A CONTAINER TERMINAL MANAGEMENT SYSTEM

Mehdi Najib[(a)], Abdelaziz El Fazziki[(b)], Jaouad Boukachour[(c)]

[(a)] University of Le Havre France & LISI Laboratory, Cadi Ayyad University, Marrakesh Morocco
[(b)] LISI Laboratory, Cadi Ayyad University, Marrakesh Morocco
[(c)] University of Le Havre France

[(a)] mehdi.najib@edu.uca.ma, [(b)]elfazziki@uca.ma, [(c)]jaouad.boukachour@univ-lehavre.fr

ABSTRACT
This paper aims to use agent paradigm for modeling a Container Terminal Management System (CTMS). Our methodology is organized along three main axes. The first objective is to describe the overall architecture of a Container Terminal (CT), its actors and modeling container's handling process. The second one addresses the problem of safety in CT and specially the case of hazardous material. The latter proposes an agent approach for the development of CTMSs in an open source environment.

Keywords: Multi Agent System, Container Terminal, Container Terminal Management System, Agent Modeling Language

1. INTRODUCTION

The main problem of managing a CT is to ensure the mobility of containers passing through the sea port to deliver them to recipients in the best conditions. Thus, optimization of container handling is the basis for improving the performance of CT and therefore its competitiveness. Each handling order must be made by agents operating in the CT satisfying a set of constraints. On the one hand, container handling is governed by internal regulations of the port in order to respect its organization. On the other hand, there's a set of constraints related to the nature of the containerized goods, for example the case of segregation conflict between the classes of hazardous materials in storage area. In addition, a seaport may be subject to different hazards introducing the rupture of its operations. Following the consequences magnitude of these dangerous hazards, it is necessary to have a risk management approach. Although applying a risk management approach on a seaport will have a negative impact on its performance. Thereby solving this problem amounts to solving a problem of decision-making characterized by reconciliation between the security aspect and the performance of the sea port.

On average, inspected containers rate is 2% of the flow of containers through the seaport. Constrained by the impact of security inspections of port performance and cost of resource allocation for their implementation, the inspection rate of containers in Le Havre seaport is 0.5% (Dahlman 2005). Therefore, the appropriateness of the inspected containers choice is critical. The choice of these containers is a multi-criteria and multi-actors decision making problem.

Using traditional risk management approaches can identify risks; define a strategy for mitigating their impact and their probability of occurrence. However, these approaches are limited in their ability to dynamically manage risks. For this purpose the definition of a risk management approach which takes into account the nature of the CT and the impact of these security procedures on the performance is required.

Seaborne containerized cargo in the world has seen a great evolution from 50 million TEUs (Twenty-foot Equivalent Unit) in 1985 to 350 million TEUs in 2004 (Kim and Gunther 2007). The relocation of production plants, the increased trade between countries and the development of a new generation of container ship with a capacity ranging between 8,000 and 10,000 TEUs (Ottjes and al, 2007) explains the keen interest for this mode of transport that allows a cost-effective to transport large quantities of goods (Lun and al 2010).

Competition among shipping companies for the attraction of a large flow of container has exceeded the maritime boundaries represented by the providers of maritime transport hub ports to accommodate ships. The evolution of the freight passing through a CT, the complex nature of these platforms and port handling dynamic processes require the development of a performance Container Terminal Management System (CTMS) to prevent the potential risks.

Using a multi-agent system allow to describe the overall operation of a system from a description of the behavior of its actors and define a model of decision-making correlated with the situational context (Le Grusse 2001). The application of Distributed Artificial Intelligence (DAI) will allow the establishment of a collaborative decision-making based on negotiation between stakeholders to address the problem of multi-actor decision-making.

The long term goal of this work is to achieve the realization of a CTMS representing reality in real time handling operations by collecting the characteristics of the containers. In addition, it includes a decision-making process that analyzes historical data provided by traceability systems to target fraudulent containers. This decision-making process is based on the use of a fuzzy rules based system. The implementation of

CTMS will evaluate the effectiveness of the decision support system for targeting of fraudulent containers and its impact on the performance of the CT. In this work, we are particularly interested in the following objectives:

- The first objective concerns the architecture description of the CT, the specification of port stakeholders and modeling container handling process.
- The second goal addresses the risk management of the containers handling and specially the case of hazardous materials.
- The third objective concerns the specification of a CTMS based on agent paradigm and the integration of the security aspect through a decision making process for the prevention of risk scenarios and targeting of fraudulent containers.

The remainder of this paper is structured as follows: the second section discusses the modeling of the CT and the container handling process. The third section addresses the problem of risk management in a CT and provides an overview on the works done in this area and specifically the risk management during handling containers. The fourth section describes our CTMS model based on agents and taking into account the security aspect. Finally, we conclude by describing the limitations and perspectives of this work.

