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Estimation of economic losses associated with intentional attacks to process facilities: a vulnerability-based approach

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As security threats increase, the development of quantitative metrics for security assessment has become a concern in the last years. Still, current methodologies mostly focus on the performance of security barriers, without considering the performance of safety barriers and the economic losses associated with intentional attacks. This study evaluated the economic losses of a successful intentional attack accounting for the combined performance of safety and security barriers. The application to a case study highlighted the importance of considering integrated safety-security approaches to guide decision makers in allocating resources correctly.

Keywords: Integrated safety-security assessment, Bayesian Networks, Economic loss estimation.

ABSTRACT

Intentional attacks may damage chemical and process facilities leading to severe consequences in terms of casualties and economic losses. Several standards and methodologies for Security Risk Assessment were developed in the last twenty years. Still, the majority of those contributions aim at evaluating the performance of security barriers, i.e., Physical Protection Systems (PPS) without accounting for the contribution of other factors, such as Safety Barriers (SB). Indeed, the performance of SB, e.g., firefighting, interlocks, etc., should also be included in security analyses, as their intervention might prevent/mitigate intentional attack scenarios (Shuaiqi et al., 2022). Moreover, approaches that focus on estimating the economic losses of a successful intentional attack are still lacking.

This work aimed at evaluating the coupled performance of PPS and SB in reducing the potential economic losses. Vulnerability, i.e., the probability of successfully carrying out the attack, and economic losses were evaluated. A probabilistic approach based on Bayesian Networks (BN) was used to quantify the analysis. The first step of the methodology was the retrieval of performance data associated to PPS (Garcia, 2008; Argenti et al., 2017) and SB (Khakzad et al., 2018). Then, the integrated performance of SB and PPS were modelled into the BN by using specific sets of nodes. The final step of the methodology was the evaluation of economic losses. In this work a simplified approach based on (Khakzad et al., 2018) was adopted, and losses were associated with the price of the damaged equipment (e.g., storage tanks) and calculated by multiplying the price of each vessel by its damage probability. The methodology was applied to a case study, which is shown in Fig. 1.

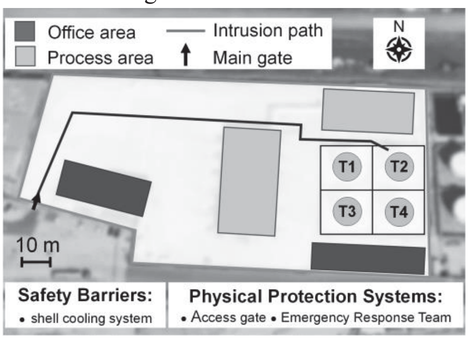

Fig. 1: Layout of the case study and barriers in place

T1-T4 are gasoline storage tanks protected by a shell water cooling in case of fire. Fig. 1 also shows the attack path: the intruder trespasses the main gate at night, and targets T2 with 15 kg of explosive. The catastrophic rupture of T2 leads to a pool fire. The consequences have been evaluated with integral models under 2/F stability conditions and eastward wind. The price of the equipment factored the costs of materials, as well as the additional costs of manufacturing, welding, transport, and installation.

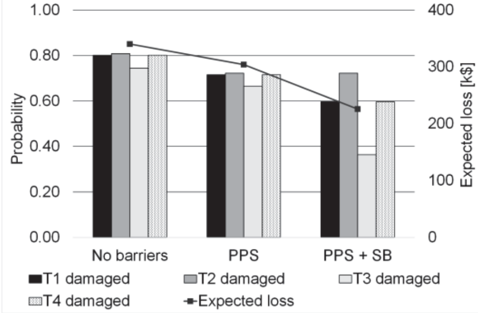

Fig. 2. Results of the application to the case study; PPS = Security barriers; SB = safety barriers

Fig. 2 shows the results of the analysis. Vulnerability of the assets has been evaluated in three cases: i) without any safety/security barrier; ii) only accounting for the contribution of PPS; and iii) synergy of PPS and SB. As shown in Fig. 2, the inclusion of PPS causes a 11% reduction in both probability of damage and economic loss. The inclusion of SB has instead a bigger impact, especially on vessel T3. The intervention of the water deluge system significantly mitigates the received heat radiation, causing a 50% decrease in T3 vulnerability. For T1 and T2 a reduction of 25% in vulnerability can instead be observed. This reflect on the economic loss, which is reduced by 34% compared to the case with no barriers.

In conclusion, this work explored the inclusion of safety-based protection in security studies. The application to the case study showed that the synergic performance of PPS and SB decreases asset vulnerability and expected economic loss. Therefore, the integration of safety and security approaches is necessary to correctly manage the resources of process facilities. Future works include a further characterization of SB performance and the improvement of the expected economic losses by including factors such as plant downtime.

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