Accidental impacts on historical and architectural heritage in port areas: the case of Brindisi

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ABSTRACT

Most port areas can produce impacts and pressures on the historical and architectural heritage, leading to potential rapid pathological effects and generating high risks in terms of damages and losses of historical, artistic and cultural values. These negative impacts are caused mainly by the industrial and productive activities which often involve the transportation and handling of hazardous cargoes and materials.

In addition to the stationary actions (air pollution, waste, water discharges), port activities could generate exceptional impacts: the so-called "major accidents", such as fires, explosions and chemical releases, which occur from time to time in industrial plants. These potential accidents can have a severe impact, depending on the interference and the distance between the historic areas urban areas and the industrial facilities of modern ports.

The present contribution analyses and discusses a given case, the port of Brindisi, suggesting a methodology for the assessment of exceptional impacts in ports, in order to identify those potential accidents and their effects on the historical landscape. Particularly, the probability and frequency of occurrence is estimated, including the consequences on heritage, in terms of potential damages and losses.

The performed assessment points out that, as often occurs in ports, the most frequent major accidents are caused by ship-ship impacts and ship-land ones involving a hazardous material. In fact, in these cases a loss of containment could be generated, with the potential occurrence of fires and explosions in sensible areas of the port context. Another risk source identified in the port is the presence of silos for grain storage in the more urban basin of Brindisi, which represents a potential hazard for the surrounding historic heritage, because of the possibility of the occurrence of a powder explosion.

The methodology proposed for this given case aims to demonstrate that in the historical port areas, such as in the Mediterranean Sea, the development and management should be accompanied, or even oriented to the protection of the historical and cultural landscape, which represents an intangible value for the city and, generally speaking, for all mankind.

1 Introduction

When analyzing the potential environmental damage on historical heritage, usually only the impact associated to the “stationary” action (Trozzi and Vaccaro, 2000) (Darbra et al., 2004a) (Puig et al., 2015) is taken into consideration. Stationary action refers here to certain conditions that exist practically always or, at least, with certain frequency. Into this category, atmospheric pollution is the main factor, with its aggression to construction materials (UN ECE 2012) (European Commission 2010). Other contributions, as for example water contamination, sandy winds, etc., can have also a significant role in some cases.
However, another potential impact can exist, associated to exceptional situations: that caused by the so-called “major accidents”. Major accident is the term applied to accidents with important potential effects and consequences on people, equipment and environment. They are usually associated to industrial plants –chemical, energy– and are essentially explosions, fires and toxic materials releases. Their effects could be blast, thermal radiation and toxic/aggressive doses.
Concerning the potential damage to buildings and historical heritage, toxic or chemically aggressive accidental releases should not be considered to be significant, as a general rule. They can originate a cloud that will move with the wind, and due to their short duration, they will not represent a real threat in most cases. Therefore, explosions and fires are the most significant potential accidental impacts.

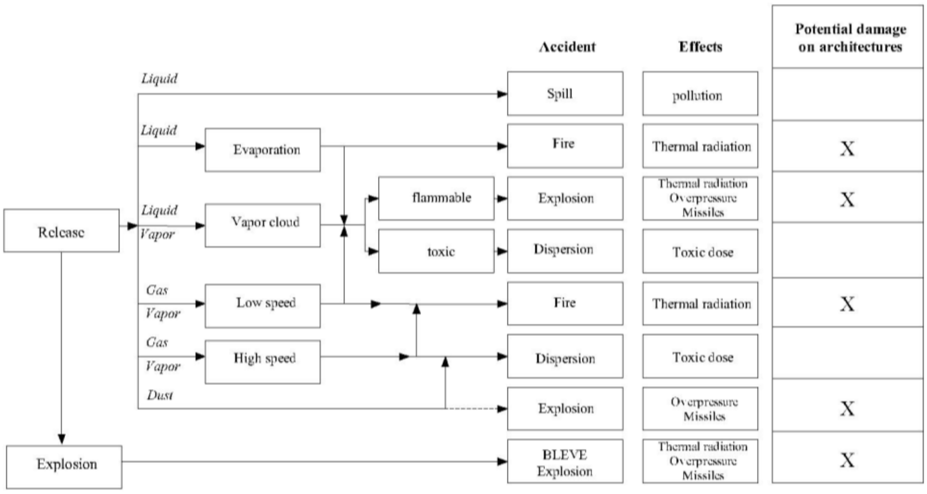
In this paper, their possible influence is analyzed for a given case, the port of Brindisi in South Italy, characterized by a high level of interference between landscaping elements and dangerous port activities. Particularly, the contribution will identify and discuss the main potential accidents in the port with their possible consequences on the historical heritage within it.

2 Major accidents scenarios

During the last decades, most port areas have undergone the transformation and integration of spaces and functions, resulting in modern industrial, commercial and touristic poles. Particularly, many of them are associated to the loading and unloading, as well as storage, of hazardous materials, such as oil, chemical products, natural gas and others, which could represent a certain risk for people and environment, including historical and cultural heritage.
Major accidents, defined as “an occurrence such as a major emission, fire, or explosion” (Directive Council EC 1997), involve the release of significant amounts of energy or hazardous materials, instantaneously or in a relatively short period. They could occur in establishments or during the transportation with ships, trains or trucks or during loading/unloading operations.
Figure 1 shows the main potential scenarios of the major accidents (Casal, 2008). Several events may follow the release of the hazardous substance. Depending on its properties, conditions and physical state, among the others. If a not flammable liquid is released, environmental pollution or toxic dispersion are the main potential accidents. If the liquid/vapor is flammable, instead, a flammable gas cloud could be produced, which, if ignited, could generated an explosion, with disruptive effect on the surroundings.
The release of a gas or a vapor can lead to other effects. If the release occurs at a high speed, atmospheric dispersion is the main outcome, although if the substance is flammable, a jet-fire also occur. If the release takes place at low speed, an explosion is possible (if it is flammable), as well as a subsonic jet-fire.

