Chapter 9

Dynamic Risk Management Strategies with Communicating Objects in the Supply Chain of Chemical Substances Within the European Union

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Additional information is available at the end of the chapter

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1. Introduction

Supply chain is a set of activities involving a group of commercial actors to create a product or a service to satisfy a customer demand. The actors are the ones who form the supply chain, they are suppliers, transporters, manufacturers, distributors, retailers and customers.

In this chapter, our objective is to describe dangers for people, environment and goods from dangerous goods exploitation. We want to show how dangerous goods can be source of accidents during storage activities. To understand the potential of chaining event we elaborate accident scenario to describe the consequences of such accidents.

This risk study in warehouse provides insights to elaborate a risks management strategy relying on communicating objects such as RFID tags and wireless sensors. Then, by exploiting the technical features that provides these smart items, it becomes possible to detect in real time any accident risks and to react in consequence.

This chapter is organized as follows. Part 2 introduces briefly what supply chain management is and gives some definitions. Part 3 describes dangerous goods in logistics and notably the risks inherent to their storages. Current regulations such as CLP is presented, it provides a standard in the European Union to classify and identify dangerous goods. Risks relative to dangerous goods manipulation are presented, segregation strategies and storage constraints must be respected to maintain the security within a warehouse. In part 4, a risk study is lead to extract three scenarios that describe the domino effect consecutive to accidents. These scenario are treated further in part 5 when communicating objects are integrated at pallet level. Then, these smart items allow elaborating real-time risk assessment that contribute to detect early accident risks and to deploy emergency procedures to mitigate that risks.

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2. Supply chain management in logistics

Depending on actors involved in Supply Chain (SC) (suppliers, transporters, customers), SC definitions can differ regarding the described interactions and dependences between actors. A definition is given by [1]: *"A network of organizations that are involved, through upstream to downstream links, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer".*

With this definition, it appears that each company owns an internal SC and participates to another SC. A SC is a succession of activities related to a specific function performed by one or several actors in order to satisfy customer demands. Then, each actor belongs to a global flow, he evolves according to three interactions: his internal tasks, his provider status and his customer status.

2.1. Supply chain management

A SC exists if at least two companies work together to the production of a particular product or service. If this association is explicitly guided to improve the performance then we describe this as supply chain management, also called SCM.

From a general point of view, the SCM can be defined as the coordination between companies internal and external activities. The goal of this management is to improve the SC performance on long term basis so that each actor of the SC can take benefit of this global management.

The SCM consists of managing the whole organizations involved in the delivery of a final product or service. Its aim is, on one hand, to produce products relying on information received from the customer needs and, on the other hand, to minimize the different supply, production, warehousing and delivery costs. The SCM gathers two parts: the integration of the company along the SC and the coordination between the physical, information and financial flows.

The main objective of the SCM is to improve the competitiveness of companies by minimizing the costs while the quality of service required by the customer is guaranteed.

3. Dangerous goods management in logistics

A good is considered as dangerous when it may present a danger on population, environment or on infrastructure according to its physicochemical properties or because of the reactions it can imply.

Activities involving dangerous goods concern all parts of the world. A global regulation is needed and should be coordinated with local authorities to make laws more reliable and respected. Since the logistics tend to be global, the control should be also global for a better efficiency.

Laws related to the use, the loading, the unloading, the storage, the transportation and the handling of dangerous material differ according to activities, status or modality of transports. Countries rely on international recommendations proposed by the Organization of United Nations to regulate the operation on dangerous goods.

The UN proposes recommendations for the dangerous goods since 1957 and updates periodically its texts. It is a reference which provides the main recommendations related to the dangerous goods notably about the different methods of transport: air, road, railway, canals and sea. A specialized authority is dedicated for each means of transportation, they are the followings:

- International Air Transport Association, IATA, is for transport by airplane;
- European Agreement concerning the international carriage of Dangerous goods by Road, ADR, manages the European transport of dangerous goods by road;
- Regulation concerning the International transport by railway of Dangerous goods, RID, is for the international transport of dangerous goods by railway;
- European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways, ADN, manages the international transport on internal canals;
- International Maritime Dangerous Goods Code, IMDG Code, is for international transportation by water.

Due to the existence of international regulations, countries or groups of countries (the European Union for example) have adapted their laws to harmonize them with the UN model. Thus, country legislations tend to follow the international regulations to make the management of dangerous goods more standard and more visible by a third.

3.1. Dangerous goods identification

Considering the important number of substances, there is a clear need for dangerous goods classification. Existing classifications of dangerous goods are based on chemical families (acid, alcohol, amide, etc.), chemical reactions (oxidation, reduction, combustion) or also on chemical compositions.

The CLP (Classification, Labelling, Packaging) regulation is relative to the chemical substances imported or commercialized in the European Union. This regulation entered into force in January 2009 and will be totally applied in 2015.

3.1.1. Obligations under CLP

CLP provides a global obligation for all suppliers in the supply chain to cooperate. This cooperation is necessary to make the different suppliers meet the requirements for classification, labelling and packaging.

3.1.2. Terminology

A new terminology is used, terms of existing regulation are kept whereas news are adopted. The term substance is used to designed hazardous material and the transformation of these substances into a new one is called mixture.

