Resilience of maintenance organization in a refining plant

Dounia TAZI[1] and René AMALBERTI[2]

[1] Institute for an industrial safety culture, chemical engineering laboratory,
5, rue paulin talabot , 31106 Toulouse France
Dounia.Tazi@ensiacet.fr
[2]IMASSA, Centre d'essais en vol - 91223 - Brétigny-sur-Orge, France
rene.amalberti@imassa.fr

Abstract. Safety of a refining plant is a critical and sensitive issue because a loss of control can lead to dramatic consequences that go beyond plant boundaries. Maintenance is an important organizational stake in the safety system of a refining plant. The maintenance of chemical installations is complex from an organizational point of view since sub-contracting is a trend in maintenance execution. Maintenance subcontractors play a critical role in chemical installations operations by assuring all maintenance execution (preventive and corrective) at any hour and in emergency if necessary. In this paper we analyse the maintenance management system of this plant using a Rasmussen theory [Rasmussen 1997] and the Vicente method [Vicente 1999].The system is represented in terms of means-ends and part-whole dimensions. This analysis is carried out through an abstraction hierarchy in order to identify the constraints and the existing safety barriers in this maintenance management system. Thereafter we compare the resiliency of the maintenance management system and the major risks management system of this plant. Finally we discuss about the resilience of these management models.

1. INTRODUCTION

Safety of a refining plant is a critical and sensitive issue because a loss of control can lead to dramatic consequences that go beyond plant boundaries.
Maintenance is an important organizational stake in the resilience of a refining plant.
The maintenance of chemical installations is complex from a technical point of view due to the process used and from an organizational point of view since sub-contracting is a trend in maintenance execution.
Sub-contracting increases the system complexity because it introduces contractual relationships and forces both the subcontractor and the client to reorganize their safety to work together.
Maintenance subcontractors play a critical role in chemical installations operations by assuring all maintenance execution (preventive and corrective) at any hour and in emergency if necessary.
Safety in this maintenance execution has visible consequences since maintenance subcontractors have more work place accidents than the refining plant workers.

2. THEORETICAL AND METHODOLOGICAL FRAMEWORK

Each work system is designed to reach given objectives. To achieve this purpose, the work system must comply with various constraints, such as regulations procedures or physical laws.

Rasmussen proposes to represents the sociotechnical system in terms of means-ends relationships, in order to show the system constraints and the way they influence work activities [Rasmussen 1986] [Rasmussen 1997]. This type of analysis can be carried out through an Abstraction Hierarchy which is a two dimensions modelling tool used by Vicente [Vicente, 1999].
Safe operation space is confined by barriers. Hollnagel classifies theses barriers [Hollnagel, 2004] in terms of material, functional, symbolic systems and immaterial barriers. The analysis of the system safety, allows to identify the limits of the safe operation space and characterize the barriers.

2.1. The Abstraction Hierarchy

The Abstraction Hierarchy represents a socio-technical system in terms of five functional levels. These are, from the highest to the lowest: the functional purpose, the abstract function, the generalized function, the physical function and the physical form.
The functional purposes correspond to the work domain purposes, the abstract functions correspond to the laws which apply to the system (regulations, physical laws…), the generalized functions represent the activities performed in order to achieve the system goals, the physical functions represent the activities involved in physical processes (performed by human or by equipment) and the physical form describes the elements that physically do the work (workers and equipment) [Vicente, 1999].This type of representation has been used in several work domains such as the marine field [Morel & al 2006].

3. THE MAINTENANCE MANAGEMENT SYSTEM IN A REFINING PLANT

In this paper we analyze the management maintenance system of a refining plant .The analysis of the work domain is carried out through an abstraction hierarchy in order to identify the constraints and the existing safety barriers of this system
This analysis allows the characterization of this system resiliency.

3.1. The work domain

The execution of maintenance is often externalized in chemical plants as it is regarded as a non core business. Maintenance execution is subcontracted for different reasons, among them: “others can make it better and/or less expensive”, a need of specialized people for each maintenance trade, a need of more flexibility and rationality…
If subcontracting maintenance is a large trend, it seems difficult to calculate the profits of such policy because the skills required to do an activity are different from those to get this activity done. In addition, this maintenance execution has visible consequences in safety since maintenance subcontractors have more work place accidents than refining plant workers

For this study, the system involved is the management system of subcontracting maintenance execution in a refining plant.

