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Area Risk Analysis in an Urban Port: Personnel and Major Accident Risk Issues

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As widely known, urban port areas represent considerably complex systems, both from the environmental and safety viewpoints, especially in case of nearness with installations of temporary storage, or handling of goods (known as “distriparks”). This paper offers a perspective on the different aspects of risk in an urban port area, considering both personnel and process related safety issues. Dealing with the latter aspect, area risk evaluation can be faced by recomposing the risk connected to loading/unloading activities and different transportation modes in the shipping areas, with the contribution due to the stationary industrial equipments/plants. The validity of the framework was tested considering a noticeable Italian case-study, starting from a detailed inventory of the more frequently dangerous goods handled in the area and the maximum credible amounts stored for a meaningful time (temporary storage).

1. Introduction

Even if the activities related to the intermediate storage of dangerous goods in marshalling yards and port areas were excluded from the Seveso II Directive (96/82/EC), they can be characterized by intrinsic high risk levels. As amply discussed in the scientific literature, urban port areas represent considerably complex systems, both from the environmental and safety points of view, especially in case of nearness with installations of temporary storage, or handling of goods (known as “distriparks”). After the containerization, port can be defined as the interface among different transportation modes, one of which is sea transportation. From the safety view point, a noteworthy characteristic is represented by the broad range of involved actors, in some instances with conflicting interests: port authorities, ship masters and owners; berth operators; on-board and port workers; terminal operators; owner and operators of different transport means in the area (rail, road, inland navigation) . This paper aims at evaluating the twofold sides of safety in the considered settings, namely connected to personnel and process risk. These issues are discussed with reference to an Italian port area of interest due to its safety implications: the Genoa harbour is located in the city area and more widely in the environment of the Ligurian Riviera. In the stretches of water opposite the oil port area, the embankment houses the runway of “Cristoforo Colombo” Airport. The harbour premises are northerly closed by the railway line Genoa-Ventimiglia. The highways A10 stretches nearby and the highway A7 towards Milan and North Europe run from it among the mountains; according to the Netherland criteria, these highway stretches are characterized by hot spots, at the limit of the acceptable level of risk associated to HazMat transportation, (Fabiano et al., 2005) also due to the presence of road/rail tunnels and consequent potential high profile accident scenarios (Vianello et al., 2012). Dealing with occupational accidents, we pointed out the main factors affecting the risk in an urban port area, considering, in particular, data on occupational injuries over two sample time spans, for the different job typologies. Considering major accident risk, the interactions between the storage installations and the vectors, susceptible of giving rise to a sort of domino effect at a reduced scale, was explored by applying standard models for consequence analysis. The presented results can provide a valuable contribution to risk analysis in urban port areas and help the definition of recommendations for the decision-making bodies (e.g. IMO – International Maritime Organization, RINA etc.) addressed to the mitigation of the risk, mainly by means of adequate design and managerial actions.

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2. Port personnel safety

Of primary interest in this study was to examine the human factor in one of the most important Mediterranean port. Due to the recent economic crisis, a considerable reduction in the overall worked days of the main Company handling containers and other good traffic, was accompanied by labour turnover, with marked in- and out- flows negatively affecting the professional experience, as demonstrated also in different manufacturing and process sectors (e.g. Fabiano et al., (2008). In some instances, an occupational accident can evolve towards a major accident in such a context. Darbra and Casal (2004) evidenced an upward trend regarding the frequency of accident occurrence, starting from the analysis of 471 accidents occurring in seaports over the time span 1941-2002; they concluded that the trend is in part attributable to the increase in port activity and the growth in sea transport of hazardous substances. Four main factors can be identified as affecting accident frequency: socio-economic factors; typical technologies used; environmental conditions; labour force typology. Among them, the socio-economic factors may be considered the most important, in that they exert a considerable influence on the accident frequency (FI), especially if considered over the long period (Fabiano et al., 2004). FI was conventionally referred to one million worked hours, calculated accurately from employees' registers, so that the index can represent a proper instrument of evaluation of accidents dynamics and evolution. We considered two time series directly connected to the economic factor: 2003-2007 and 2008-2012, respectively accounting for the pre-crisis and container traffic expansion period and the global economic crisis.

