process Analysis

This model generally concerns procurement process including: supplier management, inventory management, invoicing and delivering procedures. To analyze and describe in a simple way the main stages of this process, we consider the conceptual model depicted in Figure 2.

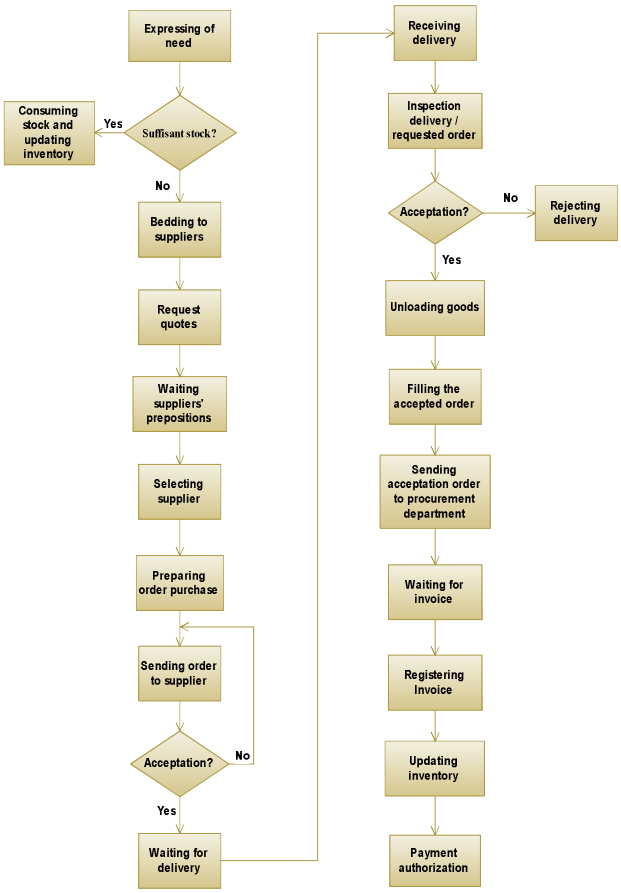

Fig. 2 Procurement process [6]

The whole process of procurement operations starts from the expressing of production need within the manufacturer factory. In order to meet this need, the process faces two cases: The first case, when the manufacturer still has a sufficient stock. The second case is when this stock is not enough to fill the production need, means the stock achieved the level where the procurement process should be launched. Consequently, at this stage the purchasing (procurement) flow starts by placing an order to the supplier, and will end at the payment authorization step as shown in figure 2.

3.2 Sourcing and Ordering Proceedings

The figure 3 shows the manufacturer places orders to the supplier. The product type and the distributions for the interval between orders and order quantities are fixed. The supplier tries to allocate goods for this new order using his raw material inventory. If the raw material is not enough, the shortage is marked as back order. These values are used for placing new sourcing orders. The lead time delivery is dependent on the product type and it is set by the supplier.

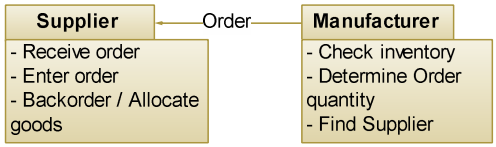

Fig. 3 Sourcing goods

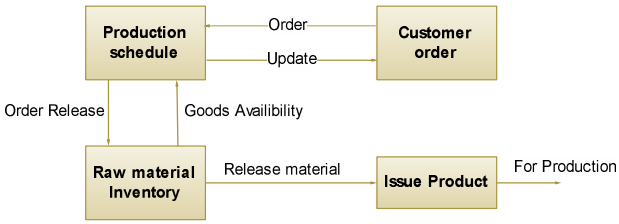

Fig. 4 Checking Orders for Production

3.3 Supplier-Manufacturer Relationship

Figure 5 details the conceptual model for the supplier-manufacturer relationship. The supplier receives orders from the manufacturer. If that supplier has an enough inventory, it immediately dispatches the ordered components to the manufacturer. In a more precise model, a minimum order quantity must be respected (it is not worth, for instance, to assign a truck for a delivery of a small order size). If the supplier does not have the quantity needed in stock, it will then manufacture the component and then delivers it to the manufacturer. In this case, the supply chain service level and cycle time will be deteriorated.

