The historical landscape of ports: from the definition of a methodology for the risk assessment to the identification of guidelines for port heritage preservation

Abstract

Since the last century, the landscape of ports has been completely changed and modernized, in order to house the new and modern activities, increasingly directed towards productive, industrial and energetic functions, among the others. Therefore, the historic buildings and spaces of ports have been characterized by severe pathological decay and abandonment. According to this, the rehabilitation and enhancement of port areas represent an important challenge, as well as an opportunity.

The PhD thesis aims to carry out a methodology for the identification of the risks - in terms of losses of material, artistic, cultural values - of historical heritage of ports, in order to define guidelines and strategies for its preservation and enhancement, as well as for the integration of the port-city system. Starting from the classification of the architectural and historical heritage of the most significant Mediterranean ports, the risk is evaluated through the assessment of the heritage vulnerability and of the potential impacts of port activities, both stationary that exceptional ones.

Finally, the methodology is applied to a given case: the port of Brindisi (Apulia, Italy), particularly interesting because the industrial, mercantile, commercial and logistic activities are close to relevant historical heritages. It points out that some historical assets of Brindisi are seriously threatened. In the view of a risk mitigation and sustainable development of the Apulian port-city, a strategic scenario is proposed: the constitution of a "Historical Park of the Port of Brindisi".

On the cover: the Aragon Castle in Brindisi

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PhD in Risk and Environmental, Territorial and Building Development

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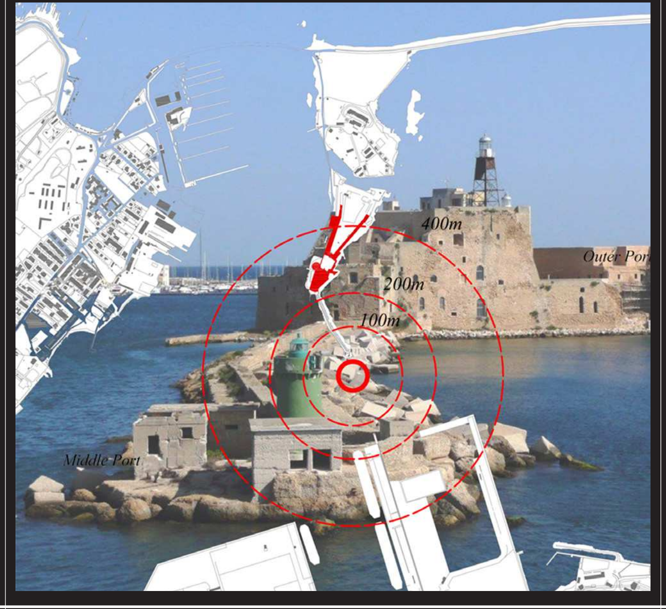

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Il paesaggio storico dei porti: dalla definizione di una metodologia per la valutazione dei rischi alla identificatione di linee guida per la conservazione del patrimonio portuale

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Abstract

Since the last century, the landscape of ports have been completely changed and modernized, in order to house the new and modern activities, increasingly directed towards productive, industrial and energetic functions, among the others.
Nowadays, most modern port areas produce impacts on the historical and architectural heritages, which combined to the their vulnerability, can lead to rapid pathological effects generating high risks in terms of damages and losses of historical, artistic and cultural values, including the abandonment of port buildings and spaces.
In fact, since the end of XIX century, industrial and productive activities, on the one hand, logistic and touristic facilities, on the other hand, have settled in port areas, changing profoundly their historical and natural landscape. Innovations and technological development in the naval engineering and in the construction techniques have led port areas to renew and expand considerably with the erection of large maritime works,

