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Resilience of chemical industrial areas through attenuation-based security

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ABSTRACT

This paper investigates the possibility of attenuation-based security within chemical industrial areas. Representing chemical industrial areas as mathematical networks, we prove by case-study that the resilience to disaster of such areas may follow a power-law distribution. Furthermore, we examine what happens to the network when highly hazardous installations would be intelligently protected against malicious acts: the network disintegrates into separate smaller networks. Hence, islands are formed with no escalation danger in between. We conclude that it is possible to protect chemical industrial areas in such a way that they are more resilient against terrorism.

1. Introduction

The importance of the chemical industry in the global economy can hardly be underestimated. From food packaging to pharmaceuticals, the chemical industry indeed has a prominent role in creating and maintaining our modern day lives. For various reasons, such as benefits of scale, exchange of material streams, optimization of energy streams, and the like, there is a long tradition of strong cluster-like linkages in the chemical industry. Chemical industrial clusters can be found around the world, and they are expanding ever more. According to De Langen [8], an 'industrial cluster' can be defined as a "geographically limited concentration of mutually related business units, associations and public or private organizations centered on a specific economic focus". If looking at a chemical industrial cluster, we may define it as a 'geographically limited concentration of manufacturing companies and service providers operating in the chemical business'. Chemical clusters may consist of tens of different chemical plants and chemical Logistic Service Providers situated in each other's vicinity, to sometimes hundreds of organizations. As such, these chemical industrial parks consist of hundreds to thousands of different chemical installations such as storage tanks, process equipment, chemical reactors, etc. Large chemical clusters worldwide include those of Houston (USA), Antwerp (Belgium), Rotterdam (The Netherlands), Tarragona (Spain), the Rhein-Ruhr region (Germany), Durban (South Africa), Edmonton (Canada), Shanghai Chemical Industry Park (China), and many others.

The security of these chemical industrial parks is important for regions and the countries where these clusters are situated and operate, as well as, in some cases, for the global economy.

Many chemical industrial parks have already been built at some location. Hence, environmental design-based security of these clusters is not possible anymore. However, looking at the five different principles of design-based safety (principles that can also be used for the purpose of design-based security), the fourth principle, attenuation by limitation of effects, or in other words by decreasing the possible extent of the undesired outcome (comparable with 'compartmentalization' in case of fire safety), can be used in existing industrial parks. Fig. 1 provides the five principles of design-based safety (based on [11] and [12]).

Attenuation of the consequences of a large-scale accident within a chemical cluster can indeed be important for the survival of a cluster as a whole. Security based on the 'attenuation of consequences' principle can therefore be seen as a way to make a chemical industrial area more 'secure by design'.

