Assessment of the vulnerability of industrial sites to acts of interference

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Consequences of attacks or acts of interference involving industrial sites where relevant quantities of dangerous substances are processed or stored (as in the case of process or pharmaceutical industries) may result in severe consequences. On the security side, several Security Vulnerability Assessment (SVA) methods were developed to analyze the problem. However, all the SVA procedures deal mainly with "security" and target vulnerability, but not with "safety" and not with the assessment of the possible consequences of acts of interference.
The present study was dedicated to the development of a method for the quantitative assessment of the vulnerability of a target to acts of interference. The aim of the work was to develop a method that could be useful to understand the potential consequences of attacks or of acts of interference, oriented to land use and emergency planning, as well as to prioritize protection actions.

1. Introduction

Consequences of attacks or acts of interference involving industrial sites where relevant quantities of dangerous substances are processed or stored may result in very severe consequences. Several Security Vulnerability Assessment (SVA) methods were developed to analyze the problem (SFK, 2002; API-NPRA, 2003; Uth, 2005). However, all the SVA procedures deal mainly with "security" and target vulnerability, but not with "safety" and are not focused on the assessment of the possible consequences of acts of interference, that is crucial to emergency planning.
The present study was dedicated to the development of a method for the quantitative assessment of the vulnerability of an industrial target to acts of interference. The aim of the work was to develop a method that could be useful to understand the potential consequences of attacks or of acts of interference, oriented to land use and emergency planning, as well as to prioritize protection actions. A schematization of the 5-steps technique is shown in Figure 1.

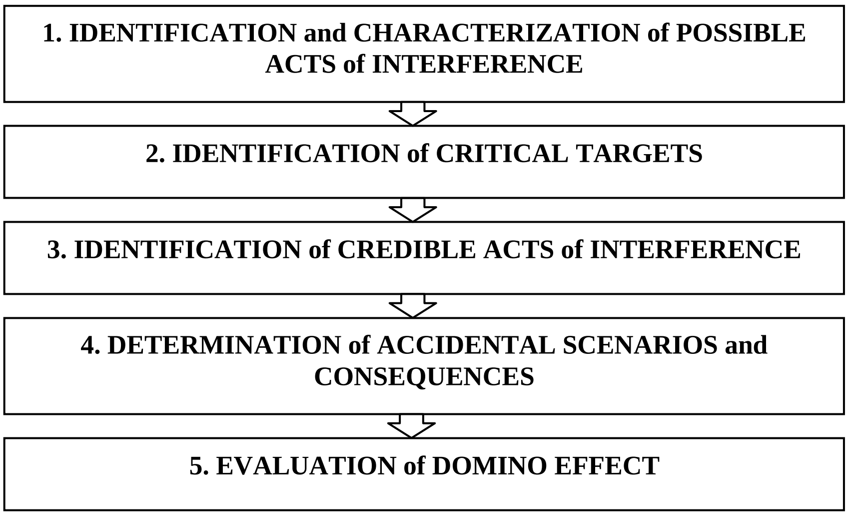

Figure 1: The five steps of the method developed for the assessment of industrial target vulnerability to acts of interference

2. Assessment of the vulnerability of an industrial target to acts of interference

2.1 Identification and characterization of the possible acts of interference

For the purpose of this work, it was compulsory to analyze in detail the characteristics of the possible acts of interference that should be considered in the analysis of possible attacks to industrial sites where relevant quantities of industrial substances are stored. Ten different categories of acts of interference may be identified from a review of the literature (SFK, 2002; Uth, 2005). In order to better describe the characteristics of these categories of acts of interference, three parameters were worked out: the required level of information necessary to successfully project and successfully carry out the interference (from A to C, increasing knowledge is required), the expected release state caused by the act of interference (from R1 to R4, increasing severity of the release), the impact vector (the physical effect responsible of the damage to equipment caused by the act of interference). A summary of some of these parameters for the ten categories of acts of interference is reported in tables 1 and 2.