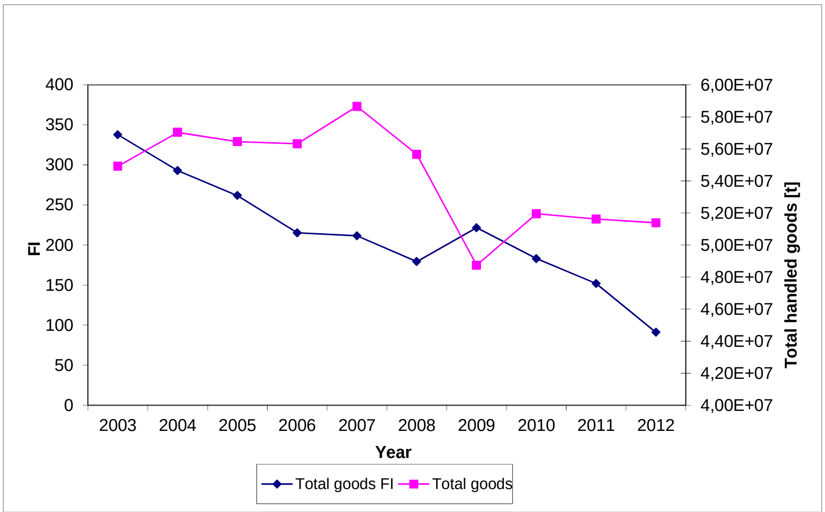

Figure 1: Frequency index for total goods handling and good traffic over the time span 2003-2012.

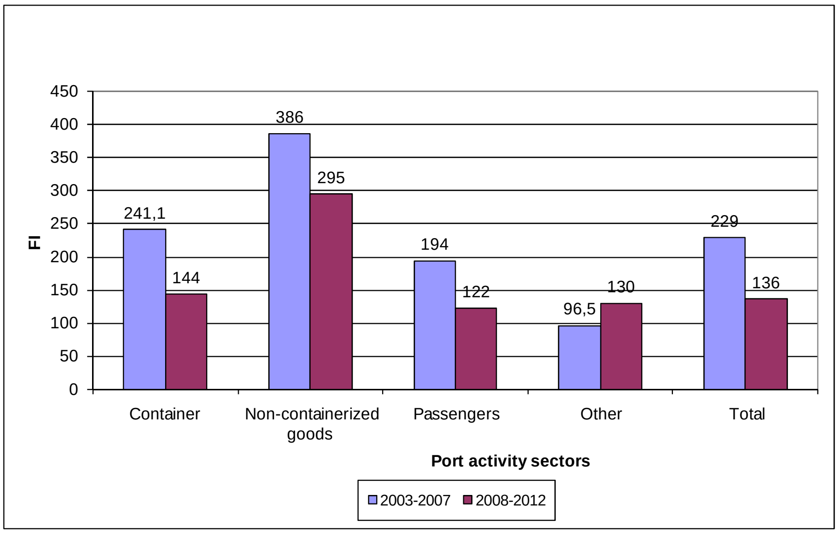

Figure 2: Average five-year frequency index (FI) calculated for the different Genoa port activity sectors.

As shown in Fig. 1, under the latter condition, the Company suffered a sharp decrease of the worked days connected to an analogous decreasing trend of FI down to a value of 91.1. The exception represented by 2009 (FI=221.7) can be connected to job function turnover, as well as to a notable presence of ex-temporary workers with concentration of manpower in the lower age ranges. When analysing the different sectors (Fig. 2), one can observe the higher accident frequency in non-containerized operations (FI = 295 in the economic crisis period), such as the sector of solid bulk material (e.g. coal), while standardized good handling exhibits the best safety performance. This trend can be ascribed to hardware improvement and technical changes in the container sector, accompanied by higher consideration on human factors, such as managerial and organizational systems, with the complete enforcement of the Italian D.Lgs. 81/2008. Dealing with the most hazardous sectors where the operations are not standardized, the interaction between the characteristics of the labour force and the job experience plays a significant role. A correct safety practice should provide procedures and adequate training able to minimize the possibilities of errors by operators, as well as designs and safeguards able to prevent injury if an accident occurs.

3. Port area safety

The sensitivity of the whole area of Genoa port has been, and still is, matter of research and discussion, being a complex system from an environmental viewpoint. Environmental risk tends to be associated with water and air pollution and soil contamination, problems related to dust and noise, movements of ships, lorries and trains, warehouse of hazardous substance, etc. (Darbra and Casal, 2004). Referring to coal, a not-containerized raw material of primary importance in the area, it is well-known that throughout the whole coal handling cycle (unloading and loading of ships, trains and trucks, loading onto, removal from piles and conveyor belt transfer) dust emission represents a serious environmental concern. Full-scale operational solution to the problem of limiting fugitive coal emissions, during transportation from an harbour site to the utilization plant were recently ad-hoc designed (Fabiano et al., 2014). The risk connected with HazMat handling and storage in port areas mainly originates from the complicated nature of activities taking place, the possibility of hardware failure either in the ship or in the inland and loading/unloading equipment, or from external events, such as bad weather conditions or fire/explosion in a ship close-by (Christou, 1999). A further hazard in a congested area like the considered one, is connected to the presence of flammable gas pipelines and their possible combined failure and consequent scenarios (Palazzi et al., 2014).