In this system the highest level is the refining activities of an energetic group. The level below is the refining plant with its organizational and management infrastructure which include the organization structure to manage maintenance subcontractors. The functional units are the plant sectors. Each sector has its own autonomy and actors: maintenance workers, exploitation operators, preventor work'safety and maintenance subcontractors for the sector.

To understand the maintenance management system, it is necessary to analyse the work domain and to represent it in terms of ends and means, whole and parts. This is done through the Abstraction Hierarchy, in which the system is broken down vertically to five levels of abstraction (functional purposes, abstract functions, generalized functions, physical functions and physical forms), and horizontally in sub-systems (refining activities, management and organizational infrastructures of the plant, functional units of the plant, and subsets of the functional units: maintenance, safety, subcontractors and exploitation)

Table 1. The Abstraction Hierarchy of the system, sub system and functional units

	Aggregation-Decomposition →		
Abstraction Hierarchy ↓	**System: Refinery Activities**	**Sub-system Management and organisational infrastructure of the plant**	**Functional units: Plant sectors**
Functional purposes	Make profits, Manage energy resources	Refine oil according to the regulations, and the crude at disposal , Supply the market according to the request	Provide products according to requests, in compliance with the safety environment and quality requirements, Guarantee costs, time and operational safety
Abstract functions	Regulations, laws, decrees	ICPE regulation, Decree 92-158 Supply and demand law, Petitions	Physical and processes laws
Generalized functions	Frame oil installations	Refine, Manage industrial and pollution risks	Guarantee production, Guarantee the application of safety, environment and quality policy, of the plant
Physical functions	Fix operating general conditions of oil installations, Frame plants operating, work and social practices		

Physical functions	Directorate-General of refining activities	Plant director and supervisory staff	Plant workers and subcontractors working for the sector

Table 2. The Abstraction Hierarchy of the components

Abstraction Hierarchy ↓ / Aggregation-Decomposition →	**Maintenance**	**Safety**	**Subcontractors**	**Exploitation**
Functional purpose	Guarantee equipment availability and functioning	Provide products according to requests, in compliance with the safety environment and quality requirements, Guarantee costs, time and operational safety	Make profits, Honour a contract Development of customers loyalty, Propose services and products in adequacy with the market needs	Operate the units in an optimal way in compliance with safety, environment and quality, requirements.
Abstract functions	Work safety process, maintenance plan, Prevention plan	Prevention plan, General conditions of safety	Laws and regulations of the specialized trade	Processes, Manufacture service requests
Generalized functions	Coordinate maintenance, Guarantee the maintenance work safety, Apply and make apply the work safety process	Guarantee the work safety in respect of regulations, rules and procedures. Contribute to prevention' actions	Carry out maintenance work following the client' requests in compliance with the rules and procedures of its company and client ones	Guarantee the running of the units and their optimal operation Guarantee the application of the safety, environment and quality policy, of the plant
Physical functions	Analyze intervention requests, Diagnose the breakdowns Schedule the maintenance actions Apply the maintenance plan Carry out the common visits with the subcontractors Lead safety audits …	Prepare and take part in the prevention plans, Fill and validate the authorizations work Lead safety audits Set up the HSE policy in the sector…	Carry out the common visits with the client, Carry out maintenance work at request, Apply the work safety process Lead safety audits	Guarantee the running of the units according to the instructions, Supervise the material , Go up the anomalies Place at disposal the materials for maintenance work, Sign the work authorizations Lead safety audits

Physical functions	Maintenance workers for the sector	Preventor work' safety for the sector	Subcontract leader and workers for the sector	Shift leaders and exploitation operators for the sector