2.2 Identification of critical targets

The purpose of an external attack to an industrial installation is reasonably to cause the most severe damage as possible. Thus, it is possible to estimate the “attractiveness” of a target (usually an equipment item inside the site analyzed) through the analysis of three elements: the kind of risk associated to the substances inside the equipment (flammable, toxic or both of them), the physical condition in the storage (that defines the behaviour of the substance after the release) and finally the amount of substance inside the equipment. The results of the analysis indicated that, regardless the kind of hazard, physical conditions of substances and type of equipment have an important influence on the attractiveness of the target. Thus, it was possible combine these two parameters in order to obtain an attractiveness level. As shown in table 3, a parameter ranging between 1 and 4 was defined to quantify the attractiveness level.

Table 1: Description of the ten categories defined for possible acts of interference

ACT of INTERFERENCE	DESCRIPTION
Deliberate Misoperation	Deliberate incorrect change of process variables (as concentration, temperature, pressure), opening/closing control and pipelines valves, switching off protective systems.
Interference using simple aids	Light damages to control/protective systems or to small components of the equipment (as glass level gauges or moving parts) or pipelines
Interference using major aids	Severe damages to control/protective systems, equipments or pipelines
Arson using simple means	Igniting flammables substances from the process sequence; setting fire to peripheral rooms or process facilities
Arson using incendiary devices	Pouring and lighting flammables liquids; using simple or professional incendiary devices with immediate, timed or remote controlled ignition
Shooting (minor)	Causing leakages in free-standing tanks or pipelines, or destroying control/protective system by shooting with small-sized projectiles (guns, rifles)
Shooting (major)	Causing damages to equipment or pipelines by the use of large projectiles or of missiles
Explosives	Using explosives to damage the installation
Vehicle Accident	Damage of equipment due to vehicle impact
Plane Accident	Serious damages or destruction of equipment due to small plane impact

Table 2: Parameters describing the different categories of acts of interference

TYPE OF INTERFERENCE	REQUIRED LEVEL OF INFORMATION	EXPECTED RELEASE RATE (ATMOSP. EQ.)	EXPECTED RELEASE RATE (PRESSUR. EQ.)
Deliberate Misoperation	C	R2	R1
Interference by Simple Means	C	R2	R1
Interference by Major Aids	C	R3	R2
Arson by simple Means	C	R3	R2
Arson by Incendiary Devices	B	R4	R3
Shooting (minor)	A	R1	R1
Shooting (major)	A	R4	R4
Explosives	B	R4	R4
Vehicle Accident	B	R3	R3
Plane Accident	A	R4	R4

Table 3: Ranking of the attractiveness level of process equipment

Physical conditions of inventory → / Equipment type ↓	TANKS	BIG DIAMETER PIPELINES	COLUMN – TYPE EQ.	REACTORS/ HEAT EXCHANGERS
LIQUEFIED GAS STORED UNDER PRESSURE	4	4	3	3
FLUIDS WITH LOW VAPOR PRESSURE STORED IN LIQUID PHASE	3	3	2	2
GAS/LIQUID STORED IN GAS PHASE	3	2	2	1
CRYOGENIC STORAGE	2	2	2	1
LIQUID PHASE	1	1	1	1

2.3 Identification of credible acts of interference

Dealing the matter of acts of interference, it is necessary to have instruments to estimate the probability that an attack can be performed successfully. A successful attack is one that actually causes a damage to the equipment and that starts a relevant release of hazardous materials able to trigger an escalation of the event. A preliminary evaluation of the conditional probability of the success of an attack (given that the attack is actually carried out) may be obtained using one of the parameters defined in step 1 of the study: the damage vector characteristic of each act of interference. A group of correlations (mostly in the form of Probit functions) may be associated to each impact vector to allow an evaluation of the probability of success a given act, depending on the characteristics of the attack and the resistance of the equipment. A summary of the damage vectors and of available damage correlations is reported in Table 4.