Concerning the inventory control policy, here in this model whether the manufacturer or the supplier can be configured to a specific inventory control policy (e.g (s, q), (s, S), (T, S), (T, s, S)). That gives a significant flexibility to the model and allows comparing several configurations. Though, basically each partner will try to maintain ending inventory equal to the current period's demand. Supposing that the period's demand for each one (supplier or manufacturer) is of size "q", the manufacturer will place an order of size "2q" for its predecessor stage. This will allow the SC elements to meet the current period's demand (q) and also maintain q units as inventory to meet the next period's demand, which is expected to be of size q. The inventory control policy could be more sophisticated. When the inventory level gets lower then a minimum specified which might be the safety stock level, an order for the material (component or product) purchase (or manufacturing) is placed. The optimum order quantity and the safety stock levels are given by the decision-maker.

Nonetheless, the text in the flowchart boxes explains the logic considered.

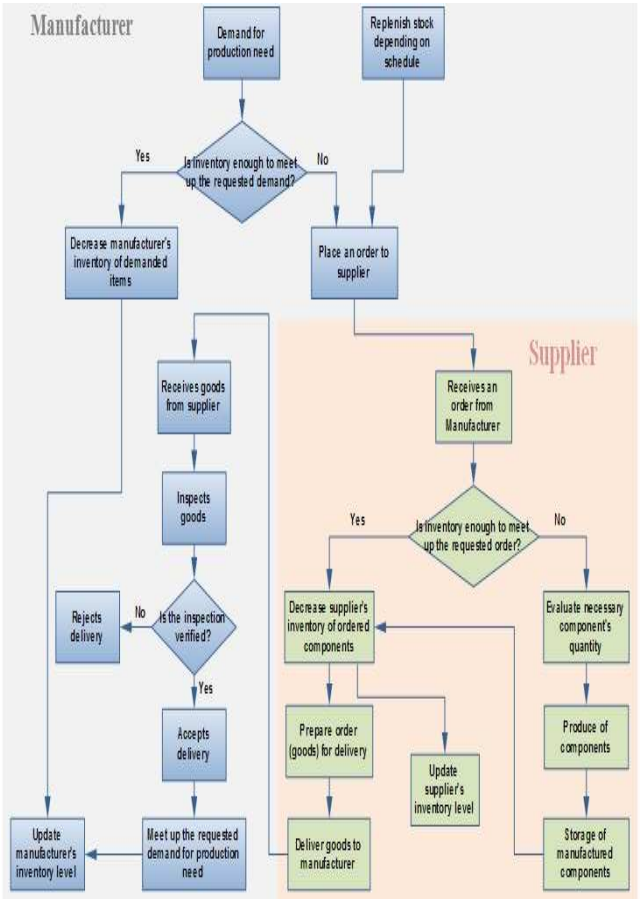

Fig. 5 Supplier-Manufacturer relationship

4. The Proposed UML Model of Procurement Process

4.1 The Unified Modeling Language

The Unified Modeling Language (UML) is an Object Management Group (OMG) specification defined by the UML meta-model, a Meta-Object Facility meta-model (MOF). It is a specification language for object modeling. It is a general-purpose modeling language that includes a graphical notation used to create an abstract model of a system, referred to a UML model. It is designed to specify, visualize, construct, and document software-intensive systems. UML is not a method since it does not introduce any approach [11]. UML is not restricted to modeling software. It is also used for business process modeling, systems engineering modeling and representing organizational structures. UML has several types of diagrams divided into three categories [14]:

- Structure diagrams
- Behavior diagram
- Interaction diagram

The clearest and most comprehensive diagram to represent business process is the activity diagram which represents clearly activities and flows.

Therefore, we chose UML as modeling language because it is an OMG standard that is becoming very popular especially in industry. UML provides suitable extension mechanisms and it does not depend on any particular methodology. Fundamentally, use case and class diagrams are used in the application model. Structural information can be specified in the class diagram, such as multiplicity among entities. The behavioral aspect is captured from activity and state diagrams to characterize the dynamic side of our approach.