2. CONTAINER TERMINAL

The container represents the standardization unit of cargo transport; he has promoted the development of intermodal transport networks. Thereby the growth of the number of containers passing through a CT has assigned the role of the primary node of the global supply chain to these maritime platforms (Longo, 2010). In addition, the CT is a multimodal transport area (Ottjes et al, 2007).

In general a CT can be described as physical flow open system with two external interfaces (Steenken 2004), land interface and maritime interface. The CT is classified into a set of zones acting as buffers for the synchronization and coordination between handling operations. Figure 1 gives an overview of the architecture of a CT.

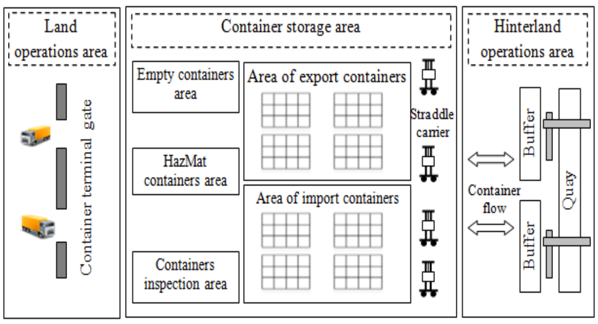


Figure 1: Overall layout of a container terminal

The structure of a CT is defined as a strategy that takes into account the nature of the handling operations (for example the case of a transshipment CT) in addition to the type of container handling material. (Dubreuil 2008) (Henesey 2006) (Wong and Yong 99) (Petering 2008) (Bakht and Ahmed 2008) identify three main areas: The area of land operations, the container storage area and hinterland area. These areas are classified into sub-areas dedicated by the type of port operations or the nature of the goods.

Container handling is a set of transport and storage operations to ensure the movement of goods between the two interfaces of the CT. In addition, the handling equipment (figure 2) has a great influence on the processes of import, export and transshipment containers. Especially in the case of the automation of handling operations in the Rotterdam seaport that distinguishes it from other seaports (Liu and al 2002). Thereby, a good specification of handling equipment is the basis for description of handling processes. (Steenken 2004) has classified container handling equipment into two categories:

- The first category includes the horizontal transport equipment containers such as trucks, containership and Auto-Guided Vehicles (AGV).
- The second category is a set of materials capable of lifting containers vertically, such as Quay Cranes (QC) and Straddle Carrier (SC).

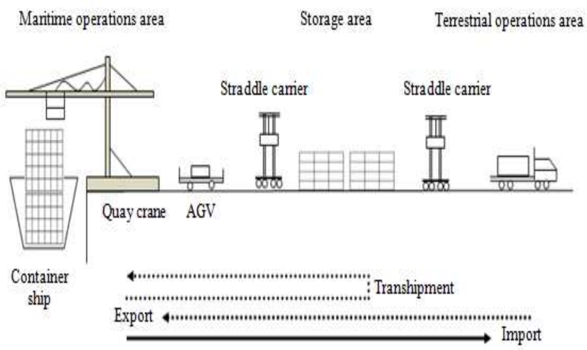


Figure 2: Container flow and handling equipment

To manage successfully a container terminal, we need to integrate informations sensors (RFID, GPS, GPRS, etc.) and information systems. In our case, we use our information system (Boukachour 2011), called GOST (Geolocalisation, Optimisation and Securisation of the Transport of containers).

GOST is a Web Services platform coupled with technological solutions to track and secure container shipping. It is designed to monitor physical movements, administrative schedules and planned shipment information in real time based on information traceability, with possible interventions to prevent malfunctions and risks of failure. GOST is not a standalone system but is interfaced with numerous existing information systems (port system, software solutions for the transit and port traction…), access geospatial data (tag GPS / GPRS, embedded computing, RFID, etc) and use secure connections (H24 and APSAD3), with appropriate services intervention if necessary. It is accessible via secure Web Services to all logistics agents. The GOST platform provide real-time and delayed time information and alerts needed to manage identified risk situations.

In order to automatically identify containers and to collect information about it, we use the concept of intelligent product. This concept comes from the field of industry, it has been adapted for the creation of intelligent containers. An approach based on the equipment of containers with RFID tags and sensors to measure temperature, humidity from the real environment. Thus, the intelligent container is considered as an entity carrying information able to communicate its characteristics to other systems and therefore to participate in decision making process. The works of (Alfaro and Rabald 2008), (Janssens-Maenhout and al 2009) and (Rizzo and al 2010) represent a concrete application of this concept, for example using intelligent containers for checking food transport conditions or to detect the traffic of radioactive materials in the containers.

3. RISK MANAGEMENT ON THE CONTAINER TERMINAL

The complexity of risk management in global supply chain requires a concentration of preventive procedures on these main links. To this end, many of these procedures are concentrated at the level of CTs due to their importance in world trade. Risk management in a CT for securing the transport container is a set of preventive measures:

- Container Security Initiative CSI
- Customs-Trade Partnership Against Terrorism C-TPAT
- Proliferation Security Initiative PSI
- Mega ports initiative to prevent nuclear smuggling.