Fine dust and powder may also generate dangerous clouds, which if ignited can lead to severe explosion. These incidents are caused by the ignition of fine particles in confined spaces, such as, for example, a silo or a pneumatic conveying system. Finally, another cause of incidents, common in industrial plants, is related to the explosion of superheated liquids or pressurized gas in tanks, which can produce overpressures and fragments.

Fig. 1 Schematic representation of accidents that can occur following the loss of containment, their effects and potential damage on architectures (Source: adapted from Casal, 2008)



3 The Port of Brindisi

3.1 Morphology

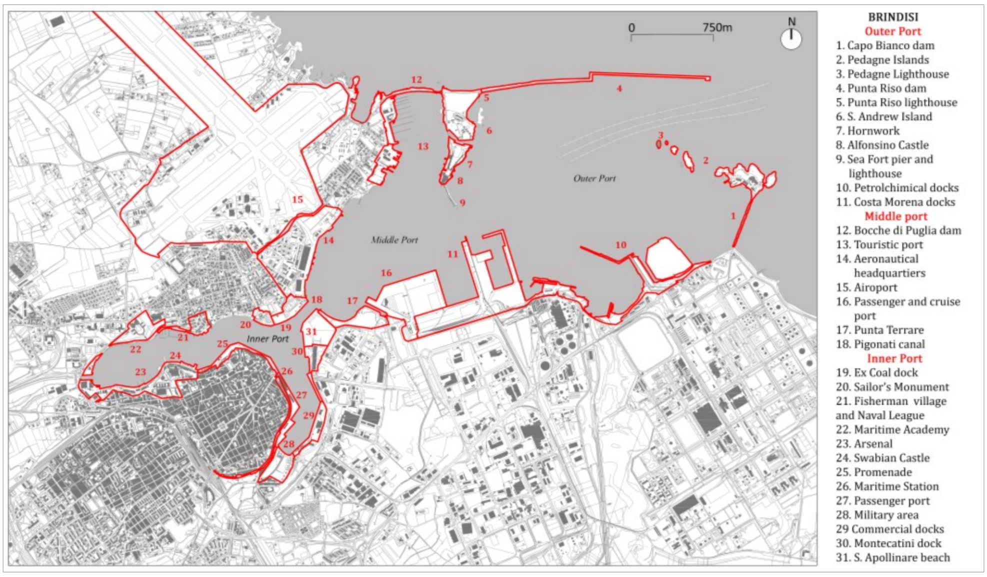
The port of Brindisi is located on the Adriatic Sea coasts of Apulia, in the South-East of Italy. Its natural configuration and strategic position make its basin as the safest in the South Adriatic Sea, since ancient times.
Nowadays, the port, which has about 5 million square meters, is characterized by three basins (Brindisi Port Authority Informer 2010): the outer, the middle and the inner port (Fig. 2). Within them, several functions and activities take place.

The outer port has a basin surface of 3 million s. m. It is delimited by the mainland on the south side, Pedagne islands on the East, the island of S. Andrew and Costa Morena docks on the West, and by the dam of “Punta Riso” on the North side. In this basin mainly industrial activities take place, partly related to the energetic and petrochemical port, including the facilities for the loading/unloading of raw materials. Military facilities are also located in the island of Capo Bianco.
The middle port has a 1.2 million s. m. surface and it is bordered by the Costa Morena docks on the South, the island of St. Andrea on the East, the dam of “Bocche di Puglia” on the North and the Pigonati Channel on West side. It houses different functions: a touristic and yacht port, a cruise and passenger port and several docks for handling cargoes of various types. In fact, bulk carriers (coal) and container ships berth on the West docks of Costa Morena, while LPG carriers dock on the East.

The inner port is located in the historical harbor of the city, active since the Roman Empire. Its two bays, of East and of West, have represented the center of the maritime traffic of the city for centuries. They have about 727,000 s. m. of surface, divided in two similar basins. The East Bay houses essentially passenger ships on one side; on the other docks, solid and liquid bulk (foods and feeds) and bunkering activities are carried out.

The West bay is the more urban area of the port. It is characterized by historical waterfront with a monumental promenade, including yacht docks. Other activities, such as fishing, are also present. The terminal part of the bay houses the military arsenal. Both bays embrace the historical city on the north and east sides.