such as docks and piers. Whereas the morphology of the port context did not allow the construction of these enlargements, the new facilities and structures have been located in the suburb areas of the cities, changing their relationship with the city center. As a result, the displacement of these activities into new areas has produced widespread abandonment and decommissioning of existing architectural heritage. When ports maintained their original position and role, the landscape has been transformed to accommodate new ships of large size, producing significant impacts and pressures on historical heritage, in terms of material, technical, technological and functional obsolescence. Furthermore, in most of cases, ports and cities represent clusters completely separated and disconnected, being managed and developed as different systems.
In recent decades, moreover, the concentration of activities, increasingly directed towards industrial and energy production, in port areas has contributed to the deterioration of environmental conditions in which there were both heritage and historic urban fabric. In addition to environmental effects, i.e. stationary ones, port activities could generate exceptional impacts, also known as major accidents: explosions, fires and chemical releases. These anthropic disasters can have severe effects on historical sites, potentially leading to their damaging and destruction.
According to the above-mentioned aspects, the preservation and the enhancement of historic buildings and spaces of ports is actually critical and complex, also in terms of management and governance of the port-city system. Thus, the rehabilitation and enhancement of historical port areas, as well as the definition of integrated models of development for urban areas and ports, represent important challenges, as well as opportunities, for coastal cities.

In this context, the PhD thesis aims to carry out a methodology for the identification of the risks - in terms of losses of material, artistic, cultural values- affecting the historical heritage of ports, in order to identify guidelines and strategies for its preservation and enhancement, as well as for the integration of the port-city system.
Firstly, in the thesis, the architectural heritage of the most significant Mediterranean port cities is analyzed, in order to build a knowledge framework for the classification and qualification of maritime and port heritage, and for the realization of the dynamics of

the port transformation over the centuries. Particularly, the morphological and historical evolution of ports in the Mare Nostrum context is discussed and described in Chapter 1, identifying the relationship between port and city in different historical period and geographical areas, as well as their dimension, number and shape of the basins, functions and morphology. In addition to this, specific categories of historical heritage are identified, focusing on the architectural, materials and functional characteristics.
Secondly, a methodology for the identification and estimation of those risks, which can affect historical heritages in ports is presented and described. The proposed method aims to evaluate risk, through the assessment of the vulnerability of heritages of ports and of the main hazards produced by port activities. The Chapter 3 of the thesis, starting from a bibliographic review of the main definition and methods, proposed a simplified methodology for assessing the vulnerability of cultural assets in ports, considered as sum of three main contributes: material vulnerability, and functional and cultural one. The assessment is provided through specific forms, defined for each specific category of port assets, as shown in the section Annexes of the thesis.
Subsequently in Chapters 4 and 5, the concept of hazard, i.e. impacts of port activities on historical heritages, is explained and analyzed proposing methods for its assessment. The hazard is considered in two main typologies: stationary and exceptional ones. The stationary impact refers to the environmental consequences, which are continuously produced by port activities, such as emission to air, water and soil. The main effects of these impacts on heritage are described in order to provide a method for their estimation. They concern mostly impacts on construction materials, on use and function and on landscaping values. The exceptional impacts, instead, are those ones potentially produced by the occurrence of the so-called major accidents: mainly explosions and fires, produced by hazardous substances in ships collision, storage and loading/unloading operations in ports. A methodology for the estimation of the frequency of those accidents, as well as of the evaluation of the consequences on historical sites, is described, mostly focusing on explosions.
The heritage classification and the definition of a methodology for risk assessment aims to identify specific guidelines for an integrated development of the port-city system,

with particular attention to the preservation and enhancement of historical sites, and the mitigation of risks affecting them in ports. Starting from a historical review of the main intervention in ports since the last century, some strategies for heritage preservation and port-city system sustainable development are explained. The main goals of the guidelines are preservation, safeguard, enhancement, dissemination of values, territorial redevelopment, risk reduction and sustainable governance.

Finally, the research methodology is applied to a given case, the port of Brindisi located in Apulia, South-East of Italy. The case of study is particularly interesting because the industrial, mercantile, commercial and logistic activities are very close and intersected to the cultural and historical heritages of the port. Once described the port history, morphology and characteristics, a vulnerability assessment of port assets is carried out revealing that the majority of them are certainly compromised. Comparing this with the assessment of stationary and exceptional impacts, it points out that there are some historical assets of the Brindisi, which are actually seriously threatened. In the view of a risk mitigation and sustainable development of the Apulian port-city, a strategic scenario is proposed: the constitution of a “Historical Park of the Port of Brindisi”. A structured strategy of intervention is defined: first of all, the redevelopment of port areas, as well as the risk reduction, should be a priority for the city in order to preserve historical properties and values; secondly, a port-city governance must be organized for defining the main future sustainable goals of the territorial system, considering cultural and historical landscape preservation and enhancement as challenge and opportunity.

