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Attractiveness Assessment of Chemical Facilities Operating in Critical Areas: Development of a Semi-Quantitative Methodology Tailored to the Maghreb Context

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Intentional acts of interference towards chemical and process installations became a relevant concern over the last decades. The successful attacks involving the release of hazardous substances contained in industrial facilities may result in severe consequences for population and environment. This issue is exacerbated in critical areas, which experience the settlement of terrorist groups, aimed at destabilizing the political and economic context. In particular, in the Maghreb area, chemical and process installations operate in a high socio-political instability context. In this perspective, standard security assessment methods dedicated to process facilities are not exhaustive and do not allow to cope with the actual value of the threat and risks involved. In the present contribution, an attractiveness assessment method is presented and tailored for industrial facilities located in critical areas, with particular reference to the Maghreb context. Attractiveness is proposed as a proxy to the attack likelihood to support security risk screening analyses. Technical and not technical factors are accounted for in the methodology, in order to more adequately depict the motives and triggers contributing to the attractiveness. The procedure for attractiveness assessment is finally exemplified through the analysis of two case studies. The analysis demonstrates the importance of not limiting plant attractiveness assessment to a consequence-based evaluation, but to instead stress the geo-political, ideological and strategic incentives in the specific Maghreb context.

1. Introduction

In the past, process and chemical facilities were not considered likely targets for acts of interference and terroristic when compared to urban areas such as malls or public transport (Baybutt and Reddy, 2003). In the wake of the events of “9/11” the government of the United States enacted security-related legislation and created dedicated institutions, such as the Department of Homeland Security. Consequently, security and industrial security as a research field has seen a big expansion from 2001 (Reniers et al., 2020), while the credibility of this threat for process facilities was demonstrated by several physical (Casson Moreno et al., 2018) and cyber-attacks (Iaiani et al., 2021) occurred in recent years.

In Europe, although directives have been enacted for critical infrastructures (2008/114/EC), no published guidelines are yet available for the security of chemical and process plants. Security concerns fall out of the Seveso Directive (2012/18/EU) as well. However, process facilities may find guidance on the assessment and management of security matters in the existing methodologies, such as the API/ANSI Std 780 (API, 2013), the CCPS guidelines for the evaluation of security vulnerabilities (CCPS, 2003), the Sandia model for vulnerability of physical protection systems (Garcia, 2008) and the methodology for vulnerability assessment proposed in (Störfallkommission, 2002). The above-mentioned approaches do not offer a rigorous systematic evaluation of attack likelihood, which is essential to properly manage security-allocated resources (Landucci et al., 2020). This evaluation is even more biased when approaching the analysis of facilities located in critical and instable contexts.

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In the present contribution, an attractiveness assessment method is presented for industrial facilities located in critical areas. Attractiveness is used in this work as a proxy of attack likelihood and supports the estimation of security-related risks for process facilities. The methodology accounts for technical aspects, such as estimated impact of accidents triggered by terrorist attacks, but also entails the evaluation of geopolitical, social and strategic factors. These aspects have a strong impact for facilities operating in critical contexts, like the Maghreb area. In this area, the intense chemical and petrochemical industrial activity coexists alongside a high sociopolitical instability and the presence of a high number of terroristic cells (Martinez et al., 2017). In order to exemplify the method in this area, two case studies are discussed (one in Algeria and one in Libya) to demonstrate the impact of non-technical aspects on the assessment of site-specific attractiveness of process facilities.

2. The Maghreb area: a critical context

The broader area of North Africa has undergone significant geopolitical changes throughout the last decade (Martinez et al., 2017). The developments taking place in the region have become increasingly interconnected and their impact has extended far beyond their borders, especially to Europe. The security environment in North Africa today is defined by at least four interconnected dynamics: 1) energy sources (gas and crude oil), 2) geopolitical antagonisms and new (im)balances of power, 3) new (human) security imperatives, and 4) increased interest in the area from external powers (Tichy & Eichler, 2018).