In the literature, especially in the case of hazardous materials the works of (Rigas and Sklavounos 2002) (Milazzo and al 2009) (Winder and Zarei 2000) were based on a post hoc analysis of the consequences of an accident during the container handling to identify special interventions strategies adapted to the studied case.

The huge flow of containers passing through a seaport imposes the adoption of a security approach for preventing risks and detecting fraudulent containers passing trough CT (Milazzo and al 2009). Risk management related to the handling of hazardous materials at a seaport is constrained by the unsuitability of conventional methods of risk management to the dynamic of its environment. In addition, the confidentiality of information due to their economic values and the concurrence between shipping firms is a handicap for decision making process. Thus, the definition of a new approach that takes into account the dynamics, complexity and uncertainty of CT information is a promising approach to assist the decision makers to prevent risks.

4. SYSTEM DESIGN

To design our CTMS, we use a Use Case Driven Approach (UCDA) in order to specify the business process to integrate. In addition, the structure into several sub-systems allows a modular system design comprising interrelated treatments in the same sub-system and promotes the reuse of these modules for other applications.

Modeling a CTMS is a laborious task and involves the description of the behavior and roles of various components of this system. The specification complexity of CT business process and interdependence between the actors throws the proposed models quality into question. In order to ensure proper system design we have adopted the concepts described below.

It does not seem feasible to get a formal description of a complex system based on informal description on its operation, especially in the case of CTMS. The different modes of operation between the CTs in the same port, the dependence on type of handling equipment and management policy applied imposes a specific model for each CT.

In our case, to model the CTMS we opted for UCDA. The basic concepts of this approach are the actors and their actions. An actor is a specific role played by a user and represents a category of users of the system. An actor can be considered as a class and users are the instances. Use cases are expressed in natural language with terms of the studied problem domain (Regnell and Kimbler 95). Use cases are an artifact that establishes the desired behavior of the system and interactions between different actors and the sequences of actions needed to achieve a result.

Use cases are a powerful tool to capture functional requirements of the system. Several methods use this approach, such as the Unified Process method, to agile development of applications. The main advantage of this approach manifests itself in facilitating the analysis process needs while keeping users at the heart of the process by adopting these requirements in natural language. The adoption of UCDA to study the system specifications will ensure consistency between the needs of users and the functional aspect of the system.

The analysis of an entire complex system as one atomic unit is a tedious task. To address the complexity problem of CTMS we conducted a division of the problem based on the structuring technique. Structuring is a fundamental technique for classifying the CTMS into several sub-systems in order to reduce its overall complexity, reduce the phase test complexity and validate its consistency with specifications. Good structure is characterized by a strong cohesion between the component entities of the same subsystem, thus reducing the interactions between subsystems.

Therefore, a weak coupling limits the impact of malfunction or modification of a subsystem on the entire system. The division should be led by the evaluation criteria the performance and the robustness of the system.
The reuse concept reduces the development time of a system while ensuring its reliability. Reuse is to design a system as a set of specialized entities reusable by different modules of the system. The adoption of this approach limits the impact of changes on the overall system and reduces the development cycle by eliminating repetitive tasks. Reuse can reduce the development cycle by removing repetitive tasks such as unit testing of modules and focuses on the integration phase of all system components.

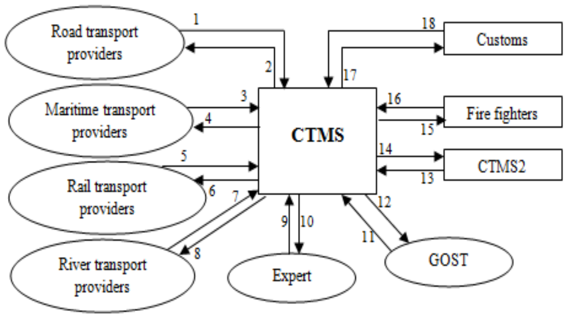
The CTMS development approach is structured in four main steps:

- Context diagram: is a primary step for the identification of system boundaries and interactions with external actors;
- Classification of the system : classification into several subsystems based on a functional grouping of consistent entities with the same goal;
- Use Case diagram: in the first step we proceed by specifying the use case diagram to identify the overall system's main actors and their roles. In the second step we define a use case diagrams for each subsystem;
- Agentification: agents are assimilated with the actors and handling equipment existing in the CT. We will proceed with a definition of all the agents forming composing the system and by specifying their functions and interactions.

5. APPLICATION

Initially, for modeling the proposed CTMS in consistent with the approach described above, we have proceeded with a macroscopic description of the system and its interactions with other actors in its environment. The second part focuses on a detailed specification of the system's agents, and their interactions.

