Safety Science xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

From land- to water-use-planning: A consequence based case-study related to cruise ship risk

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ARTICLE INFO

Article history:
Received 13 July 2015
Received in revised form 17 March 2016
Accepted 31 March 2016
Available online xxxx

Keywords:
Cruise ship risk
Costa Concordia
Jolly Nero
Norman Atlantic
Oil spill
Fire scenario

ABSTRACT

Even if safety in the shipping industry improved significantly over the last decades, by novel design and construction techniques, driven by technological, cultural and regulation improvements, recent passenger ship accidents emphasized that significant safety challenges still remain. The modern trend towards large cruise ships can pose a serious threat in terms of both people evacuation/rescue and potential impact on sensible environmental targets. This paper firstly presents a critical analysis of three passenger ship accidents, identifying main similarities with the process sector and relevant learning points. Secondly, the study approaches risk evaluation, acceptance criteria and sea use planning in connection with cruise activity, referring to the worldwide known sensible area of Portofino (Italy). By utilizing numerical methods, the study develops a consequence-based framework incorporating the effects, the hazardous distance and the reaction time scale, related to fuel spill and fire scenarios with smoke spreading. The results evidence that the approach can be a powerful tool to design optimal ship route and temporary docking points for cruise tourism, balancing economic issues and mitigating physical impact to sensitive biological communities. Additionally, it can provide a technical basis for setting-up emergency planning, with appropriate response equipment and thus minimizing coastal impact from a spill.
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1. Introduction

In the aftermath of severe accidents Regulatory Bodies, research companies, healthy organizations and more generally society are forced to re-examine the way things were done, determine immediate and root causes and make appropriate changes possibly applying novel methodologies and solutions. Owing to historical, cultural, administrative, legislative, and other reasons, the risk assessment methods applied in the EU Member States to support land use planning vary significantly (Christou et al., 2011). On one hand, every region and/or country makes its own decision on the use of QRA for gaining insights into individual risks, societal risks, and on the use of QRA for LUP. On the other hand, there seem to be no significant differences noticeable in safety performance levels of industry working under the umbrella of the Seveso Directive (Pasman and Reniers, 2014), which in the latest version, the so-called Seveso III Directive (EU, 2012), came into force on 1st June 2015. Even though the legislation regulates the use of land in many Countries considering the risk from industrial plants and mobile sources, there are still some unexplored possibilities of managing safety for man and the environment, starting from the approaches already well established in the process sector. The focus of this paper, based upon a preliminary work performed on the subject (Vairo et al., 2015), is to present a case-study combining for the first time, at least to our knowledge, use planning from land to sea water. Marine traffic risk is coupled with transport safety, shipping efficiency, distribution reliability and loss prevention, while port risk management assumes high importance, as accidents at industrial ports can result in injuries or fatalities, as well as in severe environmental damages (Fabiano et al., 2010). A correct and careful risk analysis is necessary to design and implement a Safety Management System able to pursue the policy's objectives and allowing an effective revision of the policy itself and assure that those elements and conditions used as reference for the emergency planning (internal and external) are at least preserved in time (Demichela et al., 2004). To these purposes, the methods and the data used should be steadily improved, because the accuracy of calculated risk is currently only within one or two orders of magnitude, due to the variability in scenarios, the assumed failure rates, and human factor influence (De Rademaeker et al., 2014). Port risk assessment is commonly based on its peculiar features: discrete storage of hazardous chemicals, in transportable containers, or as open piles, poses different

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http://dx.doi.org/10.1016/j.ssci.2016.03.024
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hazards, as compared to conventional storage installations, requiring ad hoc solutions to reduce environmental impact (Fabiano et al., 2014). The main environmental threat posed by ship accidents is associated with HazMat transportation and possible environmental impact following a loss of containment; in this regard, the most effective mitigation actions are mainly based on the knowledge of the long time fate of the oil spot (Palazzi et al., 2004). However, passenger ships can represent a serious threat too: even though the accident chances in modern cruise liners are very rare (Vanem and Skjong, 2006), a casualty involving a spill, or flammable cloud forming and pool fire can lead to severe consequences in terms of fatalities, property damage and impact on sensible environmental targets. Risk assessment of vulnerable coastlines and near shore waters is also an essential element of oil spill preparedness and can be done by evaluating ship traffic and the accidents likelihood, along with the probability of releases from fixed offshore installations and impact on the surrounding waters (Galt and Payton, 1999). Fire hazard to a cruise ship due to fuel leak, electrical cables malfunction, engine room troubles or caterings is considered the worst scenario in shipping industry because of life losses and its serious environmental consequences on the surrounding environment and marine life (Wang et al., 2004). This hazard is increased by the current international trend of the ship industry towards ultra-large cruise vessel, posing critical issues in terms of emergency preparedness and evacuation effectiveness. The remainder of this paper is as follows: firstly, we provide a simplified statistical overview on ship accidents and analyze three recent notable ship accidents evidencing aspects that influence major hazard risks and similarities with the process industry. Then we present a quite general approach combining land and water use planning in connection with cruise line risk, discussing its practical application in a sensible target area.