Fig. 2 Morphology of the port of Brindisi (Adapted from: Martino et al., 2015b)



3.2 Historical built heritage of the port

Fig. 3 The Montecatini shed and the grain silos on the left, the maritime station on the right

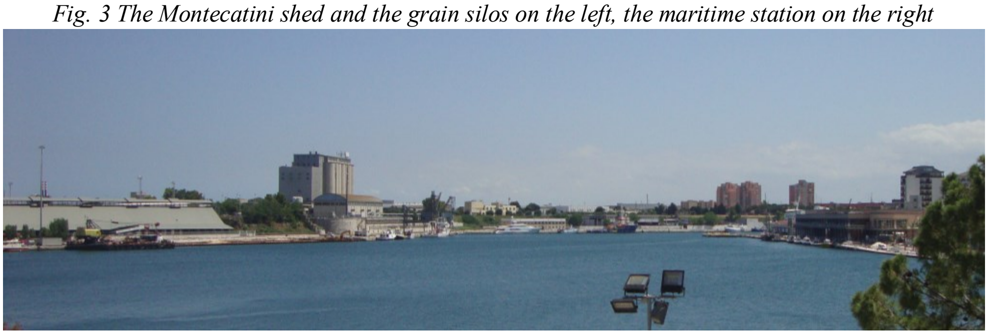
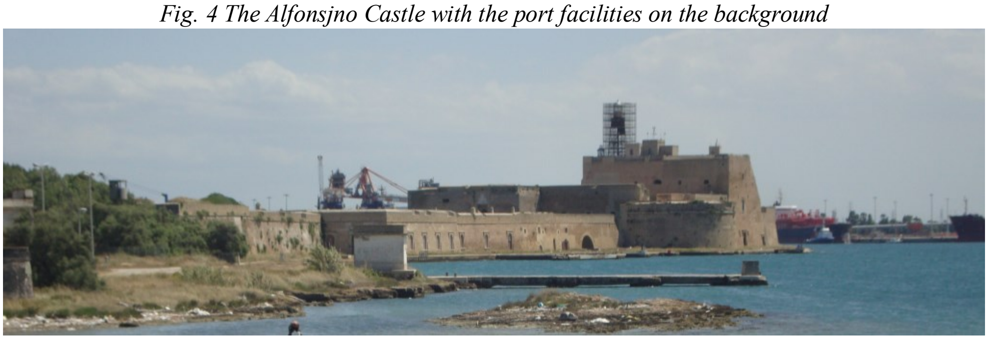


Fig. 4 The Alfonsjno Castle with the port facilities on the background



The assessment of the historical heritage has provided its classification and qualification in terms of typology, state of conservation and characteristics. Particularly, the heritage has been assigned to specific categories, identified through an historical and morphological assessment of Mediterranean ports (Martino, Fatiguso and De Tommasi, 2015a). The qualification of heritage condition (poor, fair, good and very good) has been carried out through direct surveys on sites, while the historical information has been obtained from the Brindisi State Archive and bibliographic research (Martino, De Fino and De Tommasi, 2015b).

Table 1 Assessment of heritage categories in the port of Brindisi

Classification of historical and architectural heritage of ports	**Architectural heritage in the port of Brindisi**			
Historical buildings (B):	**Heritage:**	**Category:**	**Origin data:**	**State:**
B1. *Productive and industrial archaeology*: Arsenals, warehouses, sheds and stores.	Montecatini shed	B1	1930	Fair
	Maritime Academy	B2	1937	Poor
B2. *Logistic buildings*: Customhouses, captaineries, port offices, lighthouses and maritime stations.	Maritime Station	B2	1940	Fair
	Traversa Lighthouse	B2	1861	Fair
B3. *Commercial and mercantile buildings*: Fondaci, caravanserai and similar facilities, palaces for trade and merchants, lodges or markets.	Punta Riso Lighthouse	B2	1890	Poor
	Alfonsino Castle	B4	1481	Poor
B4. *Fortifications and similar buildings*: Castles, fortresses, bastions, towers and walls.	Swabia Castle	B4	1233	Fair
	Punta delle Terrare	S2	Prehistoric	Poor
B5. *Sacred architectures*: Cathedrals, churches, monasteries and convents.	Historical waterfront	S3	XII-XIX cent.	Good
Historical spaces and areas (S)	Sailor's Monument	S3	1933	Good
S1. *Historical spaces of ports*: docks, piers, quays, wharves, basins and promenade.	Fisherman's village	S3	1960	Fair
	S. Andrew Island	S3	XV-XX cent.	Poor
S2. *Archaeological sites*: submerged and on-land remains.				
S3. *Maritime districts*: historical centers, waterfront, curtains, districts.				

The port and the city of Brindisi have one of the most important historic heritages in Apulia and, in general, in Italy. In fact, since ancient time, Greeks, Romans and other civilizations settled in Brindisi, due to its strategic position with respect to the Oriental traffics. As a consequence, nowadays, the city has accumulated several historical buildings and remains, mostly located around the port waters.

Among the historical heritage of the port of Brindisi (Table 1) it should be mentioned, firstly, in the category B1, the wooden shed of Montecatini (Fig. 3), built in the early XXth century. Other buildings in the port context are the lighthouses (Island of Pedagne, Island of St. Andrea), the Maritime Station (Fig. 3) and the Naval College, which belong to B2 category. All these buildings, except the lighthouses, were built by the Fascist Regime in the period 1930-1940.

Furthermore, some of the most important architectures in Brindisi are the fortifications (B4), which protected the city and the port over the centuries. In the inner port, West Bay, the Swabia Castle is located in the Arsenal and military areas. Between the outer and the middle port, another fortress was built in the XVth century: the Alfonso Castle (Fig. 4) with the hornwork. Among the historical areas, there is an archaeological site (S2) near the Costa Morena West docks, called "Punta delle Terrare". The other heritage concerns the historical waterfront, the fishing district and the island of St. Andrea (S3).

As can be seen in Table 1, some of these heritage elements are not well-preserved today. Moreover, some of them are located near the port facilities and infrastructures and, therefore, in some of cases, in dangerous areas.