The context diagram is the basis of a preliminary study to locate the system in its environment and identify the flow of information exchanged with external actors and related fields. In the studied case, the CTMS exchange information with a set of transport provider to prepare procedures for receiving and shipping containers. The CTMS is powered by the knowledge of experts and alerts from GOST system. In addition, it exchanges with other organizations representing related fields such as customs for the collection of information about the content and origin of the container or the firefighters in the event of an accident occurring (Figure 3).



- [1 ; 3 ; 5 ; 7] : inform CTMS about containers delivery
- [2 ; 4 ; 6 ; 8] : inform transport providers of the availability of containers
- [9] : provide knowledge for the prevention of risk
- [10] : analyse new cases
- [11]: send alerts and track the status of containers
- [12] : request information about containers status
- [13 ; 14] : Exchange information with other CTMS
- [15]: provide information about the containerized goods accident
- [16] : respond to occurrence of an accident
- [17] : target containers for inspection
- [18] : provide to system information about container

Figure 3: Context diagram of the CTMS

The aim of the proposed approach is to model a CTMS by classifying the MAS into several sub-systems in order to ease the development phase. The classification is to group agents with similar goals to form coherent subsets. In addition, the classification of the system is guided by criteria for assessing the quality of grouping the agents such as the strong cohesion between the agents of the same subsystem and the weak coupling between subsystems.

The proposed CTMS is composed of two main parts, the first one deal with decision making for risk management and consists of three subsystems: learning subsystem, supervision subsystem and planning subsystem. The second part of the system deals with handling operations in the CT. It consists of three subsystems: representation subsystem, interfacing subsystem with road transport providers, interfacing subsystem with maritime transport providers (Figure 4).

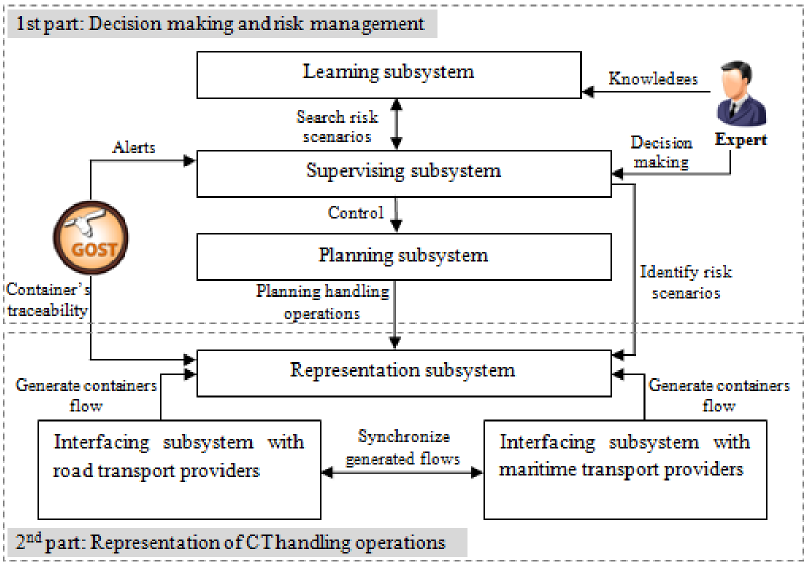


Figure 4: Classification of the CTMS into subsystems

Communication between the subsystems of the CTMS is based on an exchange of messages for the dissemination of orders and planning handling operations. The agents use the Agent Communication Language (ACL) developed by the Foundation for Intelligent Physical Agents (FIPA).

To address the complexity of modeling business processes in a CT, the specification of the behavior of individual agents at the micro level of an MAS allow the reproduction of the overall functioning of the CT in the collective interactions of agents at the macro level of the MAS. Modeling of the proposed system and specifying its functions are performed using the Agent Modeling Language AML (Whitestien, 2004).

Using AML, agents diagram allow the specification of the overall CTMS agents and gives an overview of the MAS architecture (figure5). In addition, it specifies all the interactions and dependencies between the agents by social associations.

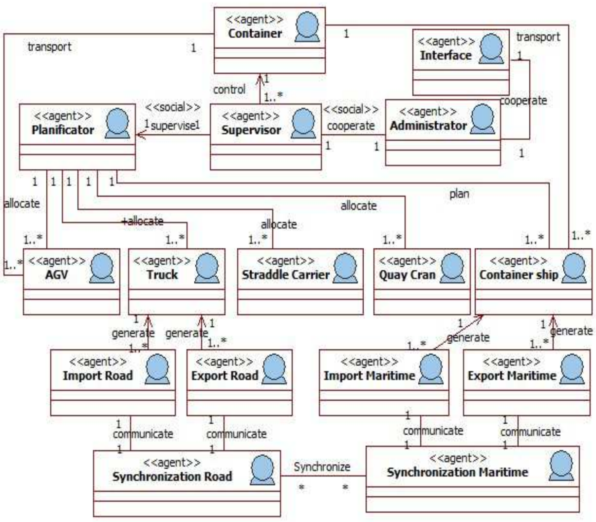


Figure 5: CTMS overall agent diagram

The agents composing the system are intentional, follow the BDI model (Beliefs, desires, intentions) they have a description of their environment and knowledge about other agents. In addition, the definition of a learning process will allow adding of new knowledge to the CTMS and therefore a continuous adaptation of the system for the detection of new risk scenarios.