As well, the properties of substances are described according to three properties: physicocochemical, toxicological and ecotoxicological. According to these three criterion, the definition of hazard classes helps to classify a substance. Then, a hazard class defines the nature of a hazard, it can be physical, on health or on the environment.

3.1.3. Classification of substances

CLP possesses specific criteria of classifications that are rules that allow associating a substance to a class of hazard or a category in this class. In particular, the classification process is based on the substance concentrations to establish the effects of those substances on the health and the environment.

CLP defines three hazard classes and 28 categories, such as:

- 16 categories for physical hazards;
- 10 categories for health hazards;
- 2 categories for environmental hazards.

For example, the physical hazards regroup explosives, flammable gases, solids, aerosols, liquids. The health hazards are relative to acute toxicity, skin corrosion, irritation and sensitization. The environmental hazards address hazardous to the aquatic environment and hazardous to the ozone layer.

3.1.4. Labelling

A substance contained in packaging should be labelled according to the CLP rules with the following information (called labelling elements):

- the name, address and telephone number of the supplier of the substance;
- the quantity of the substance in the packages;
- hazard pictograms;
- signal word;
- hazard statements;
- appropriate precautionary statements;
- supplemental information.

A substance contained in packaging is labelled according to the CLP rules and contains a set of information such as name of the supplier of the substance, quantity of the substance in the packages or hazard pictograms, see Fig. 1.

The CLP regulation helps then the identification of chemical substances through the supply chain since it provides a standard framework for the classification, the labelling and the packaging of substances.

3.2. Risks in dangerous goods storage

In the context of logistics the main considered risks are relative to the physical or information flows disruption. The case of a supply chain whose physical flow manages dangerous goods, the risk becomes different and takes another dimension.

Figure 1. Pictograms used in CLP regulation.

3.2.1. Risk definition

The Process Safety Management (PSM) defines risk as follows:

"Risk is defined as a measure of frequency and severity of harm due to a hazard. (...) In the context of public safety, risk is commonly characterized by fatalities (and injury) to members of the public".

According to this definition, several factors make difficult to assess the risk for dangerous goods manipulation. Among these factors, there are the followings:

- Because of the diversity of hazards, the chemicals physicochemical properties are different and consequently risks evolve also;
- The localization of potential accidents stays uncertain, it is not possible to determine where an accident can occur (warehouse, highways, county roads, local roads, etc.);
- The large diversity of causes implies that it is impossible to enumerate all cases and to treat these risks.

3.2.2. Risks in warehousing

Among dangerous goods, products can react when they are in contact. For these reasons, they must be stored in separate places. Strategy of storage consists in avoiding that incompatible products are neighbors. To this end, a first step is needed to identify substances as a function of their potential chemical reactions.

In order to prevent any storage of incompatible chemicals and risk of chemical reaction in case of wrong handling, seggregation strategies are used. As shown in Fig. 2, it exists

Danger Code	F	F+	T	Xi	O	Xn	N	C
F	+	+	-	+	-	+	-	-
F+	+	+	-	+	-	+	-	-
T	-	-	+	+	-	+	-	-
Xi	+	+	+	+	-	+	+	-
O	-	-	-	-	+	-	-	-
Xn	+	+	+	+	-	+	-	-
N	-	-	-	+	-	-	+	-
C	-	-	-	-	-	-	-	+

Figure 2. Identification of storage compatibilities between dangerous goods. The letter F means inflammable, F+ means very inflammable, T means toxic, Xi means very irritant, means O oxidizing, Xn means noxious, N means polluting and C means corrosive.

incompatibilities for storage that is why the maintain of segregation between products constitute a risk assessment strategy to mitigate the risk of chemical reactions.

Once dangerous goods are stored in separate places of a warehouse, other sources of risks remain:

- Container falls;
- Container damages;
- Storage conditions (humidity, heat, cold, light);

4. Risk study in warehouse by scenarios

Within the framework of scenarios modeling, three different scenarios are built, including causes and effects of accident risks that define a basis for further risk assessment by communicating objects.

The methodology used is the one usually practised in audit or studies of risks and dangers and also in the impact procedures.

4.1. Methodology

The methodology used for scenarios definition aims at characterizing, analyzing, and assessing the risks in warehouse. Those risks can have two different causes: due to logistic exploitation (e.g., shipping, handling, storage), or due to external causes such as flooding, lightning.

This first analysis, find all the regulatory constraints aims to identifying and at recording, through various tools, the potential hazards that may occur in the retailer warehouse and its operating system. The natural and human environment hazards are also analyzed. These steps are intended to identify external attackers at the retailer warehouse.

4.1.1. Risk evaluation

An analysis of the warehouse neighborhood is conducted in order to identify targets and their vulnerabilities and to characterize the severity of the dangerous phenomena. Equipments that may be impacted (eg. racks, clarks, trucks) due to internal or external logistics processes are also identified.

4.1.2. Preliminary risk analysis

A rating of hazardous phenomena identified enable to identify major accidents and through a combination of different criteria:

- Probability of occurrence of a dangerous phenomenon;
- Intensity of these effects;
- Vulnerability of the target impacted by these effects.

Following this preliminary risk evaluation, we can discard non significant risk, which are evaluated as low gravity, and probability. Therefore, we perform a detail analysis over the major identified risks.

This rating corresponds to a hierarchy through a matrix (gravity/probability) allow identifying two categories of risk:

- risk level is considered generally sufficient;
- risk has to be subject to a closer examination.