4 Potential major accidents and consequences on historical heritage

The port of Brindisi is characterized by five main functions: mercantile/commercial, cruise/passenger, military, fishing and touristic. These activities are located in different parts of the port as already explained and, because of their nature, involve hazardous materials and operation, resulting in risk factors for people, environment and buildings. Particularly, the assessment of the port and its activities points out that the main dangers for historical environment and heritage are represented by the energetic pole at Costa Morena, in the middle basin, and with the presence of the silos for solid fine bulk in the inner port. In the first case, Costa Morena houses an LPG (liquefied petroleum gas) handling dock, in which liquefied gas is unloaded from gas-carriers to the station through a pipeline. The carriers have an average capacity of gas of 6,000 tons. The presence of the silos for grain storage is another risk source for the surroundings, especially because they are located in the East Bay of the Inner Port and, thus, close to the urban zone and some historical sites.
The potential major accidents that both the energetic pole and the silos can imply are the loss of containment of a flammable material followed by a fire or an explosion, and a dust explosion in the silos. The most dangerous accident for heritage, among them, is represented by the explosions. Once the potential origin of accidents analyzed, two main scenarios have been identified, in order to estimate their frequencies and potential consequences on the port environment:

- Ship-ship collision in the port-water: LPG release and explosion.
- Accident in the grain silos: powder explosion.

4.1 Explosion in LPG ship due to collision with another ship or with docks

Estimation of frequencies:
According to a historical survey of major accidents occurred in ports (Darbra and Casal, 2004b) (Darbra et al., 2004c), the most common ones involved the transport operations and, particularly, ships impacts. In fact, 56% of 471 accidents analyzed from the Major Hazard Incident Data Service (MHIDAS) were associated to transport. In this category, ship collision (with other ships and land) was the most frequent origin of the accident, with 65% of cases. Especially in the impact accidents, ship-ship collision was the main cause, with 45% of cases, followed by the ship-land impact with 26%. In order to estimate the hazardousness of these phenomena, their frequency and probability have to be assessed. Previous studies have shown some frequencies of the most common accidents in ports (Ronza et al., 2003): the ship-ship collision producing a release and, then, a major accident, has an estimated frequency of 1.0×10^{-5} (harbor movement)$^{-1}$ or 4.8×10^{-4} ship^{-1} x year^{-1}; the average frequency of the impact between ship and jetties, instead, is 8.16×10^{-6} (harbor movement)$^{-1}$.

Table 2 Scenarios for loss of containment due to impact of ships in ports (Source: Bevi Manual, 2009)

Scenarios	Frequency
Gas tankers:	
1. Continuous release of 180 m^3 in 1,800 s	$0.00012 \times f_0$
2. Continuous release of 90 m^3 in 1,800 s	$0.025 \times f_0$
Semi-Gas tankers (refrigerated)	
1. Continuous release of 126 m^3 in 1,800 s	$0.00012 \times f_0$
2. Continuous release of 32 m^3 in 1,800 s	$0.025 \times f_0$

A methodology for the estimation of the frequency of loss of containment from ships is provided by the Purple Book and the Reference Manual Bevi Risk Assessment. The scenarios of ships failure could regard gas tankers and semi-gas tankers, as shown in Table 2. Particularly, the frequency of gas releases depends on the expected frequency (f_0) of the initial event, on the frequency of ships operation in the port and on the loading time. For the port of Brindisi, the frequency has been estimated as:

$$f_0 = 6.7 \text{ x } 10^{-11} \text{ x } T \text{ x } t \text{ x } N = 6.7 \text{ x } 10^{-11} \text{ x } 4{,}500 \text{ x } 15 \text{ x } 160 = 7.2 \text{ x } 10^{-4} \text{ visit}^{-1}$$

$$F= 0.00012 \text{ x } f_0 = 8.64 \text{ x } 10^{-8} \text{ visit}^{-1} = \mathbf{1.3 \text{ x } 10^{-5} \text{ year}^{-1}}$$

where:

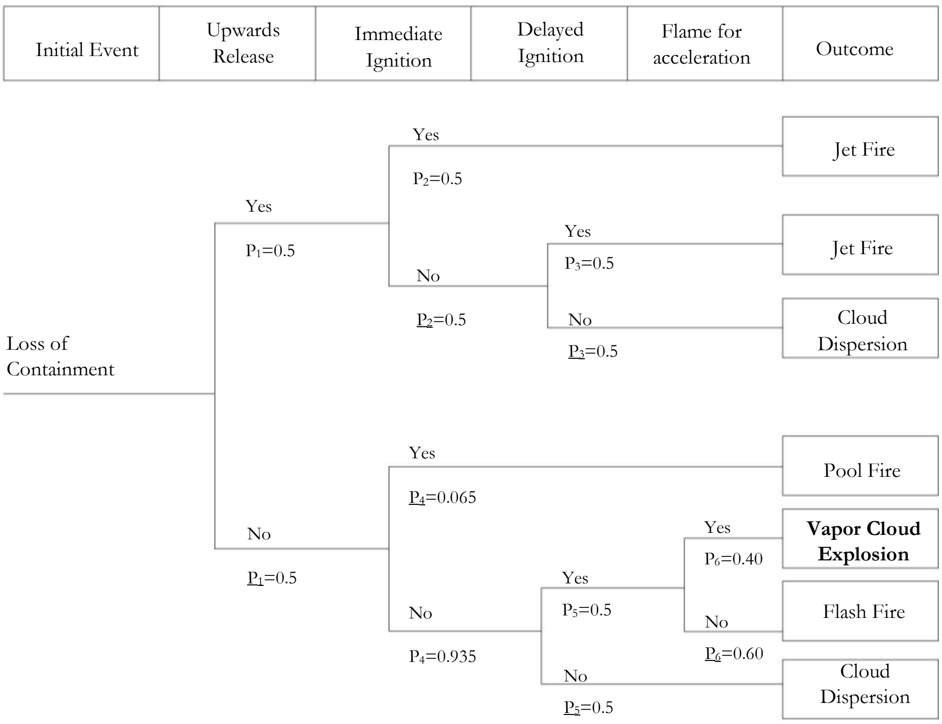
T = 4,500 ships, the total number of ships per annum in the port (Assoporti 2014)