5.1. Interfacing subsystem with road transport providers

It represents all road transporters providing container transport to the CT and delivers the imported containers to customers. It ensures the generation of the input and the output flows at the terrestrial interface of the CT (figure6).

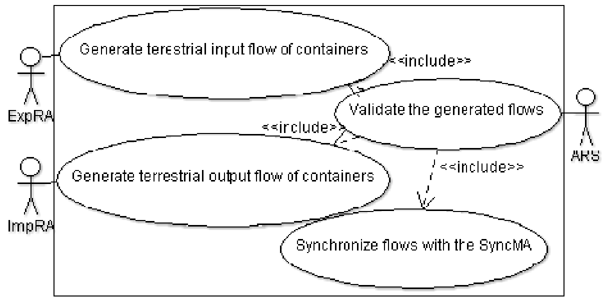


Figure 6: Use case diagram of interfacing subsystem with road transport providers

This subsystem consists of three agents:

- Export Road Agent (ExpRA): generates the flow of trucks carrying containers to the CT and thus the input flow of containers.
- Road Agent Import (ImpRA): generates the flow of trucks delivering containers to customers of CT and therefore the output flow of the terrestrial interface of the CT.

- Synchronization Road Agent (SyncRA): validates the generated container flows and cooperate with the SyncMA to ensure the support of all containers.

The functioning of this subsystem is controlled by the SyncRA, its main role is to ensure the concordance of the input and output containers flows in the terrestrial and maritime interface of the CT. It starts by sending an order to ExpRA to recover the list of generated containers at the terrestrial area. The SyncRA requests the list of generated containers at the maritime interface in order to generate the trucks delivering them to customers by ImpRA (figure7).

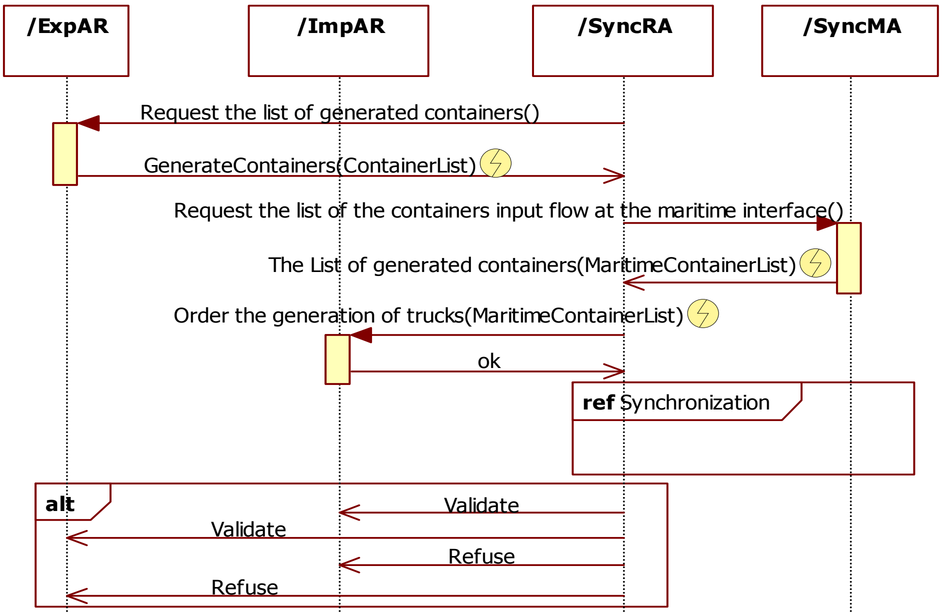


Figure7. AML Communicative sequence Diagram of the interfacing subsystem with road transport providers.