3.2. Identification of the system's main constraints

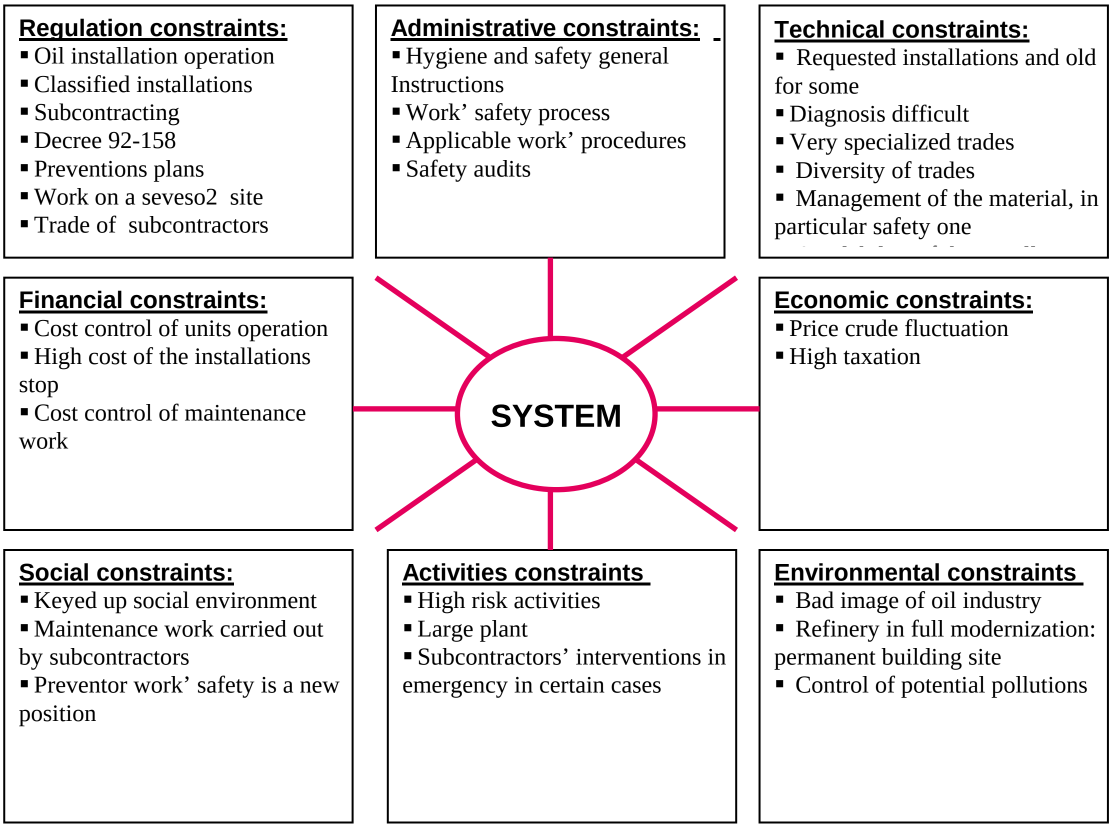

Fig. 1. Main system constraints

Figure 1 defines most of the constraints that the system bears.
The sub-contracting maintenance system is highly constrained. The regulating and the environmental constraints lead to many technical and administrative constraints at the plant level. The administrative constraints and especially the work' safety process are very explicit and prescriptive. This process defines norms that actors have to respect, there is no other way to prepare and execute maintenance job.

3.3. Prescribed operating space for subcontracted maintenance execution

The prescribed operating space is defined for the functional units (the plant sectors). This prescribed space is regarded as a safe operating space by the authorities. The safety system for subcontracted maintenance execution is based on constraints and on reducing and avoiding safety incidents or accidents.