t = 6,000 tons/400 tons h^{-1} = 15 h, the average time of loading operation per ship (Port Authority of Brindisi 2014)

N = 160 is the number of loading operations per year (IPEM spa 2015)

The frequency of an explosion occurring in a ship impact in port could be estimated with an event-tree analysis. The event-tree analysis is a methodology that can provide the probabilities of the sequences of events following the initial accident. Starting from the initial frequency of the incident (loss of containment), the diverse possibilities are considered and their frequencies are estimated by applying the probabilities of the diverse intermediate events (immediate ignition or not, delayed ignition or not, etc.); these probabilities are known from expert knowledge and can be found from the adequate sources (De Haag and Ale., 1999) (RIVM, 2009).

Fig. 5 General event tree for LPG spill (Source: Ronza et al., 2007)



Particularly, according to previous studies (Ronza, Vilchez and Casal, 2007) the release could have an upwards or downwards direction, with assigned equal probabilities of 50%. In relation to this kind of occurrence, different events could follow, depending on the potential immediate ignition probability. If the release is directed downwards, the probability of immediate ignition is low (0.065), however it is likely to occur a delayed ignition, which could lead to an unconfined vapor cloud explosion if flame front acceleration occurs. The event-tree in Fig. 5 points out that the outcomes corresponding to the diverse possible accidental sequences are jet fire, cloud dispersion, vapor cloud explosion, flash fire and pool fire. Among these possible accidents, the one which could damage the historical target is the vapor cloud explosion, its effects being blast (overpressure wave) and fragments ejection. An unconfined vapor cloud explosion following the external impact of ships in the port waters could be produced if a downwards release is ignited with a certain delay. In this case, a flammable cloud can be originated; depending on its size, flame front acceleration can occur, with the occurrence of an overpressure wave. The corresponding probability and frequency are the followings ones:

$$\mathbf{P}_{\mathbf{(UVCE)}} = \underline{P_1} \text{ x } P_4 \text{ x } P_5 \text{ x } P_6 = 0.5 \text{ x } 0.935 \text{ x } 0.5 \text{ x } 0.40 = \mathbf{0.094}$$

$$\mathbf{F}_{\mathbf{(UVCE)}} = 0.094 \text{ x } 1.3 \text{ x } 10^{-5} \text{ year}^{-1} = \mathbf{1.22 \text{ x } 10^{-8} \text{ year}^{-1}}$$

Estimation of effects:

The estimation of the effects of the blast wave on the surroundings can be carried out for an unconfined explosion using the TNT model, which associates an amount of flammable substance to those of the equivalent amount of TNT (Casal, 2008).

Considering a ship-ship collision in port-water as the initial accidental event, a failure of the LPG tank could occur, causing a spill of propane. This initial event could lead to different events with different probabilities and effects. One of them could be the unconfined vapor cloud explosion (UVCE), when a gas release is dispersed in the atmosphere and the flammable cloud thus originated is later on ignited.

In the case of Brindisi, the LPG carriers have an average capacity of 6,000 tons (with a maximum value of 20,000 tons) and are characterized by 2, 3 or 4 tanks per ship, depending on the ship size. Table 3 gives some data concerning the LPG transportation by ship.

Table 3 Generic data of the ship and substance transported

Data	
Ship typology and tanks capacity	LPG carrier (6,000 tons average capacity) with 3 tanks with average of 2,000 tons
Hazardous substance	Liquefied Petroleum Gas - Propane $\Delta H_C = 40400$ kJ kg^{-1} $\rho_{Liq20} = 500$ kg m^{-3} $\rho_{Liq55} = 444$ kg m^{-3} $\rho_{vap55} = 37$ kg m^{-3}

The collision of a ship with docks, jetties or another ship can lead to a spill of hazardous substance, in this case LPG. If a rupture originates a release, a flammable gas cloud can be generated. The mass of the fuel in the cloud has to be evaluated in order to estimate the possible effects and consequences on the surroundings. In this case, a release of 180 m^3 during 1800 s has been considered (Table 2).

The equivalent mass of TNT, a well-known conventional explosive, can be calculated. To do this, the efficiency of the explosion (very low for unconfined hydrocarbon clouds, approximately 3%), the heat of combustion (lower value) of LPG and the energy released by TNT are required (Casal, 2008):

$$W_{TNT}\,(\text{kg}) = \mu\, M\,(\Delta H_C/\Delta H_{TNT}) = 23{,}300 \text{ kg}$$

where

$M = 90{,}000$ kg

$\Delta H_C = 40{,}400$ kJ kg^{-1}

$\mu = 0.03$

$\Delta H_{TNT} = 4680\ kJ\ kg^{-1}$
(a release of 180 m^3, with $\rho_{Liq20} = 500\ kg\ m^{-3}$).