5.2. Interfacing subsystem with maritime transport providers

Ensures the generation of the input flow and the output flow of containers generated at the maritime interface of CT. The following figure describes the use case of this subsystem:

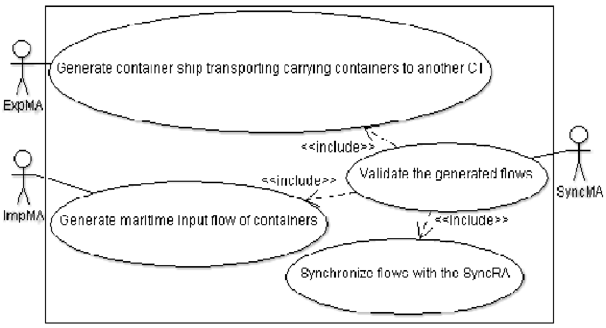


Figure 8: Use case diagram of interfacing subsystem with maritime transport providers

This subsystem consists of three agents:

- Export Maritime Agent (ExpMA) generates the container ships carrying containers, maritime output flow, to other seaports.
- Import Maritime Agent (ImpMA): generates the input flow of containers at the maritime interface by generating container ships transporting the generated containers to the CT.
- Synchronization Maritime Agent (SyncMA) validates the container flows generated by the two agents and ExpMA and ImpMA by contacting the SyncRA to interface with road transport providers to check the concordance between the input flow and output of the two interfaces of the CT.

By analogy with the interfacing subsystem with road transport providers this subsystem ensures the generation of input flow and output flow of containers in the CT maritime interface. The SyncMA is responsible for managing and synchronizing its operation with the SyncRA (figure9).

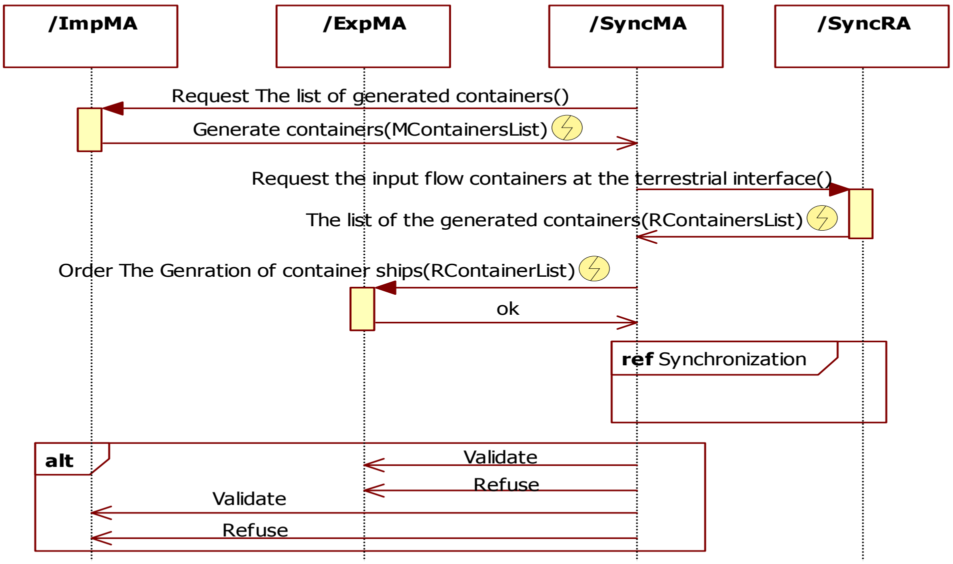


Figure9. AML Communicative sequence Diagram of the interfacing subsystem with road transport providers.

5.3. Representation subsystem

The representation subsystem reproduces the container handling operations at the CT. The purpose of this subsystem is to measure performance indicators in order to evaluate the impact of different strategies of risk management on the CT performance. Thus, to represent real operation of the CT, CTMS's agents are assimilated to the CT's actors and to the handling equipment (figure10).

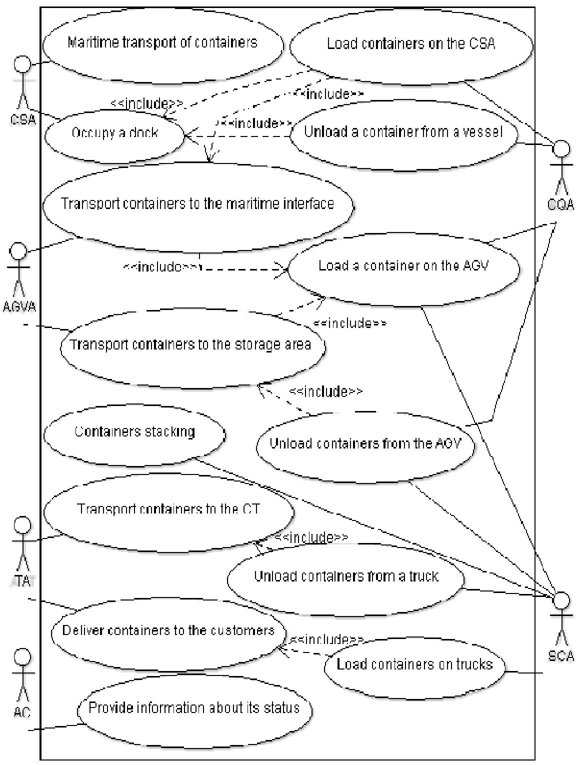


Figure 10: Use case diagram of the representation subsystem

The actors of this sub system are classified into two categories: the first one includes all active entities representing the handling equipment. The second category includes all the agents corresponding to containers generated at the two interfaces of the CT.