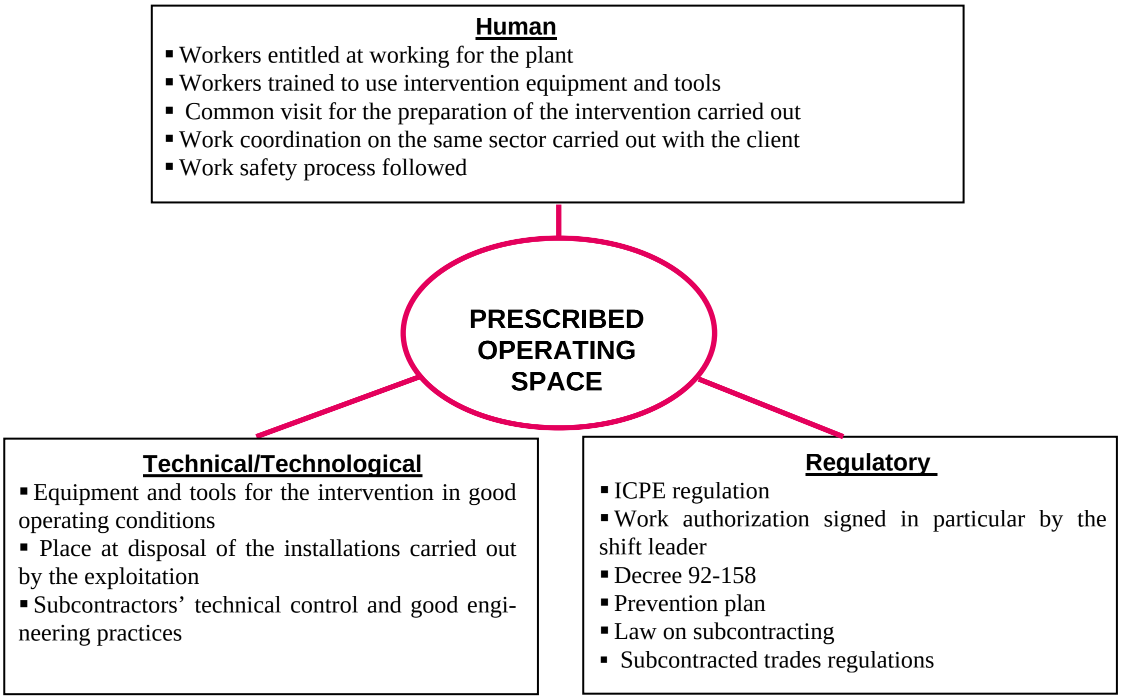

Fig. 2. Prescribed operating space for subcontracted maintenance

3.4. Identification of the functional units' barriers

Table 3. Barriers of the functional units

	Definitions	**Barriers at the functional unit level: plant sectors**
Physical or material barriers	Barriers that physically prevent an action from being carried out, or an event from taking place	
Functional (active or dynamic) barriers	Barriers that prevent an action to be carried out by establishing a logical or temporal interlock (password, access code…)	Signature and locking of work authorizations, Signature of the prevention plan
Symbolic barriers	Barriers that require an act of interpretation in order to achieve the purpose for which they were designed (signs, alarms…)	Work safety process, Preparation of the prevention plans, Place at disposal procedure, Alarms, Common visit to prepare the intervention
Incorporeal barriers	Barriers those are not usually present on the work site. In industrial context they are largely synonymous with organisa-	ICPE regulation, 92-158 decree Hygiene and safety general rules,

tional barriers (laws, regulations, rules, procedures…)	Good engineering practices

Hollnagel concept and typology of barriers is used to define the functional units barriers set up by the system to avoid maintenance safety issues [Hollnagel 2004]. Table 3 shows that there are, no physical barriers that protect the system from maintenance safety incidents or accidents. The functional barriers are based on signature of the actors.

4. IS THIS SYSTEM RESILIENT OR NOT?

Resilience engineering is a safety approach based on the management of perturbations before, during and after their occurrence [Hollnagel &al, 2006]. The goal is not to avoid the occurrence of perturbations but to manage them.

Another approach of safety is to avoid these perturbations, by reducing their occurrence.

The system management of subcontracted maintenance is a prescriptive model, based on reducing work place accidents of subcontractors. This system is highly constrained by regulations, which are formalized in the work domain through numerous procedures and processes, like the work' safety process.

In this system, maintenance actors (maintenance workers, maintenance subcontractors, preventor work' safety, exploitation workers) have almost no degree of freedom concerning maintenance execution job, there is just one best way, which is to respect the work' safety process.

Thus we can say that the system management of subcontracted maintenance in this plant is not a resilient system. Its goal is to avoid accidents and incidents but not really to manage them if they occur.