Key words:

historical Mediterranean ports; port architectural heritage; risk assessment; preservation and enhancement.

Abstract

Il paesaggio portuale, sin dal XX secolo, è stato completamente trasformato al fine di ospitare nuove attività e infrastrutture sempre più dirette verso le funzioni produttive, industriali ed energetiche. Le moderne aree portuali, al giorno d'oggi, producono impatti sul patrimonio storico ed architettonico portuale, che combinati con la loro vulnerabilità, possono portare ad un veloce deterioramento e generare fattori di rischio in termini di danneggiamenti e perdita di valori materici, storici, artistici e culturali.
In effetti, a partire dalla fine del '900, attività ed impianti industriali e produttivi, da un lato, e infrastrutture logistiche e turistiche, dall'altro, sono state insediate nelle aree portuali modificando sensibilmente il loro paesaggio naturale e storico. Le innovazioni e lo sviluppo tecnologico in ambito navale e nelle tecniche costruttive hanno portato i porti ad essere rinnovati ed ampliati considerabilmente con la costruzione di grandi

opere d'ingegneria marittima, come moli e banchine. Laddove la morfologia del contesto portuale non ha permesso la realizzazione di questi ampliamenti, le nuove strutture ed infrastrutture portuali sono state localizzate nelle aree periferiche delle città, cambiandone sensibilmente il rapporto con il centro urbano. Di conseguenza, la delocalizzazione di queste attività in nuove aree ha prodotto un diffuso smantellamento e abbandono delle preesistenti strutture portuali. Nei casi in cui, invece, le aree portuali hanno mantenuto la loro posizione originale, il paesaggio è stato trasformato sensibilmente al fine di ospitare navi sempre più grandi, di fatto producendo impatti significativi sul patrimonio storico, in termini di obsolescenza materica, tecnologica e funzionale. Inoltre, porto e città risultano essere aree completamente separati, gestite ed amministrate come sistemi territoriali differenti. Negli ultimi decenni, inoltre, la concentrazione di attività sempre più dirette verso la produzione industriale ed energetica nelle aree portuali ha contribuito al deterioramento delle condizioni ambientali nelle quali sia il centro urbano che il patrimonio storico portuale risiedono. Oltre agli effetti ambientali (o stazionari), le attività portuali possono generare impatti eccezionali, comunemente noti come "Major Accidents": si tratta di esplosioni, incendi e emissione di agenti chimici, capaci di produrre effetti severi sul patrimonio storico, potenzialmente in grado di distruggerlo. Il relazione agli aspetti descritti, la conservazione e la valorizzazione degli edifici e delle aree storiche in ambito portuale è attualmente un processo molto complesso e critico, anche in termini di gestione del sistema urbano-portuale. La riqualificazione e la valorizzazione delle aree portuali storiche, così come la definizione di un modello di sviluppo integrato, rappresentano opportunità importanti per le città costiere.

Nell'ambito del suddetto contesto di ricerca, la presente tesi di dottorato mira a definire una metodologia per l'identificazione dei rischi – intesi come possibile perdita di valori materici, artistici, storici e culturali – ai quali i patrimonio storico dei porti è soggetto, al fine di individuare opportune linee guida e strategie per la sua conservazione e valorizzazione, inclusa l'integrazione del sistema urbano-portuale.
La prima parte della tesi analizza il patrimonio architettonico dei più significativi porti del Mediterraneo al fine di costruire un quadro conoscitivo per la classificazione e qualificazione del patrimonio marittimo e portuale, oltre che per comprendere le dinamiche