It is beyond any doubts that oil fields and the recent and continuing discoveries of hydrocarbons in North Africa have been among the main drivers of the changing geopolitical and security dynamics in the region and to the exacerbation of terrorism threat experienced in the last decade. In particular, even if Islamist terrorism was already a destabilizing factor in North African states, 2011 marked a turning point in the escalation of the attacks because of the emergence of a new energy strategy of the two main Islamic militant organizations, namely Al-Qaeda and IS (Tichy & Eichler, 2018). Those two groups attribute great importance to the energy industry and its incomes, especially since gaining control or damaging plants of a given country contributes to ease their criminal activities (contraband, drug selling and so on). In that sense, the cases of the attacks to the facilities of In Amenas (Algeria 2013) and Ras Lanuf (Libya 2016), carried out respectively by Al-Qaeda and IS, are emblematic of the need of understanding Islamic militant organizations' strategies in order to improve security over the energy systems of the above-mentioned countries.

Thus, based on these considerations, the security aspects of process facilities operating in the Maghreb area represent a critical concern and the peculiar socio-political elements of this critical context are considered in the development of the present work.

3. Methodology

3.1 Overview

The proposed method for attractiveness assessment is developed considering easy to gather input data, in order to have an easy application and to obtain a quick but exhaustive screening tool. For a given industrial facility, the overall attractiveness index (I_A) is defined as the product of a hazard-based index (I_H) and a location-specific "induction index" (φ) as given by Eq. (1). The induction index accounts for the "non-technical" aspects that contribute to attractiveness and is obtained by summing 1 to the "overall attractiveness increase index" F, as given in Eq. (2). F represents the contribution of geopolitical, social and political elements that characterize the critical context of Maghreb:

$$I_A = I_H \times \varphi \tag{1}$$

$$\varphi = 1 + F \tag{2}$$

The hazard-based index I_H describes the value of the installation in terms of major accidents and severe damage potential. I_H is quantitatively evaluated through the assessment of the inherent process hazards and the vulnerability of the area surrounding the facility under analysis. The evaluation procedure concerning the index I_H is reported in Section 3.2, whilst the procedure to determine the value of index F is described in Section 3.3.

Finally, the overall attractiveness index I_A is ranked according to a qualitative three-level scale (low, medium and high), based on indications shown in Table 1.

Table 1: Qualitative ranking associated with the overall attractiveness index I_A

Index	Score Range	Qualitative ranking
	2 – 5	Low
I_A	5 – 8	Medium
	> 8	High

3.2 Index I_H calculation: estimation of hazard potential

The procedure for determination of the hazard-based index I_H has been presented in (Landucci et al. 2020), a summary of the method is shown in Figure 1. The features of the Maghreb area require an adequate tailoring of the hazard-based index, particularly regarding the territorial vulnerability. The Maghreb region features zones with limited population density around industrial establishments; moreover, these zones are not characterized by the presence of vulnerability centers, e.g., such as malls, stadiums, etc. For this reason, a population vulnerability index I_{PV} is introduced, which only takes into consideration the average population density of the areas potentially impacted by the escalation of accidents triggered by external acts of interference. This index was scored based on the indications reported in (Landucci et al. 2020), thus obtaining an allowable I_{PV} span in the range from 1 to 2.