Table 4. Comparison between sub-contracted maintenance management system and major risks management system

System management of sub-contracting maintenance	**<u>Objective: Avoid accidents and incidents</u>** ▪ Based on constraints ▪ Hyper specified ▪ Lot of procedures and rules to respect ▪ Compatible with subcontractors turn-over ▪ Almost no degree of freedom for maintenance actors	**RESILIENCE** ↓	↑ **CONSTRAINT**

System management of major risks	**Objective: Manage accidents and incidents** ▪ Based on actors expertise ▪ The system relies on the good engineering practices of the actors ▪ Under specified ▪ Training of actors through situation scenarios

In this table we compare the management system of sub-contracted maintenance and the management system of major risks in the plant. We've seen that the management system of subcontracted maintenance is a system based on constraints, with almost no degree of freedom for the actors especially for subcontractors. This system is not a resilient one, its objective is to reduce perturbations, here the subcontractors work place accidents. This system even if it's not a resilient one, is a system that reduces work place accidents: from 2001 to 2006 work place accidents for subcontractors and plant workers have been divided by 2.5. This model of management is sure but not resilient.

The other system we studied is the system management for major risks in the plant. This system is based on actors' expertise and their good engineering practices. Actors' ability to manage major incidents is improved through situation scenarios, which take place every week. In this system actors have several degrees of freedom, and adapt their behavior to scenarios.

5. WHY CHOOSING A NON RESILIENT SYSTEM TO MANAGE SUBCONTRACTING MAINTENANCE?

What led the plant to choose a non resilient system to manage subcontracting maintenance? First a highly constrained system can protect the client from some legal problems: regulations in subcontracting are numerous, one way the client have to protect himself is to propose a highly constrained contracts and to check if the subcontractor follows all the rules. Secondly, confidence between subcontractors and the client has to be constructed; at the beginning of the contract the client is not sure about subcontractors' skills and abilities to do the job in a safe operating space. Third, this system allows a traceability of all the stages of the sub-contracted operation. Another benefit of this system is that it has good results in reducing work place accidents even if it is never enough.

This system has also some drawbacks. This system based on constraints let no degree of freedom to subcontractors so they can not improve their technological know how by testing new solutions. [Amalberti, 2001]. They seem to be only performers and can't change the way of executing their tasks, this leads to a lack of knowledge on how to manage system' disturbances. Thus the system is less and less resilient.

In comparison what are the benefits and drawbacks of the management system of major risk management? This system is based on actors' expertise. The first benefit is that the actors' degrees of freedom allow them to improve their technological know how; and the improvement of actors' technological know how allows the management system to evolve. Actors are trained to manage critical issues through situations scenarios, this improve the system resilience to disturbances.

The drawback is that it is difficult to measure the results of this system. Even if the actors are trained, will they be able to manage a real crisis? When the training is complete? How many situation scenarios are necessary? It is difficult to answer to these questions.

6. CONCLUSION

The purpose of this paper is to study the resilience of the management system of subcontracting maintenance, in a refining plant. We analyzed this system trough an abstraction hierarchy in order to identify the constraints and the existing safety barriers. This analysis revealed that the system is based on constraints and that its objectives are to avoid disturbances especially subcontractors' work place accidents. The comparison between this system management of subcontracting maintenance and the system management of major risks shows that the first one let almost no degree of freedom for the actors and doesn't allow the improvement of their technological know how but has good results in reducing work place accidents even if it is not yet enough; the second is based on the actors expertise and training but it seems difficult to measure it efficiency.

The management system for subcontracting maintenance in this plant is safe but not yet enough, and is not resilient. The problem is how to improve the system safety, by reinforcing the level of constraint or trying to let some degrees of freedom to the actors and taking the risk not to improve safety?

REFERENCES

Amalberti, R (2001), la conduite des systèmes à risques, 2nd edition, paris, le travail humain, presses universitaires de France.

Hollnagel, E. (2004), Barriers and accident prevention, England, Ashgate publishing company

Hollnagel, E., Wood, D., & Leveson, N. (2006), Resilience Engineering, *Concepts and precepts*, England, Ashgate publishing company

Morel, G. & Chauvin, C. (2006), A socio-technical approach of risk management applied to collisions involving fishing vessels, Safety Science, 44, 7, 599-619

Rasmussen, J. (1997), Risk management in a dynamic society: a modeling problem, Safety Science 27, 2-3, 183-214

Rasmussen, J (1986), Information processing and human-machine interaction, North Holland, Elsevier.

Vicente, K.J. (1999), Cognitive Work Analysis, *Toward safe, productive and healthy computer –based work*, Mahwah, NJ: Lawrence Erlbaum Associates