4.2. Scenario 1: Aerosol explosion

The warehouse is likely to receive products classified under the heading 1412 UN code, bottles generating aerosols. The propellant gases contained in these bottles is most of the time of butane or propane under pressure.

In this scenario, we describe the explosion of aerosol (air freshener). It is considered as an inflammable.

4.2.1. Risk evaluation

The principle of a generating bottle of aerosols is to allow the propulsion of the product (lacquer, deodorant, adhesive, maintenance product, ...) out of the bottle thanks to a gas under pressure contained in the bottle. Common bottles have a varying volume from 50 to 500 ml and contain between 30 and 150 G of product plus propellant gas.

The behavior in fire of aerosols generators of depends on one hand nature on propellant gas and on the other hand on the nature of the conditioned liquid. Therefore, if the propellant gas is a flammable gas standard butane or propane, there is a risk of explosion. The bottles are then dispersed by missile effect and can be in their turn a propagator of fire.

In the same way, if the liquids contained are flammable liquids, they will support the fire. The generators of aerosols are thus the subject to specific storage, depending on the nature of the containing products (gas and/or liquid).

4.2.2. Preliminary risk analysis

Based on the calculating probability scale and the calculation of gravity scale, this scenario occurred and may occur throughout the life of the installations and no person will be impacted.

The method used to assess the effects of an explosion of aerosols in a warehouse is multi-energy model. Explosion cloud formed by the gas contained in a bottle would not reach the thresholds of overpressure. Regardless of the distance to the cloud, a target suffers less than 20 mbar pressure which causes no human and material damage. We consider the explosion of the cloud formed by the simultaneous outbreak of 100 bottles of aerosols, which is extremely unlikely even when taking into account that the bottles are for most made on aluminium.

4.3. Scenario 2: Fire truck incident

This scenario develops the consequences of the fire on a truck loaded with pallets, we assume that the truck is loaded exclusively with generic aerosol or fertilizer.

Nitrate-based fertilizers (that do not contain high nitrate content) are not capable of detonation. The ammo-nitrates high or medium dosage, French standards or European are difficult to detonate in the absence of contamination. Furthermore, dust fertilizer containing ammonium nitrate in the air are not combustible and do not present an explosion risk, unlike the dust of grain or organic fuels.

4.3.1. Risk evaluation

The detonation is possible in some cases:

- Contamination of the nitrate high or medium dosage of substances fuel (fuel, oil, plant protection products) or incompatible;
- heating of the nitrate high or medium dosage especially if it is contaminated, and maintenance of a containment of the gases emitted by the combustion;
- Severe impact of projectile on the product or shock very violent in contact the nitrate.

4.3.2. Preliminary risk analysis

Based on the calculation probability scale and the calculation of gravity scale, this scenario event thought: occurred and may occur throughout the life of the installations or may unlikely event: something similar already encountered in the sector of activity or this type of organization at the global level, without any possible corrections made since bring a significant reduction in its probability is guarantee and no person will be impacted.

The following scenario develops the consequences of a fire truck loaded with pallets at a unloading dock site. The fire or explosion of aerosols and fertilizer is due to inflammation of a palette (mechanical heating, inflammation, engine, non-compliance with the prohibition of smoking). We left the assumption that a cigarette would be has the origin of the starting point of fire. We leave the principles which another vehicle charged with manure would be been parked on the quay dimensioned. The starting point of fire and the propagation with the truck containing of manure cause effects missile, explosions, and dangerous heat fluxes for the man as well as the toxic dispersion of smoke, of projection has missile effect as well as discharge of water and product polluting for environment.

4.4. Scenario 3: Hazardous liquid spill

Accidental discharge is related to the presence of liquid products on site. The spill may trigger the leakage of an important quantity of hazardous liquid. A leakage of hazardous substances can occur due to the fall of one or more pallets of a rack but also due to a weakness in on (or a series) of container (bottle, can). A spill of hazardous substances can have an impact on the environment and on people.

4.4.1. Risk evaluation

Because of the loss of integrity of a container, a liquid will flow and form a pool of dangerous liquid which mainly function of the topography, the viscosity of the product and quantity.

The multitude of references and stored products do not enable to study exhaustively all dangerous chemical reactions. However, all possible precautions are taken to avoid storing incompatible products in a single cell.

4.4.2. Preliminary risk analysis

This scenario occurred and may occur throughout the life of the installations and no person will be impacted. We will find a fall of pallet that will provoke liquid spill which is the starting point of fire, projection missiles effect, various explosions and propagation of smoked and gas dangerous for the man and the environment.

According to the nature of fire, it must there have a respect of the means of extinction, in this case of figure it will be impossible to respect this standard, and the means of extinction set up, will cause a pollution of the natural environment.

4.5. Scenarios modelling

In this section, we model the scenarios presented previously by UML diagrams to describe the sequential chain of events following an accident. In particular, we are interested in identifying the main damages and consequences of accidents involving dangerous goods.