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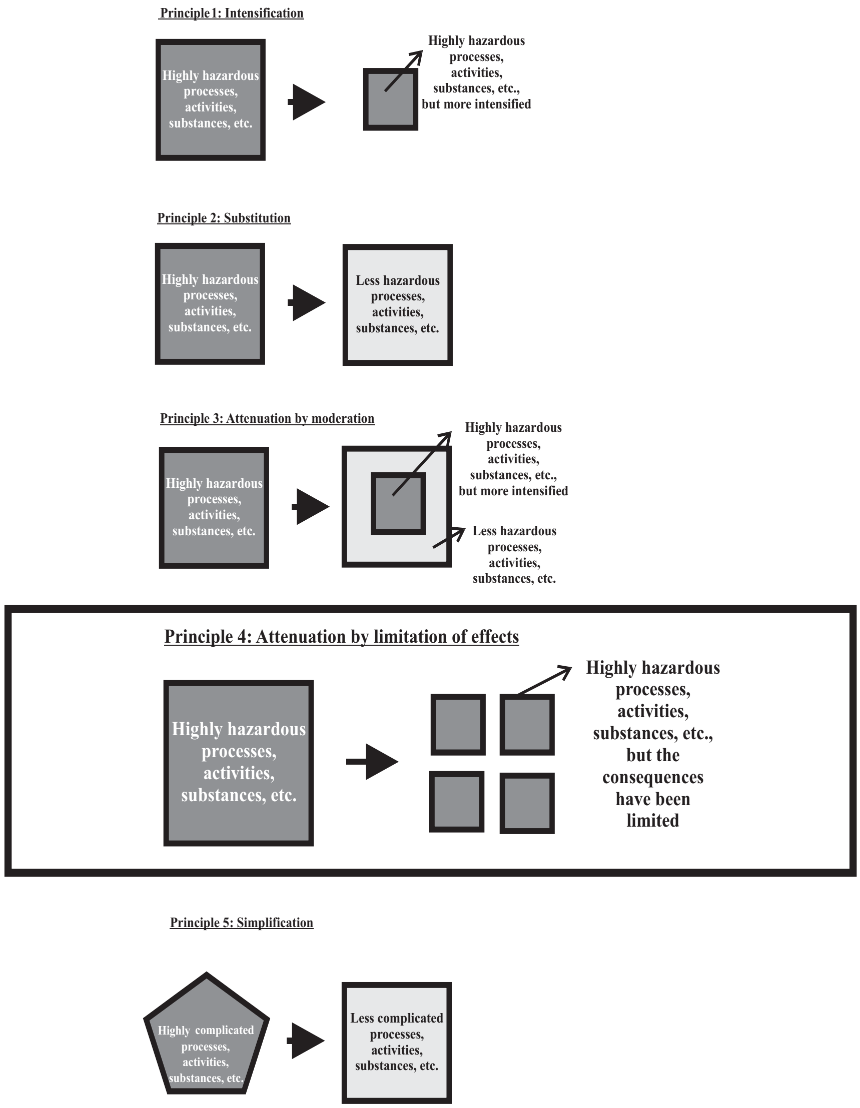

Fig. 1. Five principles of design-based safety.
Source: based on [12].

Another way to look at the attenuation principle, is that it builds resiliency into the chemical cluster. Resilience as a concept, can be looked upon from different angles. Often, resilience is understood as some kind of capacity or ability to recover relatively quickly after an important undesired event (see e.g. [3]). Obviously, such understanding of resilience only takes the re-active part of the concept into consideration, while resilience concerns both the re-active and the pro-active part of dealing with major mishaps. Therefore, in this article, we use the definition by Leveson et al. [14] stating that resilience is "the ability of systems to prevent or adapt to changing conditions in order to maintain (control over) a system property". The property we are concerned about in this article is security (of a chemical industrial area). As Leveson et al. [14] put it, the system must be resilient in terms of avoiding failures (deliberately induced or not) and losses, as well as responding appropriately after the fact.

As indicated by Kröger [13], single failures may develop into serious breakdowns and cascade into dependent systems. To reduce vulnerabilities, risk governance strategies should be developed including all major actors in the decision-making process. Improved analytical capabilities to overcome deficits of 'traditional' methods in coping with complexity, should be developed. Chemical industrial areas form no exception to this observation. In this context, the concepts of self-organized criticality (SOC) and highly organized tolerance (HOT) are interesting study drivers linking real-world phenomena with power-law scaling. However, as Markovic and Gros [15] indicate, current experimental evidence is still inconclusive with respect to a possible causal relation of the emergent power laws to an underlying self-critical state. These authors also indicate that it is possible in many circumstances to tune a system toward a critical point. When considering a chemical industrial area to be 'the system', it would thus be interesting to verify whether it follows a power-law.

Chemical industrial areas can be seen as critical infrastructure subject to a cascade effect: if one installation is blown up, other installations in this area may be affected. There may evidently be an influence of the built-in safety of certain chemical installations on the likelihood of success of a malicious act on such installations, and safety may thus be a parameter to be considered while investigating resilience. However, this is only the case in some instances and it cannot be generalized. In case of a chemical industrial area, it is thus interesting to verify how resilience to protect against terrorist attacks, can be achieved. A chemical park cannot be easily compared with another socio-technical system, such as for example a single chemical plant. Chemical industrial parks are characterized by different organizational cultures (and hence, different security cultures and various security climates),