Once the equivalent mass of TNT evaluated, the so-called scaled distance has to be calculated:

$$d_{sc}\ (m) = R / (W_{TNT})^{1/3} = R * 0.035$$

where

R is the distance to the target, m.

Using the following function, the scaled distance can be associated to of the maximum value of overpressure at a specific distance:

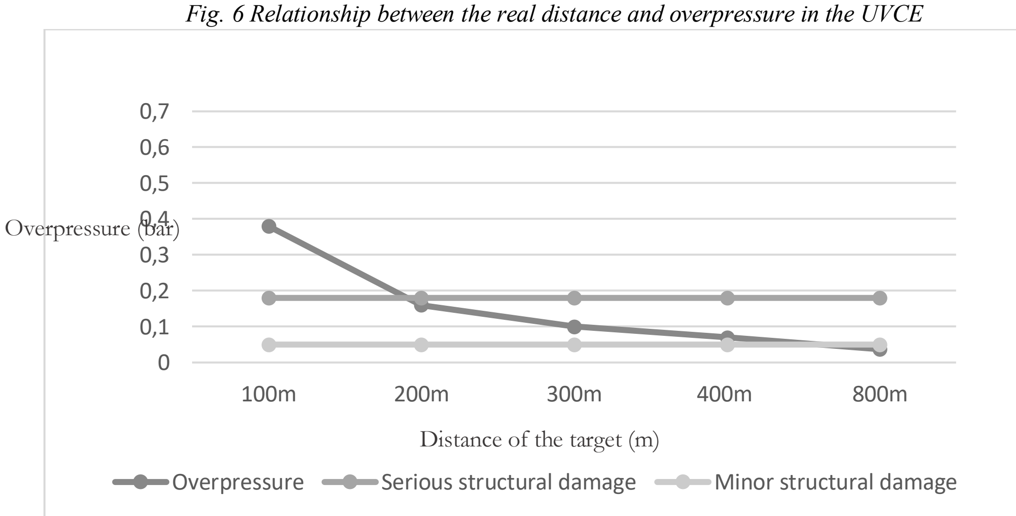
$$\Delta P\ (bar) = 1/d_{sc} + 1/(d_{sc})^2 + 1/(d_{sc})^3$$

The results obtained for the overpressure at different distances can be seen in Table 4 and Figure 6.

Table 4 Relationship between the distance, the scaled distance and the overpressure

Distance R (m)	**Scaled distance d_{sc} (m $kg^{-1/3}$)**	**ΔP Overpressure (bar)**
100	3.5	0.380
200	7.0	0.160
300	10.5	0.100
400	14.0	0.070
800	28.0	0.037

Fig. 6 Relationship between the real distance and overpressure in the UVCE



The calculation of the peak overpressure leads to the identification of the potential damage of the blast on buildings and equipment, in this case with cultural and historical values. Data obtained from real cases have been gathered as criteria for predicting the effects of the overpressure. Particularly, for pick overpressure less than 0.03 bar, the damages on buildings are not serious, regarding only the breakage of windows in most of cases. Peaks of overpressure from 0.05 to 0.18 bar, instead, can produce several damages on structures, although not the complete destruction of them. If ΔP has a value from 0.15 to 0.18 bar structural damages could occur, especially producing cracks in masonries and brickworks of buildings. Sometimes walls and roofs could also collapse under these values of overpressure. From 0.18 bar overpressures, serious structural damages are likely to occur on buildings and equipment: at 0.35 bar most of buildings are destroyed, while from 0.50 to 0.70 bar the destruction of the most resistant structures is possible (Casal, 2008).

5.2 Powder explosion in silos

In the inner port of Brindisi, especially in the East Bay, a plant for processing and storage of bulk fine solids is located. It consists of a silo with a capacity of 50,000 tons, which is close to the docks of the port, where bulk carriers unload products. Once the last trends of the port analyzed, in terms of cereals, food and feed, the Brindisi plant handles an average value of 0.4 million tons per year (Assoporti 2014).

The explosions of silos, which can have very severe effects and consequences, have occurred from time to time, as shown by statistical surveys (Abbasi and Abbasi, 2007) (Demontis and Cremante., 2012). Despite the fact that the last decades have shown a decreasing trend, these accidents still occur in food plants with certain frequency. Particularly, some surveys have related the frequency to the tons handling of plants (Table 5). In the case of Brindisi, the average frequency is about 1 x 10^{-3} $year^{-1}$ or 1 x 10^{-6} $(operative\ hours)^{-1}$.

Table 5 Expected frequencies of grain explosions (Source: Demontis et al., 2012)

Million tons per year	Expected frequencies
0,05	1 x 10^{-7} $(operative\ hours)^{-1}$ 1 x 10^{-4} $years^{-1}$
0,25 – 1,25	**1 x 10^{-6} $(operative\ hours)^{-1}$** **1 x 10^{-3} $years^{-1}$**
1,5	1 x 10^{-5} $(operative\ hours)^{-1}$ 1 x 10^{-2} $years^{-1}$

The prediction and modelling of the effects and consequences of dust/powder explosions is very complex. Nevertheless, basing on statistical data or historical surveys, it is possible to estimate some of the most dangerous effects on the context in which the accident occurs. Regarding the effect of dust explosions of silos or plants, some accidents occurred in the past can be assessed. One of these, particularly, is the explosion of a grain storage facility of the "Societé d'Exploitation Maritime Blayaise" (SEMABLA) occurred at Blaye in 1997 (Masson and Lechaudel, 1998). The accident occurred in a vertical silo, 33 m high. The whole capacity was about 130,000 tons, 40,000 of them in vertical silos and the other in the ground. After the explosion, 16 of 44 cells were largely in place, while the others were destroyed. The effects of the explosion involved a large area surrounding the silo: fragments and projectiles were found at a distance of 500 m from the source, producing damages to dwellings (the closest ones were 230 m far), especially broken windows.