This subsystem consists of six kinds of agents:

- Container Ship Agent (CSA): represents the vessel carrying the containers, it is characterized by its capacity (TEUs), Size, arrival and departure date.
- Quay Crane Agent (QCA): load and unload containers from container ship, it is characterized by container handling time and its speed.
- Automated Guided Vehicle Agent (AGVA): transport containers between the container storage area and the maritime operations area. It is characterized by the container size that can move and its speed.
- Truck Agent (TA): transport container to the customers. This agent is characterized by the container size that it can carry.
- Straddle Carrier Agent (SCA): ensures stacking containers and at the storage area and it load and unload containers from trucks and AGVs. This agent is characterized by its speed and the size of containers.
- The Containers agents represent entities carrying information about the container; they are characterized by size, nature of goods, the quantity of the goods, origin of goods and the history of ports by which the containers were handled. The agent container updates its features by contacting the traceability system GOST.

The agents of this subsystem are controlled by the PA. It assigns handling tasks to agents to transport containers between the two interfaces of the CT. The following scenario describes the container transit process and its interactions with the other agents.

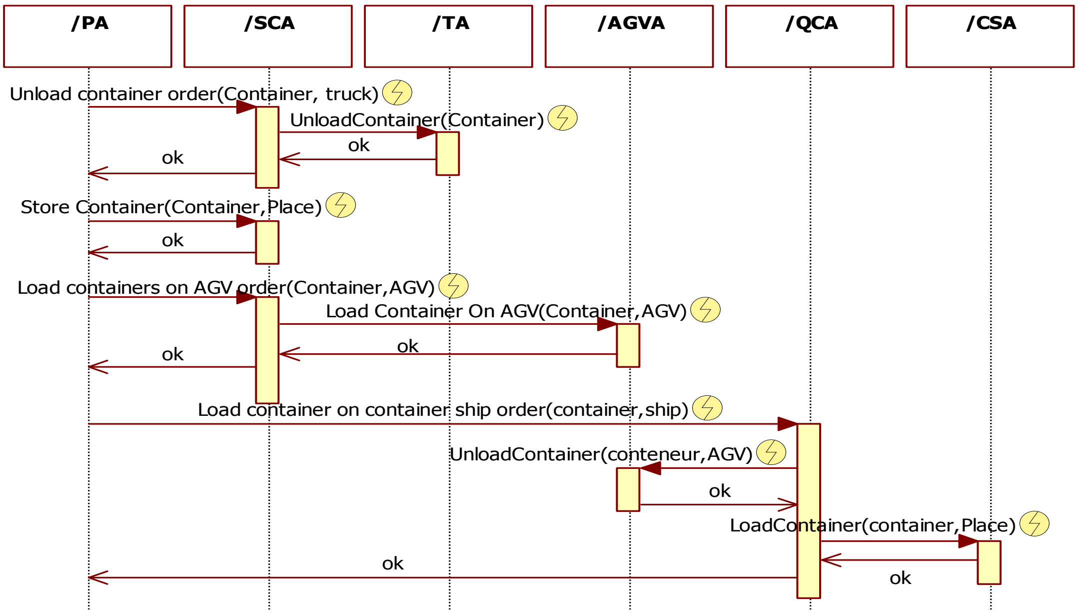


Figure 11: AML Communicative sequence Diagram of representation subsystem

5.4. Planning subsystem

Consists of a planner agent that allocates resources for handling containers. In addition, it ensures the allocation of containers storage places in CT (Figure 12). The PA pilots the operation of the representation subsystem and cooperates with the supervision subsystem in order to validate his decisions.

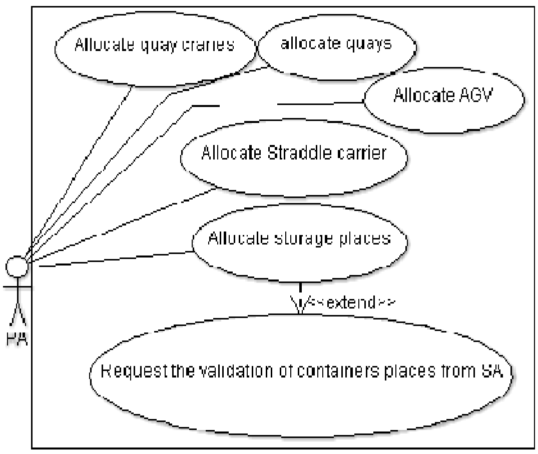


Figure 12: Use case diagram of the planning subsystem

5.5. Supervision subsystem

The supervision subsystem controls handling container operations in the CT and analyzes container information in order to target high risk containers that will be subject to inspection procedures by customs officials. First, the SA validates the storage location allocated by the PA and verifies the compliance with the rules of segregation between the classes of hazardous materials. In addition, it targets high-risk containers based on a case base containing information relating to the previous fraudulent containers detected during customs intervention (false declaration of goods, drug trafficking ...). Furthermore, this agent uses also a quantitative risk method for targeting risk containers based on the product of the probability that the container is fraudulent and the consequences of an incident relating to this event. The figure 13 describes the use cases of this subsystem.