che hanno portato alla trasformazione delle città portuali nel corso dei secoli. In particolar modo, viene analizzata l'evoluzione storico-morfologica dei porti del Mare Nostrum nel capitolo primo, identificandone le relazioni con i centri urbani nei differenti periodi storici e in contesti geografici differenti e descrivendone dimensioni, forma e numero dei bacini portuali, funzioni e morfologia. Inoltre, specifiche categorie di patrimonio storico portuale sono definite, sulla base delle caratteristiche architettoniche, materiche e funzionali.
La seconda sezione della tesi si focalizza sulla definizione della metodologia per l'identificazione e stima dei fattori di rischio che caratterizzano il patrimonio portuale. Il rischio viene valutato attraverso la stima della vulnerabilità del patrimonio storico e della pericolosità prodotto dalle attività portuali, sia come impatto stazionario che eccezionale. Il capitolo terzo della tesi, a partire dallo stato dell'arte di definizioni e metodologie principali, propone un metodo semplificato per valutare la vulnerabilità del siti culturali nei porti, considerata come somma di tre contributi significativi: vulnerabilità materica, funzionale e culturale. La valutazione viene effettuate mediante specifiche schede compilative, definite per ogni categoria di patrimonio portuale.
Successivamente, nei capitoli quarto e quinto del lavoro di ricerca, il concetto di pericolosità, ossia di impatto delle attività portuali sul patrimonio storico, è discusso, identificando metodi per la sua valutazione. La pericolosità viene considerata in due tipologie: impatto stazionario ed accidentale. Gli impatti stazionari coincidono con le conseguenze ambientali che vengono prodotte in maniera continua nei porti, come le emissioni in aria, acqua e suolo. I principali effetti di tali aspetti ambientali sono analizzati al fine di poterli stimare. Si tratta di impatti su materiali, su uso e funzione e sui valori paesaggistici del patrimonio storico portuale. Quelli eccezionali, invece, sono impatti che potenzialmente possono essere prodotti da incidenti e disastri nei porti: esplosioni e incendi, causati da materiali pericolosi a seguito di collisioni tra navi o mezzi, di operazioni di carico/carico o stoccaggio. Una metodologia per la stima delle frequenze di accadimento di tali incidenti e dei loro effetti sui siti storici portuali viene esposta con particolare attenzione al caso delle esplosioni.

La classificazione del patrimonio storico e la definizione di una metodologia per la valutazione del rischio ha come principale obiettivo quello di definire linee guida e strategie per uno sviluppo integrato dei sistemi porto-città, con particolare attenzione alla conservazione e valorizzazione del patrimonio culturale dei porti e alla mitigazione dei rischi. A partire da un'analisi storica dei principali interventi realizzati nelle città portuali negli ultimi decenni, specifiche strategie per la conservazione e per uno sviluppo sostenibile dei porti storici sono identificate e descritte. I principali obiettivi coincidono con la conservazione, la tutela, la valorizzazione, la diffusione dei valori storico-culturali, la riqualificazione territoriale, la riduzione dei rischi e, infine, la gestione sostenibile ed integrata. In fine, la metodologia di ricerca è stata applicata ad un caso di studio, il porto di Brindisi situato in Puglia, a Sud-Est della penisola italiana. La scelta del presente caso è spiegata dal fatto che nel porto brindisino attività industriali, produttive, mercantili e logistiche sono molte vicine ed interfacciate con area urbana e Beni culturali portuali. Descritta l'evoluzione storica del porto e le sue caratteristiche principali, la valutazione di vulnerabilità viene eseguita sui siti storici del porto, rivelando che la maggior parte di essi sono attualmente compromessi. Comparando le vulnerabilità con l'analisi degli impatti stazionari e accidentali, si evince che nel porto di Brindisi vi sono importanti siti storico-culturali seriamente minacciati. Nell'ottica di una riduzione dei rischi e di uno sviluppo sostenibile del porto pugliese, uno scenario strategico viene proposto e descritto: la costituzione di un "Parco Storico del Porto di Brindisi". Le principali strategie di intervento identificate riguardano la riqualificazione degli ambiti territoriali del porto e la riduzione dei rischio e degli impatti, che dovrebbero essere prioritari per la conservazione del paesaggi portuale. Inoltre, attraverso una gestione mista ed integrata tra enti territoriali e stakeholders, i principali obiettivi del sistema città-porto dovrebbero considerare la conservazione e la valorizzazione del patrimonio culturale e storico una sfida ed una opportunità.

key words

porti storici del Mediterraneo; patrimonio architettonico portuale; valutazione del rischio; conservazione e valorizzazione.