Thus, it points out that for a target located at a distance between 200-500 meters, damages could be produced by the projectiles and fragments ejected by the explosions.

5.3 Consequences and effects on architectural heritage

The assessment of potential accidents in the ports of Brindisi has led to the identification of the heritage elements with the highest risk. Especially, the castle and the fortress of Alfonso of Aragon (1481), the wooden shed of Montecatini Society (1930), the Maritime Station (1940) are the architectures with the highest potential risk, because of their closeness to the energy pole of Costa Morena and the grain silos.

Firstly, the calculation of the accident consequences in terms of blast wave has been carried out for the castle. According to the results of the TNT equivalency, the impact of a vapor cloud explosion from an LPG carrier in the port originates a dangerous

area for buildings with a diameter of 400 meters, as shown in Figure 7. Over this distance, a building will be affected by a blast wave able to originate some damages (Casal, 2008). Between the second and third target distance (200 – 400 m), minor structural damage could occur. In the case of stone-masonry buildings, such as the fortress, cracks could be generated due to the blast wave. These consequences depend on the building material and structural characteristics, including their state of preservation. The castle, as shown in Table 1, is in poor state of conservation and, then, is a somewhat vulnerable element.
The risk of a powder explosion in the silos, located in the East Bay of the Inner Port, may affect several buildings, some of them with an historical value. The Montecatini shed and the Maritime Station are between 200 and 500 meters far from the potential explosion source (Fig. 8). Furthermore, they are not in good state of conservation, because they are not used, nowadays. As previously described, the survey of past accidents points out that at this distance damages may be generated, in terms of breakage on glasses and walls, with potential cultural and historical losses. Projectiles and missiles could reach also residential buildings that are in the surroundings, representing therefore a risk for people.