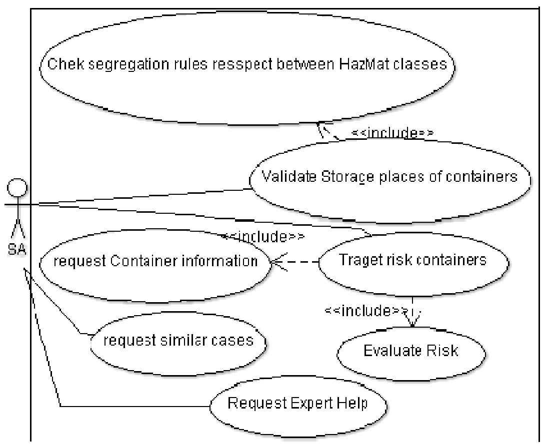


Figure 13: Use case diagram of the supervising subsystem

In order to prevent risk scenarios, SA analyze containers information and evaluate the risks. Furthermore, it validates PA decision especially in storage places allocation.

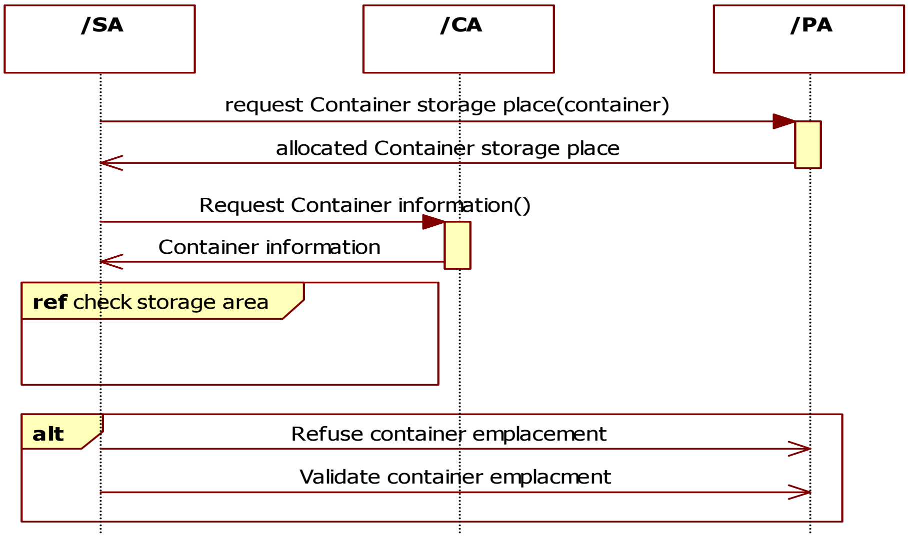


Figure 14: AML communicative sequence diagram of supervision subsystem

5.6. Learning Subsystem

Ensures archiving of previous fraudulent containers detected by the customs. Also, it stores information about risk scenarios. The main role of this subsystem is to provide SA with risk scenarios. The following figure presents the use case of this subsystem:

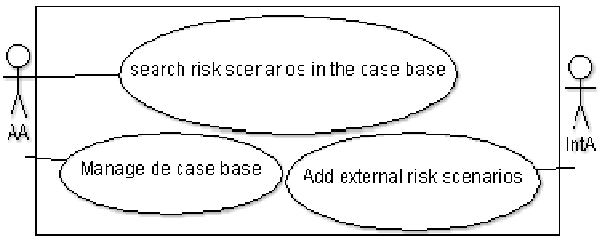


Figure15. Use case diagram of the learning subsystem

This subsystem is composed of two agents:

- Administrator Agent (AA): Manages the case base and stores new risk scenarios and information about risk containers detected by the system.
- Interface Agent (IntA): insures interfacing the learning subsystem with external.

6. CONCLUSION AND PERSPECTIVES

In this article we discussed the CT structure and the risks arising from the container handling operations and specially in the hazardous materials case. Then we proposed a CTMS model based on agent paradigm classified into several subsystems to reduce the complexity of the problem and to have a strong cohesion between the stakeholders operations. In addition we proposed the integration of risk management in the CTMS through the supervision subsystem preventing risk scenarios during handling operations.

In the future work, we will detail the supervision decision making process based on the decision rules provided by customs in order to target high risk containers. Furthermore, the implementation of the CTMS model using JAVA and the open source framework JADE (Java Agent DEvelopment Framework) is on progress.

The integration of risk management approaches in the simulation of the CT will allow the evaluation of the risk management strategies impact on the CT performance.

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