As we said, the accidents are evaluated by several measures, by the place and by the number of persons within this place. The type of accidents we consider and which can occur during the manipulation of dangerous goods is correlated to the chemical features of those goods. Further, the main effects we consider in our scenarios are the followings:

- Release of substances which are toxic to health and to the environment;

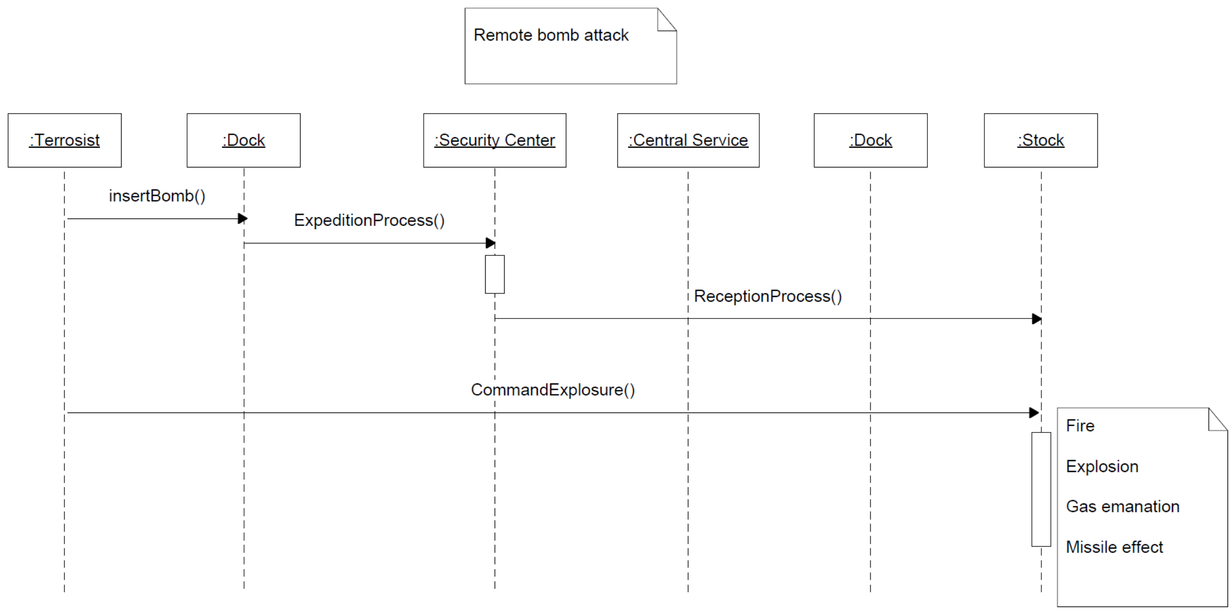

Figure 3. Scenario 1: a bomb attack triggered from a stored pallet.

- Release of thermal energy;
- Release of pressure.

The consequences that derive from an accident depend obviously on the type of dangerous goods, the area population, the accident time, the accident place, etc. Here, we are interested in describing the impacts of accidents by scenarios. In particular, we study the consequences of energy release according to the two phenomenons of Unconfined Vapor Cloud Explosion (UVCE) with the first scenario and the Boiling Liquid Expanding Vapour Explosion (BLEVE) with the second scenario.

4.5.1. Scenario 1: Aerosol explosion

Based on the scenario introduced as Scenario 1, we describe how a bomb attack can occur in a warehouse. We propose a first sequence diagram; see Fig. 3, to model this scenario.

We remark that the bomb is transported from a first place to the final storage place where the bomb attack is triggered. Nevertheless, by considering that terrorism attacks have a probability to miss their targets, we can assume that a remote bomb attack can potentially become a road accident when the bomb explodes at an untimely moment.

We describe by an activity diagram, see Fig. 4, the events following a bomb explosion once it has been stored. The first events are relative to the way that the bomb is susceptible to explode when the trigger is activated; it can burn first before exploding. Once the explosion happens, the shock wave provokes damages on near products and a domino effect starts from the pallet to the rack beams. With time the whole pallets are susceptible to burn and then to explode. The fire and explosions provoke pressure effects and thermal effects which have consequences on persons present in the stock. The damages caused by this bomb attack are measurable by three dimensions: the human, the structure and the merchandises damages. Here the humans damages are relative to the persons working in the warehouse and who