For the sake of avoiding complication of the system and for the brevity of the paper, we restrict our study and chose the main activities and operations of procurement process. And as mentioned previously, we have been utilized UML because it allows modeling the static and the dynamic behavior of our system.

4.2 Use Case Diagram Analysis of Procurement Process

Use case modeling is very popular within the software engineering community and service requirements can be effectively analyzed through use case modeling [24]. A use case represents a coherent unit of functional behavior that is offered by a system to one or more actors. It defines the behavior of the system and its interactions with the involved actors. The behavior is triggered by an action performed by one of the actors.

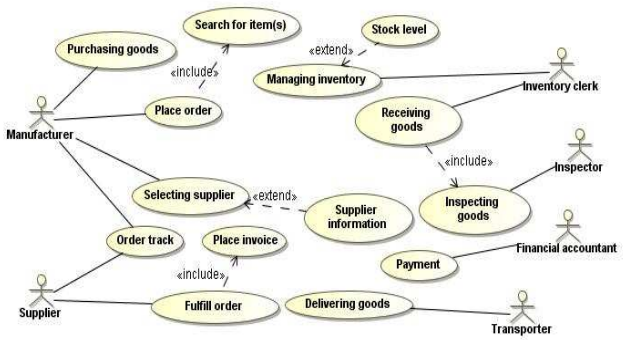

Fig. 6 Procurement process use case diagram [6]

Figure 6 illustrates the procurement process use case diagram; it represents the functional abilities of that system which are designed by fifteen use cases, whereas the stickman characterizes the primary actors who are the manufacturer and the supplier. Since we are analyzing that procurement process, then our position in this problematic is from the manufacturer's side towards the supplier's. Hence, the foremost use cases of this system are:

- **Consume:** the manufacturer consumes the on hand stock which is available in its warehouse, to meet the production needs. Holding stocks generates different types of costs, such as possession costs and fixed installation costs which should be reduced at the best possible. The search for the finest solution for reducing costs related with holding stocks leads managers to use different inventory control policies (procurement policies).
- **Placing order:** while this order is being placed, searching for the required item(s) in the inventory will be done automatically and that involves the inventory clerk, who is considered as an employee in charge of the inbound and outbound of products in the inventory.
- **Selecting supplier:** once the manufacturer identifies his need, subsequently starts looking for a supplier according to specific criteria (e.g. price, quality, delivery deadline, geographic localization, environmental, etc). Though, successful procurement depends on locating or developing suppliers, analyzing their capabilities, selecting and working with them to achieve continuous improvement.
- **Order track:** the selected supplier receives the order from the manufacturer, in order to prepare and carry out the order.
- **Fulfill order:** the supplier begins accomplishing the order, respecting the deadline and the required details in the order (contract).
- **Delivery:** in our approach we have considered that delivery service is made available by the supplier himself (Transporter). Meanwhile, an invoice is attached to delivery to be presented to the manufacturer.
- **Receiving goods:** it is the inventory management's responsibility; includes inspection of goods to verify required specifications (e.g. quantity, quality, etc) as well as the evaluation of suppliers, their products and services.
- **Purchasing goods and Payment:** belongs to purchasing department of manufacturer, as well as receiving goods and payment arrangement.

4.3 Class Diagram Analysis of Procurement Process

Class diagram, is the most important in object-oriented modeling of business concepts. The use case diagram shows only the viewpoint of system/actors relations. Yet, the class diagram checks the intern structure and gives an abstract representation of objects. The principal elements of this static view are classes and their relationships, such as associations, generalization, aggregation and other types of dependencies. The analysis of system class is built on the basis of use case. As analyzed above, we can design class diagram of each module after identifying classes and their associations, cardinalities and functions.