3.1 Analysis procedure

In order to overcome the inherent differences among the activities performed within Genoa port, we categorized the following items: container terminal where loading, unloading, trans-shipment, storage and handling of dangerous goods is carried on; fixed installations – temporary storage sites, tanks, or HazMat warehouses; ferry terminal - where loading and unloading of HazMat tank trucks is performed.
Table 1 summarizes the criteria adopted in the study to overcome the different classification approach set down by Seveso II Directive and IMO regulations. It must be noted that the only activities relevant to fixed installations are the handling and storage of hazardous substances, without any process implication. Generally speaking, these installations consist of quays and jetties for docking ships; shelters for loading and unloading trucks / railcars; storage tanks; pump station and control rooms.

Table 1: Harmonization approach for hazardous substances handled in the port area.

Category (D.Lgs. 334/99 and amendments)	IMO class	Risk
Annex I, Part 2, point 1 – Very toxic	IMO 2.3 - IMO 6.1	Toxic release
Annex I, Part 2, point 2 – Toxic	IMO 2.3 - IMO 6.1	Toxic release
Annex I, Part 2, point 5 – Explosive	IMO 1	Fire / Explosion
Annex I, Part 2, point 3 – Comburent	IMO 2.2 - IMO 5.1 - 5.2	Fire / Explosion
Annex I, Part 2, point 6 – Flammable	IMO 3 - IMO 4.1	Fire / Explosion
Annex I, Part 2, point 7 – Very flammable	IMO 3 - IMO 4.2	Fire / Explosion
Annex I, Part 2, point 8 – Extremely flammable	IMO 2.1 - IMO 3	Fire / Explosion
Annex I, Part 2, point 10 – Other categories	IMO 4.3	Fire / Explosion
Annex I, Part 2, point 9 i – Dangerous for the environment	IMO 9	Environ. pollution
Annex I, Part 2, point 9 ii – Dangerous for the environment	IMO 9	Environ. pollution

Following primary events were identified: releases of hazardous substances due to loss or breakage of components (pipes, hoses, loading arms, valves, flanges, tanks, and pumps), alarm systems failures or human errors; fire due to external phenomena. For each risk scenario and probability class, the envelopes of areas of damage associated with the accident scenarios were plotted on the maps of the port areas. In order to identify possible domino effects linked to the operations of transfer of hazardous substances from fixed plants to ships, the damage areas represent as well the potential fire scenarios that may occur along the quays or piers. Following main accident causes were sorted: collisions between vehicles and between vehicles and fixed obstacles; fall of containers during HazMat handling in parking area, trans-shipping or loading/unloading; packaging flaws; HazMat transportation of dangerous goods not completely classified, or illegal transportation. For each category it was estimated the expected frequency of occurrence for flammable release; toxic release, environment hazardous release. The problem of frequency quantification requires an in-depth evaluation, so as to avoid over conservative assumptions, as recently highlighted by Milazzo and Aven (2012). In calculating the frequencies following considerations were applied: fire/explosion frequencies were estimated using a simplified event tree, considering IMO 3 class that collects the highest HazMat traffic load; dealing with releases classified as toxic to humans, the starting frequency coincides with the release one; environmental pollution frequency was calculated in connection with sea contamination, either directly, or through the water collection networks. A comparison with accident statistics occurred in the port area allowed verifying the validity of the conservative assumptions adopted for the container terminal. Subsequently, the accident scenarios were sorted according to the probability classes set down by Italian legislation. For each container terminal, fire/explosion scenarios characterized by the highest damage impact were selected. Graphic quantitative output include: the envelope of the damage areas for a single container involved, applied to the perimeter of the dangerous goods park (if any); the envelope of the areas of damage for multiple containers involved, applied to the perimeter of the dangerous goods park; the damage areas for a single container involved, applied to the railway station extension (if any); the damage area for a single container involved, applied to the quays and wharves of the terminal. The evaluation of transportation risk within the port area was faced starting from a framework developed in Liguria and detailed elsewhere (Fabiano et al., 2002). For each road or railway stretch, we estimated the type and average yearly HazMat traffic from statistical data. Following vehicles were identified: road and rail vehicles for the container transport (in packages or in bulk); tank-containers (for liquids or liquefied gases); multiple element gas container (MEGC) for pressurized gas; trailers or semitrailers (in packaging or in bulk); road/rail tankers for liquids.