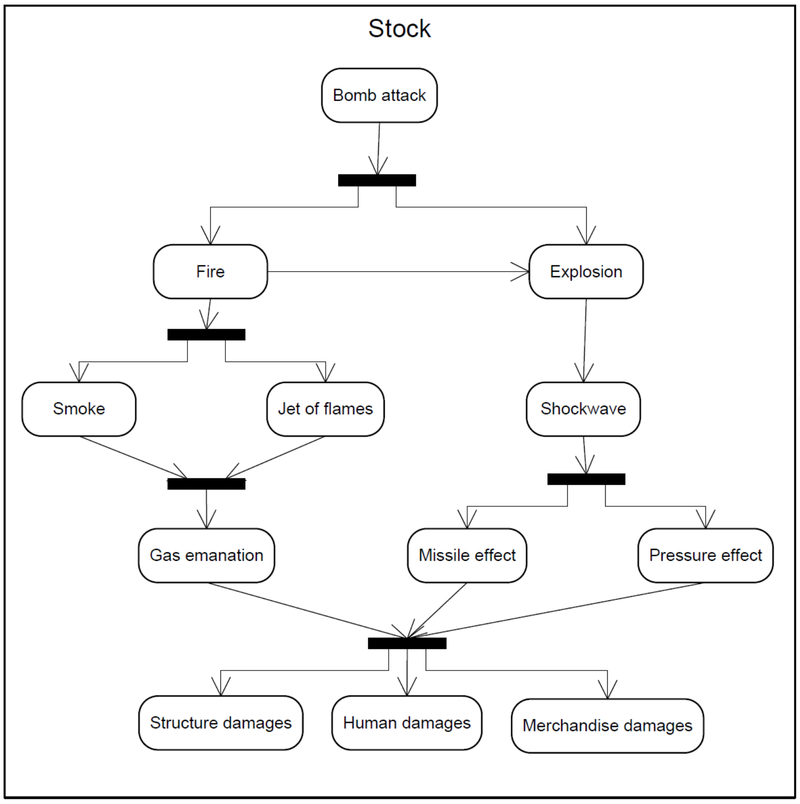

Figure 4. Scenario 1: activity diagram for a bomb attack.

have: inhaled gases, been victims of missile effects or building collapses, been burnt. The structure damages regroup the building destructions notably the racks, the traverses and the building structure. The merchandise destructions are easily evaluable and correspond to the pallets implied during the fires and the explosions.

This first scenario describes actually the consequences of a Boiling Liquid Expanding Vapor Explosion, BLEVE. This scenario describes the chain reaction explosion generated from the expansion of inflammable vapors produced by gas substances (previously kept under pressure in a liquid state). The effects that derive from this type of explosion are effects of excess pressure and fire balls projections and provoke damages on people, structures and goods. This type of event entails three main dangers: the shockwave from the explosion, the thermal flow from the fire and the projectiles from the damaged goods.

4.5.2. Scenario 2: Fire truck incident

This scenario involve a set of actors during the loading or the unloading of a truck. Then, the transporter is present and follows the operations while the driver handles pallets between the dock and the stock. This scenario is modeled by a sequence diagram in Fig. 5. The accident occurs in the dock after the driver knocks its cargo against another one on the dock.

We describe by an activity diagram, see Fig. 6, the chain of events from this accident. As we see, the collision is the trigger of this scenario and occurs on the dock. The presence of a cigarette increases strongly the accident consequences. The shock provokes the release of gas which concentrates to form a cloud around the dock and the truck. The cigarette provides

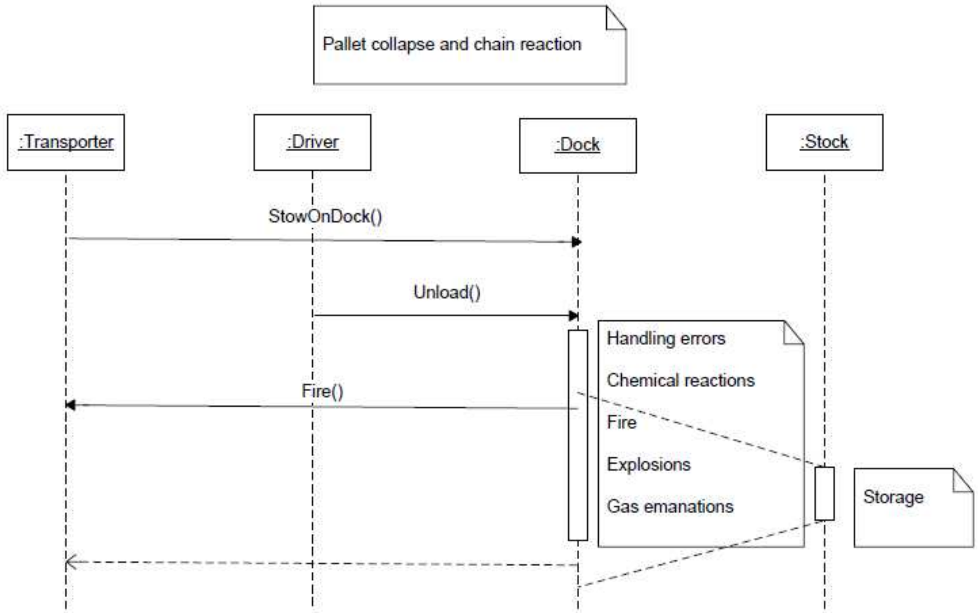

Figure 5. Scenario 2: a pallet collapse and a chain reaction on dock.

the spark so that uncontrollable events start. In presence of the cigarette, the released gas provoke thermal and pressure effects. The damages caused by this accident spread on four dimensions: the human, the structure, the merchandises and the environment damages. The human damages are relative to the person evolving around the accident place. Among them, we can cite the transporter, the driver, the person who works near the dock and near the stock. The structure damages implies the dock itself which can be deformed by the explosion, the truck which can burn and also the warehouse building which can suffer from the explosion. The merchandises destroyed are the ones present on the dock or the ones which burnt during the fire. This type of accident provokes the formation of toxic gas clouds which are polluting the environment. Before and after the cloud explodes the mixed gases stay in suspension and moves with the ambient air. It constitutes then environment pollution.

4.5.3. Scenario 3: Hazardous liquid spilt

The third scenario describes how a rack failure is susceptible to involve a collapse of pallets and then provoke an accident. The pallets fall over each others contributing to gas emanations and liquid spreads, see Fig. 7.