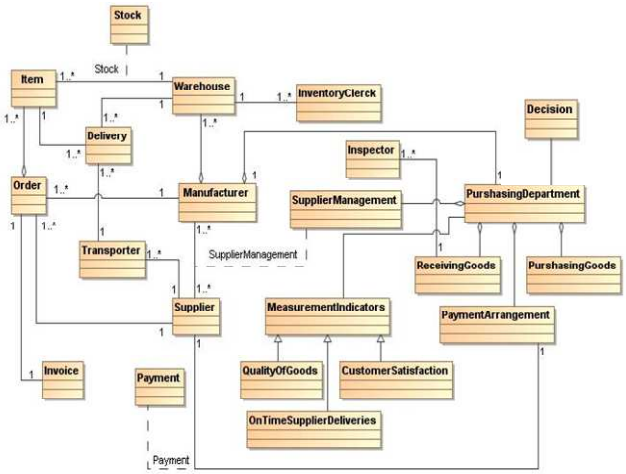

Fig. 7 Procurement process class diagram

The analysis of procurement process class diagram is built on the basis of use case diagram. As analyzed above, the classes of the system includes manufacturer, purchasing department, warehouse, order, purchasing goods, delivering and receiving goods, transporter, supplier, supplier management, and measurement indicators. The class diagram is shown in figure 7.

Yet, the class diagram or the use case diagram, gives a static vision of the functionality [20]. For this reason, we have carried out some dynamic diagrams to show the behavioral aspects of this mechanism.

4.4 Activity Diagram Analysis of Supplier-Manufacturer Relationship

Activity diagrams describe the dynamic behavior of a system. The aim to use activity diagrams is to model the workflow behind the system being designed. Sequencing of activities can be controlled by means of conditions. Two activity diagrams can synchronize their execution by sending and receiving signals. Activity diagrams can be subdivided into swim lanes. Each swim lane represents activities that are performed in a particular location, department, or by a specific actor [18]. Figure 8 is an activity diagram explaining the flow of objects and events involving the manufacturer and the supplier.

The activity diagram in figure 8 shows the various flows (information and material) between supplier-manufacturer relationship and describes the generic activities of procurement. The proceeding of this process starts just next the initial activity (**lack of stock**), then two activity states run simultaneously (**selecting supplier**, **place order**). In this model we took into account the rejection cases of order, which might be at the supplier level as well it can be at the manufacturer level.

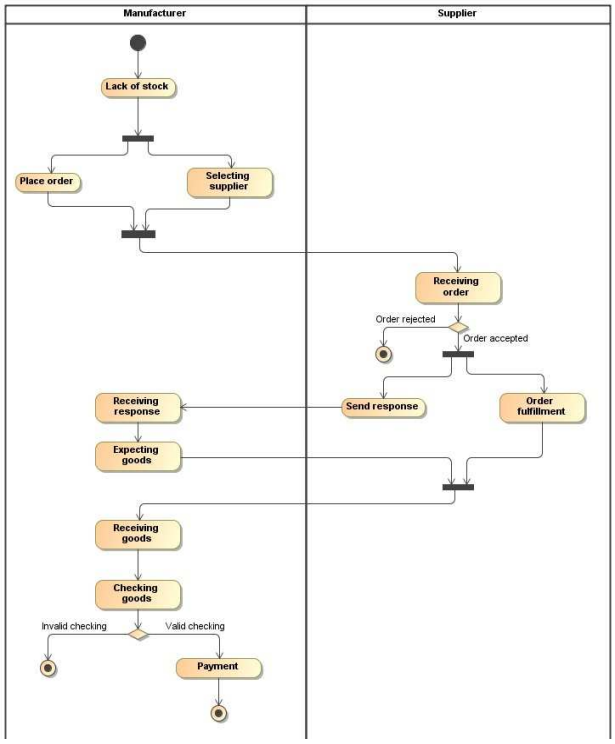

Fig. 8 Supplier-manufacturer relationship activity diagram

4.5 State Diagram Analysis

Also known as statechart, introduced originally by Harel. D [8], is a finite state machine extended with hierarchy and orthogonality (parallelism); used in system modeling and in computer science. It describes the behavior of entities capable of dynamic behavior by specifying its response to the receipt of event instances. Further, statecharts may also describe the behavior of other model entities such as use cases, actors, subsystems, operations, or methods.

Figure 9 shows order cycle; initially the order is placed and awaiting for response (order accepted or order rejected). If this order is accepted, then it will get ready to be delivered towards the manufacturer's warehouse for checking. Another condition of accepting or rejecting this delivered order, after checking and authenticating the requested requirements. Finally, in case of validating the checking, the supplier expects to be paid.