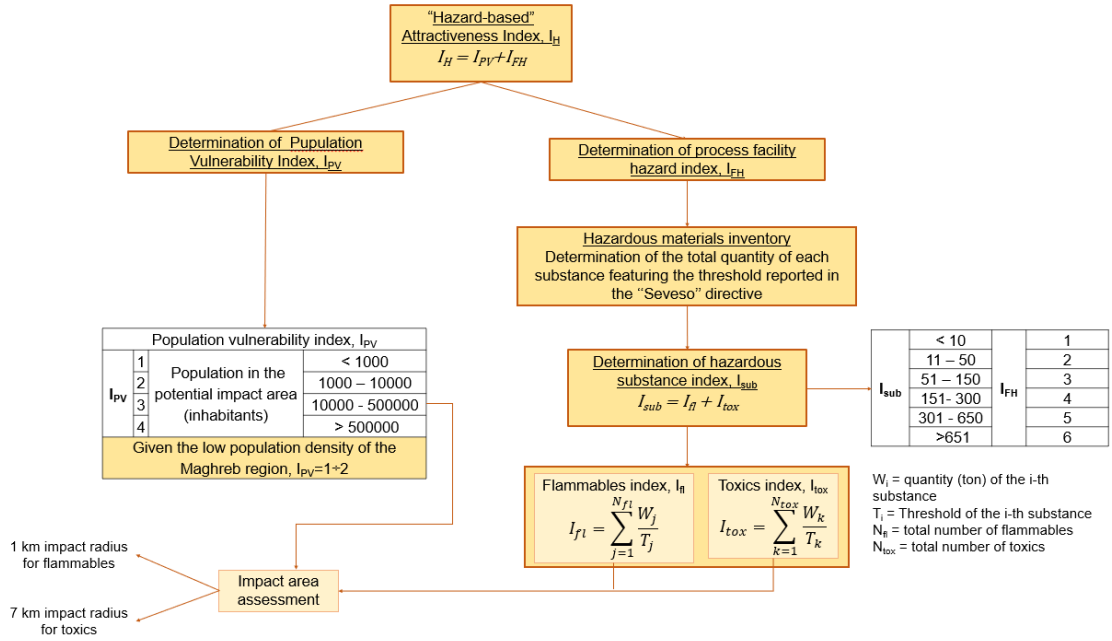

Figure 1: Hazard-based attractiveness index I_H determination methodology catered to the Maghreb area.

3.3 Index F calculation: estimation of non-technical triggers

Beside considering the destructive potential of a successful attack, threat agents may have other incentives to attack a facility. In fact, it is worth to consider the presence of strategic military or government targets located in the proximity of an industrial installation as well as the presence on site of chemicals, which may be used as Weapons of Mass Destruction (WMD); in addition, threat history in the area also has to be taken into account and this is especially relevant for the Maghreb area, as explained in Section 2.
Based on these considerations, the approach developed by Argenti and Landucci (2016) is tailored to the specific aspects of the Maghreb area. The overall attractiveness increase index F is calculated as follows:

$$F = \sum_{i=1}^{m} w_i \times \sigma_i; \quad \sum_{i=1}^{m} w_i = 1 \tag{3}$$

where σ_i is the score associated with the security aspect i and w_i is the correspondent weight. The weighting system has been derived by the adoption of the Analytic Hierarchy Process through the pairwise comparison method (Saaty, 1988); the details are reported elsewhere (Argenti and Landucci, 2016). The summary of the scores and weights associated with the relevant security aspects are reported in Table 2. The table also reports the assumed states for each aspect. As it can be noticed in Table 2, a binary nature is considered for criteria S_1 to S_5, as distinguishing between the presence and absence of certain conditions was considered sufficient for the assessment, while discrete states are assumed for criteria S_6 to S_{10}.

Table 2: Scoring and weights of non-technical aspects – adapted from the work of Argenti and Landucci (2016).