2. A survey on sea accident risk

In the maritime sector, despite a several century experience and many catastrophes, there is not a long accident investigation tradition in which the mission of learning lessons is separated from the allocation of blame and disciplinary actions against the officers on board of seagoing vessels (Dechy et al., 2012). The statistics about accident frequency presented in several papers can provide an overall view of the levels of safety involved in the shipping activity, allowing the quantification of the actual safety levels for different ship types, the main failure modes also considering parameters such as ship sizes, ages, and flag (Guedes Soares and Teixeira, 2001). A noteworthy analysis performed on 471 accidents occurring in seaports by Darbra and Casal (2004) covering the time span 1941–2002, showed a clear upward trend of the accident frequency in port areas in part attributable to the increase in port activities and in part to the growth in hazardous substances sea transport. In this context, they evidenced as well two main contributing operations, namely collision (44% of events) and transport (57% of the accidents). Darbra et al. (2004) presented a further exhaustive accident analysis covering 1033 port accidents from MHIDAS database. They evidenced that the main accident types were loss of containment (70% of the cases), fire (30% of events) and explosion (24% of cases), even if with several overlapping scenarios during accident evolution or escalation. Suggestively, following the same order of the process industry, even if with different percentages, this study evidenced that the most frequent accident affecting population is fire (30%) followed by explosion (24%) and gas cloud (5%). An analysis covering the period 1987–1998 and including 6111 ship accidents, during open sea transport, irrespectively of their severity performed by Fabiano et al. (2002) allowed sorting the three main accident cause as mechanical and electrical failures with engine troubles (30%); collisions (24%) and stranding (12%). By considering only major accidents, from the same study it followed that the immediate causes are human errors and severe atmospheric events (23%), on-board fires and explosion (20%), followed by collision (19%); interestingly in this case, technical troubles or failures were identified as determining cause only in 4% of the events. As observed by Kelman (2008), the hazards in the marine supply chain involve a complex interaction of natural effects, hardware serviceability and vigilance on the part of the crew: in most circumstances, the degradation of any one of these will not lead to an incident, but a combination of any two raises the risk of an incident significantly. According to Lloyds Register (2010), the cause of high severity accidents over the years 2000–2010 causing total loss and considering all ship types, can be summarized as depicted in Fig. 1, from which the most relevant scenarios can be sorted: foundering (49.1%) stranding (18%) and fire/explosion (14.7%) are the most common causes. From the same source, it resulted that cargo vessels cover 44.5% of total loss record, fishery 26.6%), tankers and bulk carriers 15.2% and passengers ship, including cruise, cover a percentage of 6.3%. Dealing with passenger vessel accidents causing injuries and fatalities, Talley et al. (2006) identified as main determining causes human mistakes rather than environmental and vessel-related causes. Likewise in the process sector, the contribution played by human errors should be considered alongside all phases of the process, i.e. design, construction, operation and ship management. This item and the determining role of possible safety deficiencies and management shortcomings on sea accidents were drivers for the introduction of the International Safety Management (ISM), also given the major challenge offered by an ad hoc Safety Management System in reducing the spill frequency due to failure (Milazzo et al., 2010). Dealing with the maritime transport of bulk on containerized products, Kelman (2008) argued that in contrast to what might be expected, frequently the most outwardly hazardous goods have a lower frequency of serious incidents than the more benign cargoes. The items of faulty perceived safety of the ship and the route are well represented by the high-profile accidents occurred over a limited time span (2012–2014) in a rather narrow geographical area.

2.1. Three recent notable ship accidents

A preliminary study is here presented aiming at identifying "what did go wrong" starting from available factual data. In fact, the following case studies provide three recent examples of the severe consequences of lapses in concentration, technical errors, failure to ensure that safe practices are followed at all times and emergency procedures be effectively and promptly activated, with causation result of wrong risk estimates, lack of overview, and communication between individuals involved. They seem confirming also in these last years the previously mentioned role of human error (Talley et al., 2006), in determining high severity ship accidents.

2.1.1. Costa Concordia, 13 January 2012

Costa Concordia represented a perfect example of a modern cruise ship designed for a total onboard people of 4890 (of which 3780 passengers). It was built in the years 2004–2005 by Fincantieri CNI S.p.A. of Sestri Ponente (Genoa, Italy) and equipped with state-of-the-art electronic aids to navigation, security and resources management systems. The passenger ship with on overall length of 289.59 m was provided with two electric motors of total power $2 \cdot 21{,}000$ kW at 146 rpm, ensuring a nominal speed of 19.6 nodes. The ship capsized in January 2012, causing 32 fatalities, under calm sea and clear visibility conditions, having struck a rock in the Tyrrhenian Sea, near the shore of Giglio Isle, on the

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