Fig. 7 Dangerous area for scenario no.1

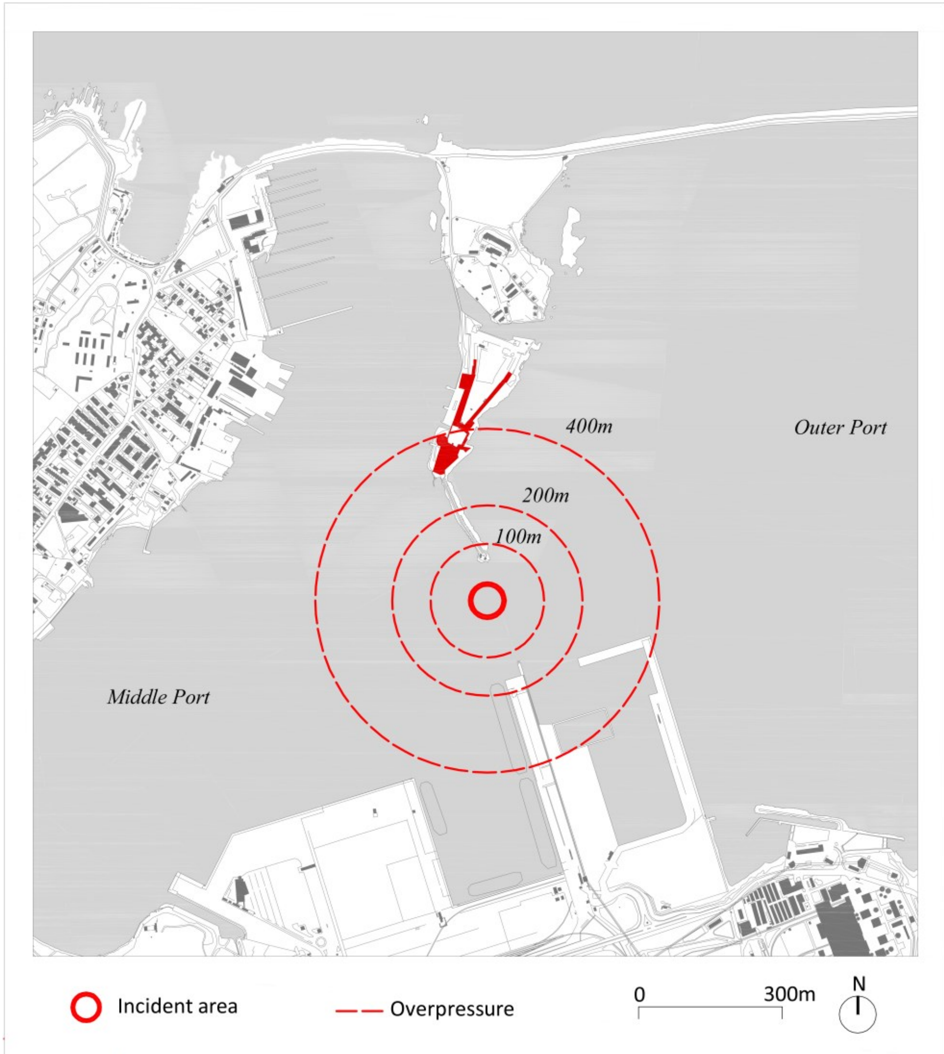
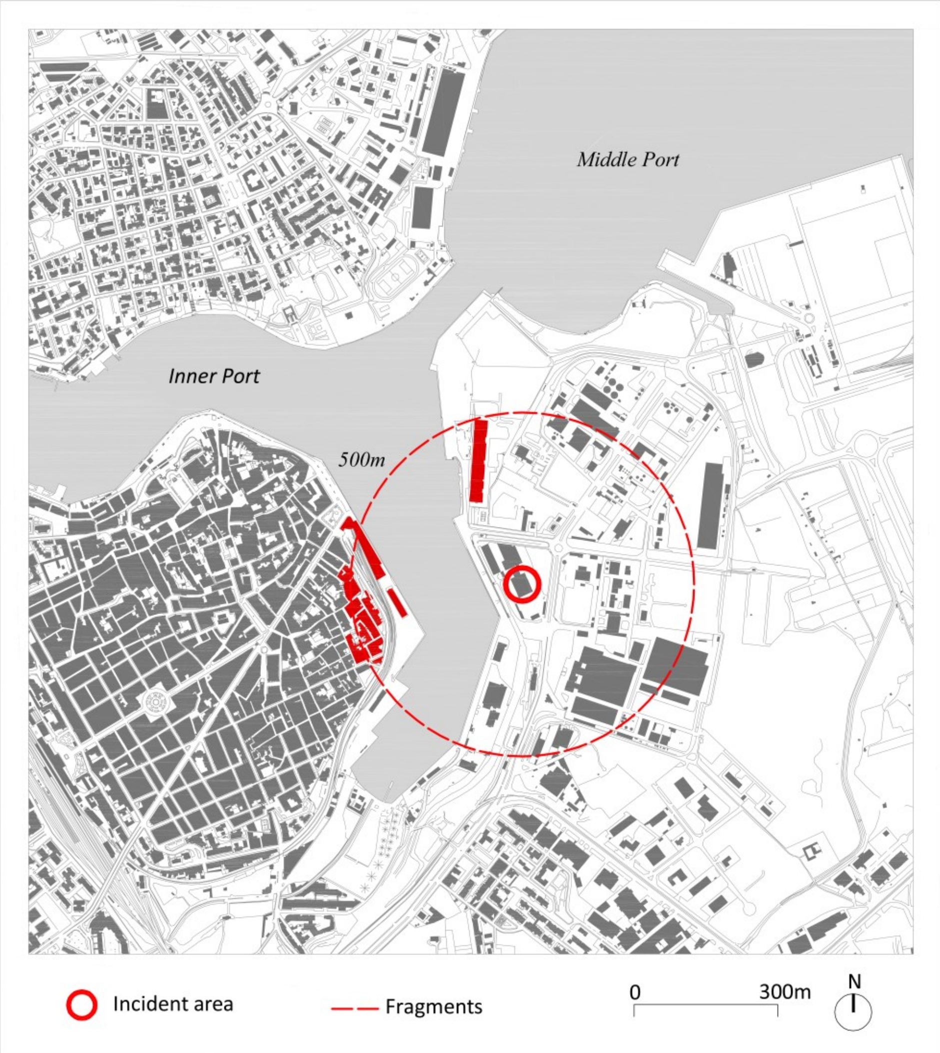


Fig. 8 Dangerous area for scenario no.2



6 Discussion and conclusions

The assessment of exceptional impacts on landscaping elements and historical heritage in port context has been carried out, focusing on the specific case of the port of Brindisi, in order to identify the heritage at risk.

Firstly, it points out that the Brindisi has all the main characteristics of a modern port: passengers, cruises, cargoes and energy docks, located in different basins with a high level of interference with urban, historical and natural landscape.

Secondly, the assessment of port activities has revealed that there are some potential accident scenarios with effects on landscaping components. Two main scenarios have been identified and assessed: an explosion of an LPG release after ships impact near the Costa Morena docks, and a dust explosion in the silos located in the East bay of the inner port. Particularly, the frequencies and the potential consequent damage on heritage have been estimated for the identified scenarios.

The results show that one of the dangerous areas in the port is the East bay of the inner basin for the Montecatini shed, the Maritime Station and some residential buildings in the historic center of the city: a potential explosion could lead to material damages of these architectures, due to the fragments ejection.

The other important element of the port landscape at risk is the Alfonsino castle, which is close to the dock where LPG and coal are handled. Particularly, considering a ship-ship impact near the canal of Costa Morena, a vapor cloud explosion may be originated in certain conditions. The effects on the castle could be severe, in terms of overpressure and fragments. Due to the poor state of preservation of the fortress, cracks could be produced on the stone-masonry structures, with a potential risk of loss of cultural and artistic features.

The analysis performed has shown that, although the frequencies of these accidental impacts are very low, they should be taken into account in the management and planning of ports, as they could have effects on landscape more serious and disruptive than stationary impacts.
This contribution is part of a wide research on architectural heritage of historical ports at risk in the Mediterranean Sea. The main goal will be the definition of a methodology for risk assessment in order to identify guidelines for preservation and enhancement of heritage of the sensible and critical context of modern ports. Future work will deal with the development of a Risk Charter for Historical Ports of Apulia (Italy), in which they will be considered both stationary and exceptional impacts of port activities, on one hand, and vulnerability of heritage, on the other one.

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