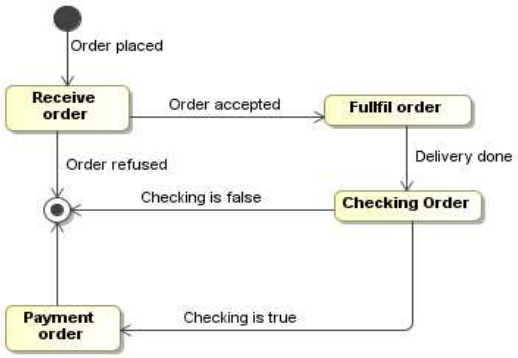

Fig. 9 Order state diagram

The second state diagram in figure 10 illustrates the different statuses of stock in procurement process. It begins with **consuming stock,** whereas the available stock amount is used for production needs, as long as this stock is superior to the threshold. On the other hand, when this stock is under the determined threshold, then the production system starts consuming the **safety stock**. Meanwhile, the order is launched (**Transit stock)** to replenish the **on hand stock** once again.

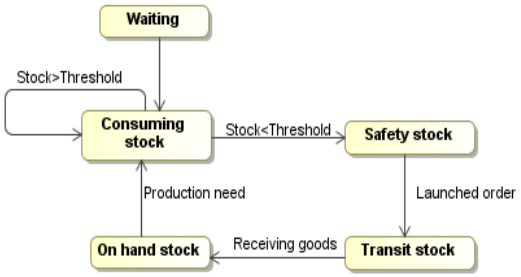

Fig. 10 Stock state diagram

5. Conclusion

In this paper, a dynamic simulation model has been built for procurement process including: ordering process, suppliers' selection, storage management and delivery process. The aim is to integrate the dynamic aspects of procurement and to give a generic character to the model, and on the other hand, to make the first component of a simulation model of the entire supply chain within manufacturing industries. The originality of this work lies in the assessment of the relationship supplier-manufacturer, based on a reusable simulation model which made of a set of conceptual and UML models. The latter was chosen because it is the facto standard for modeling object-oriented systems. It is also widely accepted in industry and academia and provides suitable extension mechanisms.

At first, we introduced the supply chain and the procurement issues according to the literature review. Indeed, the existing models are dedicated to specific companies and have some limitations, hence the need for flexible and reusable pattern of procurement process. Therefore, we have listed a set of features which we have incorporated in the model. Then we have modeled the static and the dynamic views of procurement process.

As future research work, we intend to simulate this model in order to analyze and to evaluate the performance of procurement process and to provide a tool for decision aids. We also aim to apply this model to simulate a real example of a manufacturing company.

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Abdessamad Douraid, graduated with bachelor of Electronic Engineering Systems from the faculty of science Ben M'Sik - Casablanca in 2007. Received the Master's Degree in Industrial Engineering and started his PhD studies in the same field in 2010 at the University Hassan II "Ecole Nationale Supérieure d'Electricité et de Mécanique" (ENSEM) Casablanca - Morocco. Currently he is a member of Amal Entreprises Organization of new entrepreneurs. His areas of interest are Industrial Engineering, Supply Chain Management, Modeling, Simulation and Optimization.

Dr. Saad Lissane El Haq, Is a Professor at ENSEM (Ecole Nationale Supérieure d'Electricité et de Mécanique) in Casablanca, Morocco. He has received the PhD degree from the University of Nancy I, France, in 1990, and he also has a Doctorate in Automation and Computer Science from the EMI (School of Engineering Mohamadia), Morocco, obtained in 1998. He is currently researcher in LISER (Laboratory of Computer Systems and Renewable Energy). He actively involved as a researcher and teacher in the areas of production automation and supply chain optimization.

Hamid Ech-Cheikh, obtained his bachelor in Biomedical Instrumentation Technology and Maintenance from the University Hassan I (Faculté des Sciences et Techniques - Settat). Master's degree in Industrial Engineering from the Univsersity Hassan II – Casablanca (Ecole Nationale Supérieure d'Electricité et de Mécanique ENSEM). Presently, he is a PhD student within the Laboratory of Computer Systems and Renewable Energy (LISER) at the same Engineering School (ENSEM). Research interests include Logistics Management and Multi-echelon Distribution Systems (Simulation and Modeling).