3.2 Results and discussion

Table 2 summarizes the primary scenarios considered within the container activities. In this study, considering as negligible the probability of a catastrophic failure (nearly instantaneous release), event trees were developed for the continuous release of flammable liquids or gas (compressed and liquefied). An example of the container scenario is provided in Fig. 3, referred to a MEGC holding toxic gas, during the handling inside the terminal or road transportation. The accident scenario considers the rupture of a module having a volume of 2.5 m^3, the release of compressed toxic gas boron trifluoride (BF_3 IDLH: 75 mg/m^3) and the subsequent dispersion into the atmosphere at the most frequent conditions elaborated from the nearby meteorological fixed station (stability class: D; wind speed: 4 m/s; humidity: 66%; ambient temperature: 20°C).The critical rupture is based on the hypothesis of a hole with 51 mm diameter. Fig. 3 evidences the IDLH maximum length corresponding to 900 m in connection with effect duration of 900 s. Fig. 4 shows the extension of the downwind distance as a function of the crosswind one, for the same release scenario. The adopted representation allows identifying possible domino effects from fixed sources in the port area or during transfer operations of HazMat between terminals and ships. In this respect, it should be noted that the damage areas for accidents on piers or docks are also relevant for any accidents on-board the container cargo ship.

Table 2: Primary scenarios considered in the risk calculations.

Scenario	IMO Class
Fire/Explosion	IMO 2.1 – IMO 3 – IMO 4.1 – IMO 4.2 – IMO 4.3 – IMO 5.1 – 5.2
Toxic release	IMO 2.3 – IMO 6.1
Environmental pollution	IMO 9

Figure 3: Release scenario from a multiple element BF_3 container.

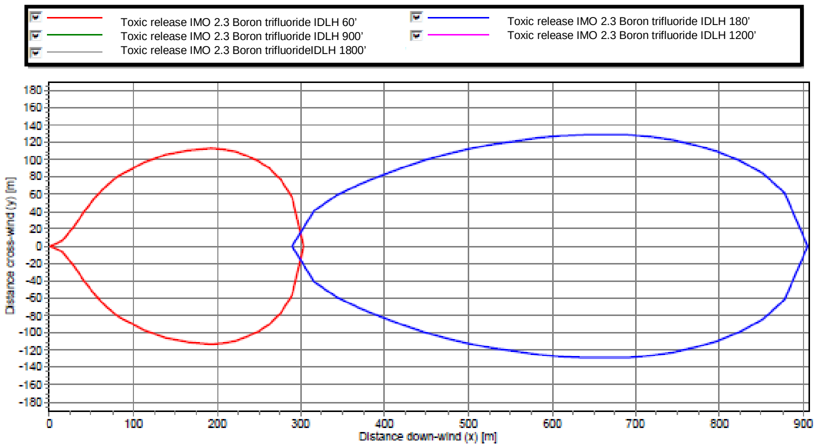

Figure 4: Downwind vs. crosswind distance at IDLH for a multiple element BF_3 container release.

In developing domino effect analysis, we started from the selection of the accidents giving rise to stationary thermal irradiation (pool fire/ jet fire) and the possible fire engulfment of equipment. Subsequently, we identified all active/passive systems suitable to protect the equipment. The probability of escalation was calculated starting from the primary frequency of occurrence of the event, considering the probability of immediate ignition of the substance released and the different layer of protection probabilities (i.e.: quick interception system, active protection systems such as gas detection / fire, fixed water-cooling systems). Dealing with ferry terminal scenarios, we considered releases of flammable liquids on board road trailers considering a loss of containment of the tank/package.

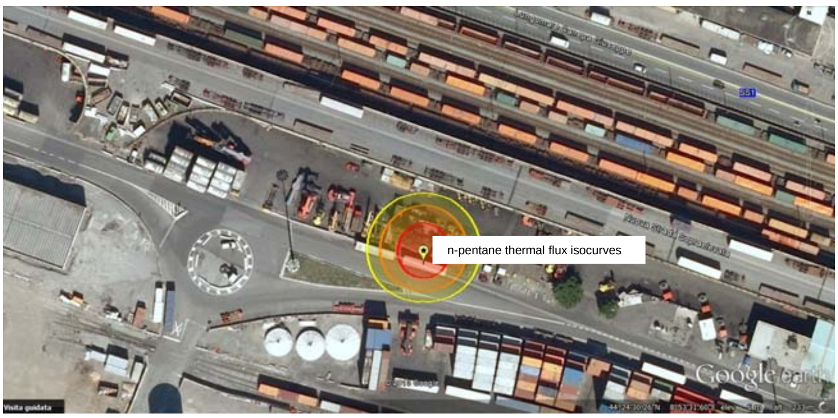

Figure 5: Pool fire scenario from a n-pentane tank truck loss of containment.