ID	State	Aspect	Score (σ_i)	Weight
S_1	presence	Public ownership/ State participation in company management. Company may be seen as a symbol of state authority	1	0.0324
	absence	Private ownership	0	
S_2	presence	Presence of military targets, institution buildings, embassies, monuments of high symbolic value, critical infrastructure in the site proximity.	1	0.1445
	absence	Absence of military targets, Institution buildings, embassies, monuments of high symbolic value, critical infrastructure in the site proximity.	0	
S_3	presence	Chemicals which can be used as WMD are stored, handled, processed/, produced in significant quantities in the site.	1	0.1445
	absence	Chemicals which can be used as WMD are NOT stored, handled, processed/, produced in significant quantities in the site.	0	
S_4	presence	Similar facilities or facilities owned by the same Company object of past attacks	1	0.1692
	absence	Similar facilities or facilities owned by the same Company never object of attacks	0	
S_5	presence	Terrorists'/ activists' groups are active in the area	1	0.1445
	absence	No terrorists'/ activists' groups are active in the area	0	
S_6	low	A context of political stability and democracy exists. Governing authorities are legitimated and supported by populace.	0	0.0819
	medium	Few opposition groups willing to mine government authority exist and may be blamed for violent actions. Existence of political factions.	0.5	
	high	Political instability and internal conflicts exist. Social order control and maintenance is periodically disrupted.	1	
S_7	low	Strict legislation concerning the transport, selling and detention of weapons of any nature. Effective and diffuse implementation of controls by police forces.	0	0.0653
	medium	Legislation concerning the transport, selling and detention of weapons is present, but control is not a priority.	0.5	
	high	The transport, selling and detention of weapons is poorly ruled and uncontrolled. Third-party interests in favouring the weapons market.	1	
S_8	low	Company reputation and image are extremely positive. Local community judges company activities beneficial.	0	0.0726
	medium	Company activities accepted by local community. Few/minor aversion motives	0.5	
	high	Company reputation extremely negative. Existence of organized aversion groups.	1	
S_9	low	High level of engagement of local stakeholders. Transparency and continuous information sharing to enhance community awareness of company activities.	0	0.0726
	medium	Medium level of engagement of local stakeholders. Company activities are accepted by local community. Few aversion motives of minor importance.	0.5	
	high	No engagement of local stakeholders, climate of suspicion and mistrust.	1	
S_{10}	low	No interactions with cultural/historical, archeological, religious heritage. Absence of activists' groups on the area/No evidence of aversion by activist groups.	0	0.0136
	medium	No significant negative interactions with cultural/historical, archeological, religious heritage. Sporadic demonstrations of aversion by local activist groups.	0.5	
	high	Negative interactions with cultural/historical, archeological, religious heritage.	1	

It is worth to remark that the problem complexity may not exclude a cross-influence among aspects considered in the present study, which was however neglected for the sake of method simplicity.
As it can be noticed from Table 2, the highest relative importance in increasing the perceived value of a facility, and thus attractiveness, is assigned to the existence of past history of malevolent acts against the facility under analysis (see Section 2). Then the facility proximity to strategic targets, the storage and handling of WMD precursors and the confirmed presence of terrorists/activists' cells in the area were considered as secondary aspects. Given the proposed scheme of scores and weights, the location-specific "induction index" (φ) spans over the range 1 to 2.

4. Definition of case studies

The methodology for attractiveness assessment is applied to two case studies, both located in the Maghreb area but with different features. Installation A (In Amenas plant) is located in Algeria, in a highly isolated area surrounded by the desert, where suspicious movements are difficult to track and control. Installation B (Ras Lanuf plant), on the other hand, is located in a densely populated area in Libya, in the proximity of other industrial complexes. Both installations are assumed to treat petroleum products, LNG (Liquefied Natural Gas) and LPG (Liquefied Petroleum Gas). Table 3 shows the estimated hold-up of hazardous substances for both installations; it can be observed that Installation A has a significantly lower hold-up of petroleum products, while a higher hold-up of LNG/LPG compared to Installation B. Both installations have a past history of intentional attacks, some leading to fatalities, as documented in Section 2.

Table 3: Hazardous substances hold-up for the case studies. Petroleum products include gasolines, naphtha, kerosene, diesel fuels.

Item	Installation A	Installation B
LNG-LPG (ton)	7398	3010
Petroleum products (ton)	14351	754046
Reference	(Statoil, 2014)	http://arc.com.ly/en/

5. Results and discussion

Figure 2 shows the results of the attractiveness assessment for the case studies. According to the qualitative ranking in Table 1, Installation A has a medium overall attractiveness index, while Installation B has a high overall attractiveness index. Installation A and B have roughly the same induction index *φ*; this is due to the fact that both installations operate in a similar context, so the non-technical aspects that increase attractiveness (see Table 2) are similar. The context in which these two installations operate caused a raise of 60% in attractiveness, compared to installations that operate in a hypothetical non-critical context (i.e., featuring a unitary value of the induction index φ).