We propose an activity diagram to describe the actions, see Fig. 8, leading to an accident. Here, we don't use any aggravating facts and we consider that the gas emanation and liquid spreads stay stable and don't provoke yet any explosions. Nevertheless, this unstable situation represents a danger for different reasons. Thus, the gas emanations are toxic for the persons working in the warehouse and the different pallet collapses and rack damages constitute structure and goods damages.

5. Integration of communicating objects for a dynamic risk management

Over the past few years, communicating objects have become a new emergent solution to secure the international trade by providing tracking tools [2–4] and environmental monitoring

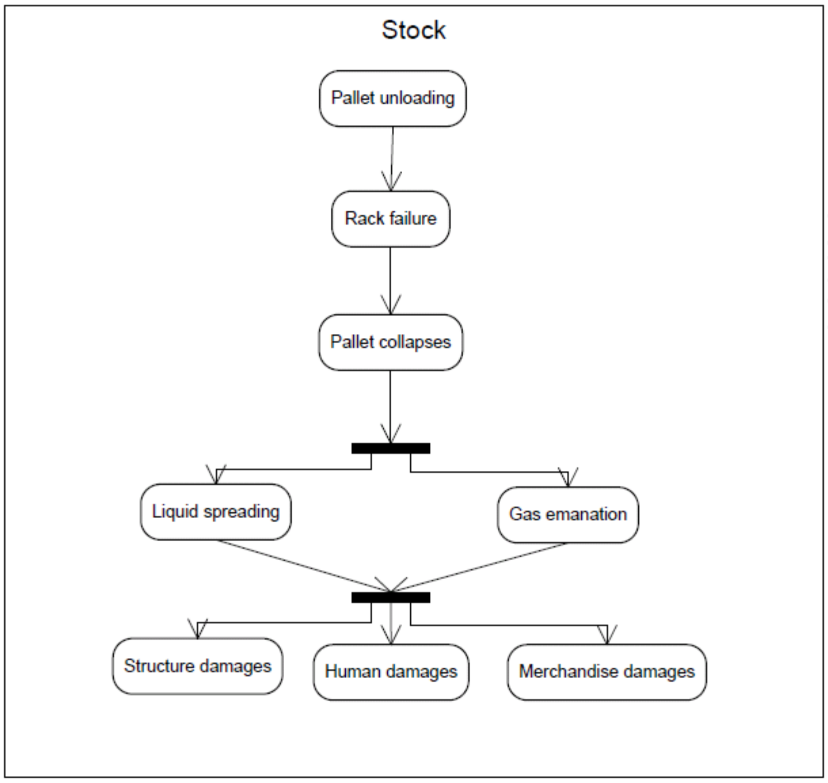

Figure 6. Scenario 2: activity diagram for a pallet collision on dock.

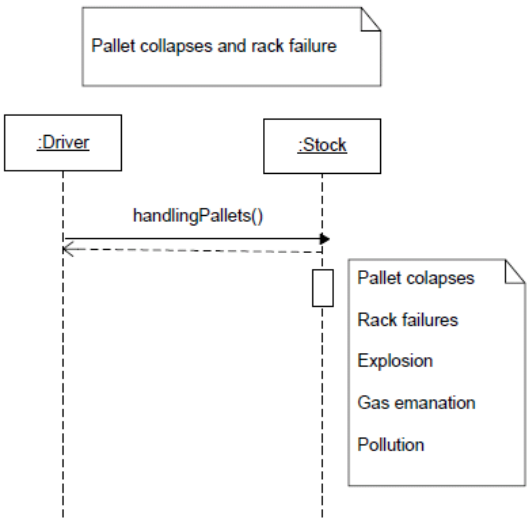

Figure 7. Scenario 3: rack failure and chain reaction.

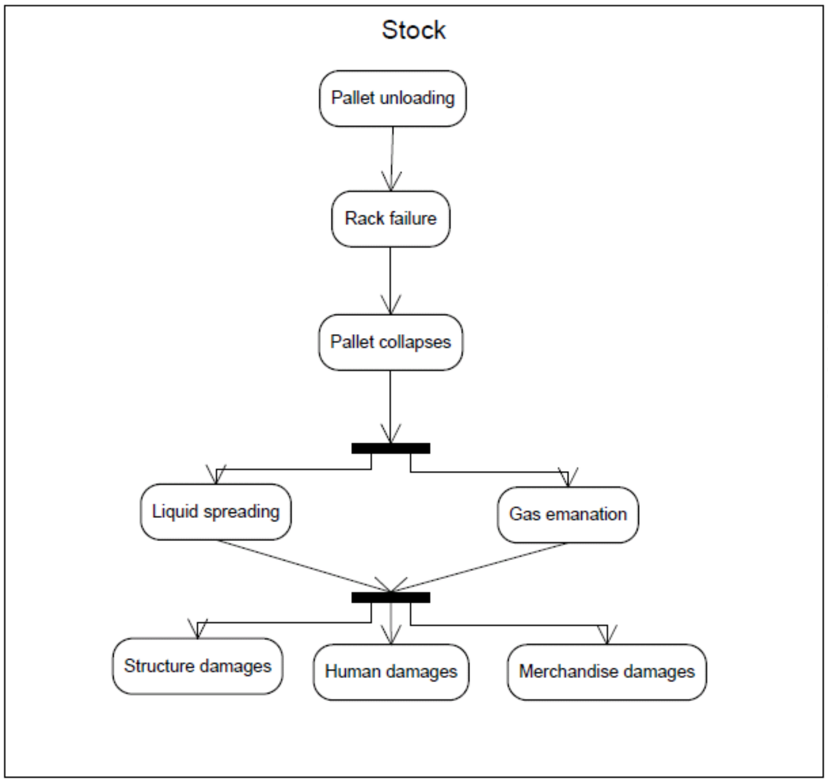

Figure 8. Scenario 3: activity diagram for a rack failure.