Given the limited route length, we did not considered the presence of safety features such as hot box detection, rail switching, crossing, etc. suitable to influence rail transportation failure rates. The evolving accident scenario considers pool-fire and possible escalation. Fig. 5 shows the damage distances connected to a primary scenario of pool-fire from n-pentane tank truck LOC, with maximum radius at the threshold limit of 3 kW/m^2 corresponding to 23 m. These results are compared with an analytical model for the evaluation of the maximum flame temperature (Palazzi and Fabiano, 2012) , also to evaluate possible knock-on effects. In calculating risk associated to transportation, we included the high-rating contribution of loading/unloading activities at the beginning and endpoint of the port route, applying standard methods to derive effect distances for different scenarios. As stationary equipment is subjected to stricter allowance rule than transportation, the combined evaluation was faced evaluating the societal risk of the scenario affecting the point and the estimation of the distance to the stationary guide value, so as to obtain cumulated contours for interference with vulnerable objects (Boot, 2013).

4. Conclusions

In this work we faced the analysis of personnel and process-like risk within an urban port area. The risk analysis on mobile sources (connected with HazMat handling, shipping activities and road/rail transport) was performed according to the same logical process applied to establishments and stationary equipments. The broad variability and non-homogeneity of the substances handled in the terminal was faced by a harmonization relying on IMO classification with a cautious assumption to the most dangerous substances of each class The main appeal of this study consists in the attainment of a homogeneous representation, with comparable data of the area risk, considering the contribution of different sources, both from the operational point of view (factories, carriers, container parks), and from inherent hazards viewpoint. Risk recomposition and mapping in the port area evidenced some critical issues, mostly related to the evaluation of some risk sources so far unknown. This awareness must surely involve careful preparation of contingency planning, although the preliminary study evidenced that no vulnerable objects are present within the 10^{-6}/y contour map. Furthermore, the risk of interferences suitable to give rise to escalation is very low, and only related to some well-identified areas of container parks.

References

Boot H., 2013, the use of risk criteria in comparing transportation alternatives, Chemical Engineering Transactions, 199-204 DOI: 10.3303/CET1331034

Christou M.D., 1999, Analysis and control of major accidents from the intermediate temporary storage of dangerous substances in marshalling yards and port areas, J. Loss Prev. Process Ind. 12 109-119.

Darbra R.-M., Casal J., 2004, Historical analysis of accidents in seaports, Safety Science 42 85-98.

Fabiano B., Currò F., Palazzi E., Pastorino R., 2002, A framework for risk assessment and decision-making strategies in dangerous good transportation, Journal of Hazardous Materials 93, 1-15.

Fabiano B., Currò F., Pastorino R., 2004. A study of the relationship between occupational injuries and firm size and type in the Italian industry, Safety Science 42, 587-600.

Fabiano B., Currò F., Reverberi A.P., Pastorino R., 2005, Dangerous good transportation by road: from risk analysis to emergency planning. J. of Loss Prevention in the Process Industries, 18(4-6): 403-413.

Fabiano B., Currò F., Reverberi A.P., Pastorino R., 2008, A statistical study on temporary work and occupational accidents: specific risk factors and risk management strategies, Safety Sci. 46, 535-990.

Fabiano, B. Currò, F., Reverberi, A.P., Palazzi, E., 2014, Coal dust emissions: From environmental control to risk minimization by underground transport. An applicative case-study. Process Saf. Environ. Prot. 92, 150-159.

Milazzo, M.F., Aven, T., 2012, An extended risk assessment approach for chemical plants applied to a study related to pipe ruptures, Reliability Engineering and System Safety 99, 183-192.

Palazzi E., Fabiano B., 2012, Analytical modelling of hydrocarbon pool fires: Conservative evaluation of flame temperature and thermal power, Process Safety and Environmental Protection 90, 121-128.

Palazzi E., Currò F., Reverberi A., Fabiano B., 2014, Development of a theoretical framework for the evaluation of risk connected to accidental oxygen releases. Process Saf. Environ. Prot. DOI: 10.1016/j.psep.2014.02.015

Vianello C., Fabiano B., Palazzi E., Maschio G., 2012, Experimental study on thermal and toxic hazards connected to fire scenarios in road tunnels. J. Loss Prev. Process Ind. 25, 718-729.