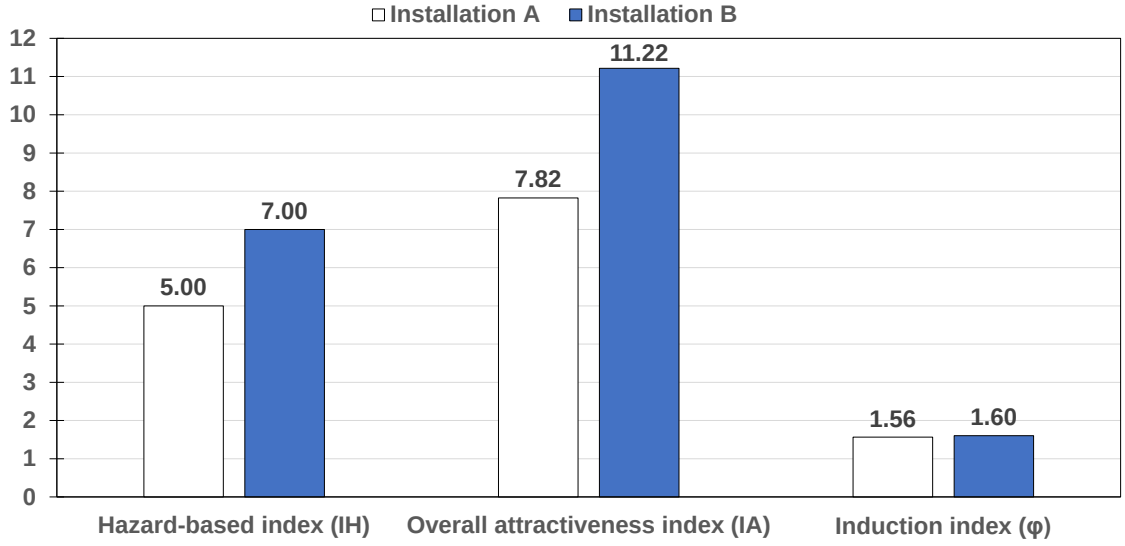

Figure 2: Results of attractiveness assessment for installation A (white bar) and installation B (dark bar)

Installation B has a higher hazard-based index I_H; this is because installation B has a higher hold-up of hazardous substances and is located in a denser populated area compared to Installation A, which is in turn located in a virtually deserted area. An intentional attack to Installation B could lead to major accidents and more severe consequences compared to Installation A.
It is crucial to highlight that the developed methodology may contribute to analyze only a limited part of a complex Security Risk Assessment (API, 2013) study. Nevertheless, determining the attractiveness of a process plant is aimed at supporting a preliminary screening to prioritize resources (CCPS, 2003) and to determine further assessment needs in relation on the credibility of attacks to a given process facility in a particular context. Identifying possible security criticalities for a given facility and addressing specific security preventive measures is crucial for the security management of industrial facilities.

6. Conclusions

As the threat to chemical and process facilities has increased in the last years, structured methodologies are required in order to obtain a realistic estimate of attack likelihood. In the present contribution, attractiveness is adopted as a proxy of attack likelihood. A methodology for attractiveness assessment is presented and applied to the Maghreb area context. The methodology takes into consideration two main aspects of attractiveness. The first aspect is related to the plant hazard potential and considers technical factors, leading to the definition of a hazard-based index I_H. The second aspect is related to the perceived value of the target to a potential threat; therefore, it includes non-technical considerations, like geopolitical and social context and is expressed through the induction index φ. The procedure is exemplified through the application to two case studies, located in critical areas of Maghreb. The assessment shows that the context in which these installations operate is crucial and determines a raise of 60% in attractiveness compared to similar facilities located in other socio-economic contexts. This highlights the importance of undertaking a sound threat and context analysis for the security assessment of facilities operating in the Maghreb area.

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