[5, 6]. Then, tracking tools provide geolocation solutions that can be used to detect any risks inherent to goods location. environmental geolocation gives the possibility of detecting any "unusual" or "dangerous" environmental conditions such as high temperature or incorrect constraints.

In this chapter, a SCM approach that exploits RFID tags and wireless sensors is presented. The studied supply chain manipulates chemical substances that represent potentially hazard for persons and environment. The developed approach integrates constraints from existing regulations and complies with them to finally propose a dynamic risk assessment.

5.1. Supply chain actors and activities

The studied supply chain involve different actors that manipulate chemical substances:

- Chemicals providers are located in Asia. They prepare pallets by loading chemicals on communicating pallets and organize the container loadings in the Shanghai harbour;
- Transporter by road or by ship, transport containers and deliver them in Le Havre port or to the retailer warehouse;
- Retailer in France for big-box stores. This actor organizes the pallet storages. Operators unload containers to store pallets in racks, load pallets in containers and finally send them to the downstream supply chain actor.
- Customers, they are big-box stores around Paris. They receive containers, unload them and transfer chemicals from communicating pallets into common ones and send back them to the pallet-provider.

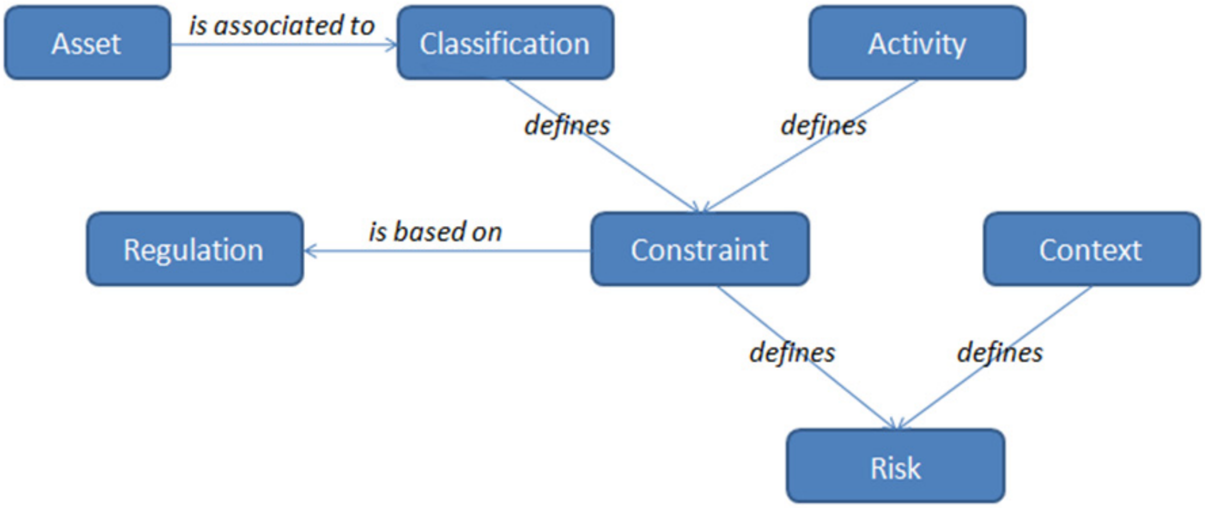

Figure 9. Risk assessment description. The risk assessment is based on classification and activities that define constraints to be respected along the supply chain.

The communicating objects are integrated at the pallet level. The cost is shared by the different actors and the programming of communicating objects is realized by an upstream actor: the pallet-provider. This last is responsible of writing information in RFID tags and initializing wireless sensors.

5.2. RFID technologies

A basic RFID system contains three elements; a tag, a reader and a middleware. A tag is mainly formed by a microchip attached to an antenna. An RFID tag is read when it receives radio signals from the reader and sends data back to the reader. The reading and writing process between the tag reader and the RFID tag can be realized from centimeters up to meters depending on the system characteristics.

5.3. WSNs: Wireless Sensor Networks

Wireless Sensor Networks (WSANs) refer to a group of sensors linked by a wireless medium to carry out phenomenon sensing and acting in consequence. The devices deployed in the environment are considered as nodes. Nodes are sensors whose main features are: low-space, low-cost and low-power, they are able to collect environmental data.

5.4. Risk assessment with communicating objects

The proposed risk assessment is based on the chemicals physicochemical properties. Depending on these properties, the substances are classified to a specific class of hazard according to the CLP regulation. From this classification, constraints are deduced and must be respected all along the supply chain. Then, chemicals evolve in an environment that defines their "context". The combination of the identified constraints and the environment of chemicals are the source of risks, see Fig. 9. The deployment of communicating objects for a dynamic risk assessment allows monitoring in real-time pallet environments.