Table 4: Damage vectors and correlations for the evaluation of the probability of success of an attack

ACT of INTERFERENCE	DAMAGE VECTOR	DAMAGE CORRELATION
Deliberate Misoperation	n.d	Not available in the form of mathematic expression
Interference by Simple Means	n.d.	
Interference by Major Aids	n.d.	
Arson by simple Means	Radiation	Equipment vulnerability model (Cozzani et al., 2006)
Arson by Incendiary Devices	Radiation	
Shooting (minor)	Impact	
Shooting (major)	Impact	
Explosives	Overpressure	
Vehicle Accident	Impact	Specific studies or simplified vulnerability models (Susini et al., 2006)
Plane Accident	Impact	

The evaluation of the success of an attack should take into account the protections that could be present at the target plant and that could affect the possible success of the act. In order to represent how strongly these protections can influence the probability of success of the attack, the LOPA (Layers Of Protection Analysis) approach (Summers, 2003) may be used. In this method, designed for traditional safety analysis, the probability of an accidental scenario following a “top-event” is related to the product of the failure probabilities of the several protection layers existing. At the present stage of the work only a qualitative application of this technique is possible. Figure 2 shows the layers that must fail in order to allow the equipment damage. The assessment of the probability of failure of each layer may provide a more detailed assessment of equipment vulnerability.

2.4 Determination of accidental scenarios and consequences

After the evaluation of the damage state following the attack, it is possible to obtain a range of expected release states that may be triggered. The methods to evaluate the scenarios and their consequences are the same used in traditional safety analysis, e.g. event trees and correlations for the evaluations of physical effects. Some attention must be given to the analysis of the event trees: some peculiar acts of interference (as Arson, Explosives and Shooting) may influence the possible accidental scenarios that may follow the attack, since the ignition is more probable than in other situations.

With respect to the evaluation of physical effects, nothing is different from traditional risk assessment, and proven correlations (for example those derived from TNO’s Yellow Book) can be used successfully to estimate the possible consequences for the population present around the plant.

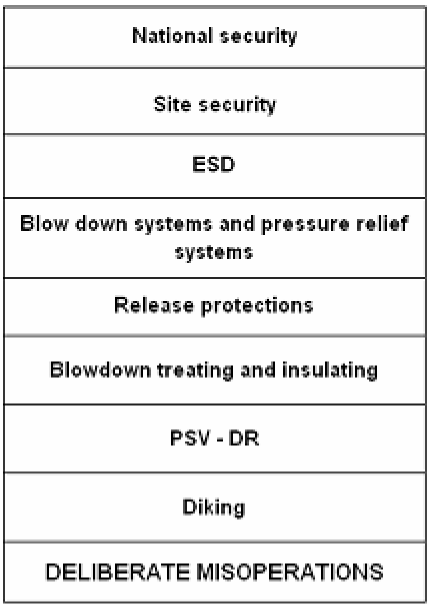

Figure 2: Graphical representation of the layers of protection that may prevent equipment damage caused by Deliberate Misoperation

2.4 Evaluation of domino effect

The final stage of the assessment is the analysis of the primary scenarios, in order to assess if they could trigger escalation events. The analysis of possible escalation may be performed as in the case of traditional risk assessment, thus considering the possible damage to the equipment exposed to the impact vectors that may derive from the primary scenarios. A preliminary identification of possible targets of domino effect may be carried out using the escalation thresholds defined in previous studies for radiation and overpressure (Cozzani et al., 2006).

3. Conclusions

A method for the identification and the assessment of the vulnerability of industrial targets to acts of interference was developed. The method allows to identify credible acts of interference that may be carried out to damage an installation, and to estimate the consequences of an attack. The method is mostly useful to pinpoint the more critical equipment items (i.e. those more vulnerable to damages and/or more dangerous in terms of potential consequences). This is helpful for risk analysis but also for resource management, since it allows focusing the security and safety protections on specific targets. The approach is also of importance for emergency planning and land use planning around possible target installations.

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