Different sensors are associated to form a cluster of sensors able to monitor a set of constraints. Sensors send data to a centralized software that translates them into accident risks in case of unusual values. By this way, the software is able to send alert messages to supply actors that are currently responsible of goods so that they can intervene on goods.

The accident risks treated by the software are associated to sensors, they are the following:

- Overheating (temperature sensor);
- Pallet squashing (pressure sensor);
- Pallet overturn (stability sensor);
- Pallet lost (gps sensor);
- Gas release (gas sensor);
- Fluid leak (fluid sensor);
- Solid product dumping;
- Humidity constraint (humidity sensor);
- Incompatible product (RFID tag).

5.5. Scenarios: Explosion and chemical reactions on stow

In the first scenario, the events occur at dock where the truck is stowed and a forklift driver is unloading pallet and put them on the dock before storing them further on rack. The dangerous goods considered are aerosols and are commercialized as air fresheners.

Sensors present on pallets send periodically their data to the software. A terrorist triggers a bomb explosion (remote activation by mobile phone for example) from a pallet that is still on the truck cargo. Different events occur from this explosion: thermal and smoke emanation, release of toxic gases and missile effects. Pallets in the container and on the dock will be damaged by the blast wave, the main consequence on goods is the loss of aerosols containment. Consequences are expected on environment, on warehouse workers and on warehouse building structure.

As soon as the explosion occurred, sensors present on pallets that suffer from the bomb consequences will immediately be damaged and will not emit anymore whereas sensors present on dock will emit only few seconds before being destroyed by fire. The software that collects data will receive unusual values such as increasing heat and gas pressure and in consequence will sends an alert message to the warehouse manager. This last is responsible of the security maintain and will understand that an accident occurred on a dock. He will then deploy emergency procedures and will be helped by the software that provide strategic information with the alert messages. The software will send information about the pallet whose sensors are broken, the CLP designation of goods present on these pallets will be sent. By this way, the retailer manager will know exactly what the involved goods are, he will adapt emergency procedures as a function of physicochemical properties of goods.

In the second scenario, the context and the assumptions are the same than the first one: the action takes place on the stow where the truck is being unloaded by an operator. Goods considered are housekeeping products, they are flammable liquids. An handling error such as a pallet is poorly loaded and taken by the forklift driver with a slight offset provokes a collision between the handled pallet and others already unloaded on the dock. This collision provokes a liquid leakage on the dock and a trigger event like a spark or an electrical arc created by a cell phone provokes a fire.

This accident is treated by the same way than the scenario 1. The pallet collision and collapse on dock correspond to unusual stability values. The software sends an alert message to the warehouse manager who will be able to locate the place where the accident occurred and will coordinate the emergency services relying on qualitative and quantitative information about chemicals involved in the accident.

5.6. Scenarios: Pallet collapse and domino effect in stock

The scenario 3 takes place in the warehouse storage area and involves operator, pallets and racks. During operator movements, we assume that the rack structure can be damaged by forklift collisions and the accumulations of such shocks can potentially provoke rack damage that can lead to the rack destruction due to the supported pallet weights.

The detection of a collision between a forklift and a rack can be detected relying on the stability sensor values transmitted by sensors. If more than four pallet have their stability values modified between 20% and 40%, the software translates this situation into "rack stability" alert and sends it to the retailer manager. From this alert, the retailer manager will trigger emergency procedures to check the involved rack. Then, the software provides different information relative to pallets whose stabilities have evolved, these information are exploited by the retailer manager to locate them using his internal WMS (Warehouse Management Software). Then, if the pallets whose stabilities have evolved are neighbours and located near the rack structure, an internal alert of "rack collision" is emitted and the forklift drivers that operate in the cell are convoked for a further debriefing.

In the scenario 4, we assume that forklift drivers move in the stock area when a forklift loses its cargo that fails. Stability values transmitted by sensors of this pallet will trigger a "pallet fail" by the software. The software provide also gps location of the involved pallet but this information cannot be exploited by the warehouse manager because none mapping exists between the geolocation and the location in the storage area. For that reason, an internal alarm is triggered in the corresponding cell to inform forklift drivers about a pallet fallen but none other accurate information are available.

6. Conclusion

In the global context of supply chain management, the three common flows of goods, information and physical are subject to modelling regarding optimization concerns. Risk studies allow identifying logistics missions that may represent danger on persons, environment and goods. Scenarios are then extracted to describe risk management strategies and then improving emergency procedures.

In this chapter, three scenarios are developed to answer specific events, located in quite precise places and representing real risks. The chosen scenarios presented three types of accidents:

- the creation of an explosive area resulting from a leak of aerosol;

- a departure of fire from a truck stowed;
- a breakdown of racks causing a toxic mix dangerous goods;

In the presented scenarios, only the product concept and application of procedures and risk prevention differ. It is the analysis of risks, its causes and its impacts which will enable to set up one of the mechanisms of detection and prevention.

The integration of communicating objects such as RFID tags and wireless sensors offer new features for a dynamic risk assessment. Sensors are then used for accident risk detections, collected data are transmitted to a centralized software that is able to compare them with confidence intervals and in case of mismatches alerts are sent. Then, communicating objects are used to risk detection and also to risk mitigation. Risk mitigation consists in providing strategic information (involved goods, their quality and quantities, accident place, etc.) to emergency services that can then plan and adapt their intervention.

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