Contents

Chapter 7

Introduction

Nowadays, Mediterranean port areas with historical and cultural interest could be considered as “landscapes at risk”. In effect, modern ports are very sensible environments where industrial, mercantile, military activities, among the others, interfere with urban settlements, natural and cultural landscapes. In those contexts, natural and cultural components should be affected by impacts, producing a somewhat state of threat.

The historical value of ports is ascertained and widespread in Mediterranean area, where the historical and cultural component has a higher relevance than in other international cases. Since ancient times, they were the centres of civilization and commercial traffics. In fact, it is very common the discovery of archaeological sites in port context or in maritime areas close to them. They are remains of ancient docks and quays, or rests of warehouses and other facilities. Some important examples are the sites of Leptis Magna in Libya and the port of Claudius and Trajan near Rome, at Fiumicino. Besides the ancient structures, ports are characterized by the presence of a very large variety of buildings, facilities, spaces and areas, with a potential historical and cultural value. Examples of industrial archaeology are located in several Mediterranean ports, as in Marseille, Brindisi, Genoa and Trieste. Other typologies of historical heritages of port areas are related to the commercial vocation, as palaces for merchants, for goods storing, for trade and negotiations. Referring to the military and defensive system, which characterized port-city during the centuries, maritime arsenals with castles and fortresses represents examples of other port architectures with cultural properties. Navigation and shipping, as main activities in ports, concerns logistic areas and facilities, as docks, quays, lighthouses, customhouses and offices. Other cultural assets of ports can be religion and sacred architectures (cathedrals and monasteries) and, finally, residential areas (waterfronts, fishing districts, historical centres).

These historical buildings and spaces, located within the port areas, since the last decades have been highly compromised and threatened by the effects of port activities and transformations: the visible consequences are represented by material decay and damage, losses of cultural identity and significance, decreasing of historical authenticity and deterioration of the overall natural and historical landscape, which is considered as a unique testimony of Mediterranean culture. In addition to this, modern port contexts in most cases result separated and isolated from the city and the surrounding territory, producing territorial fragmentation, inaccessibility and disuse.

Since XIX century, in order to house the new modern facilities, ships and activities, the original basin of ports has been transformed, modernized and enlarged, generating impacts on built heritage and changing significantly their relationship with the urban zone and the historical sites. In other several cases, the ancient site was not appropriate and the activities were settled in the suburb areas, leading to the abandonment of historical facilities and spaces. Furthermore, the concentration of activities increasingly directed towards industrial and energetic production in the port areas has contributed to deteriorate the environmental conditions.

In relation to the abovementioned aspects, it becomes necessary to protect the port landscape, to recognize and prevent risks (e.g. potential losses of historical, material and cultural values) affecting the port heritage, in order to develop sustainably port activities, respecting and enhancing all the components, from the economic to the environmental, social and cultural field, in continuity of EU2020 goals.
Thus, the current research thesis aims to define a methodological process for the identification of the risk factors affecting historical and cultural heritages in Mediterranean port contexts, in order to individuate guidelines and strategies for an “integrated” development of historical ports, with particular attention to the preservation and enhancement of historical and cultural landscape. Firstly, the research analyses the historical and morphological evolutions of the most significant Mediterranean port cities, focusing on the classification of architectural heritage and identification of the main techniques of construction of port infrastructures. Secondly, the main risk factors affecting historical landscape in ports are identified and analysed. The risk assessment is carried out through the definition of a simplified method for the evaluation of heritage vulnerability, on the one hand. On the other one, the main impacts of port activities on heritage, e.g. hazards, are described considering two typologies: stationary and exceptional impacts. Subsequently, starting from the cataloguing of heritage and the risk assessment methodology, strategies and guidelines for preservation and enhancement, as well as for port-city “integrated” development, are explained.
Finally, the overall methodology is applied and experimented on a given case, the historical port of Brindisi (Apulia, South-East of Italy), is described and discussed. The methodology proposed for this given case aims to demonstrate that in historical port areas, such as in Mediterranean Sea, the development and management should be accompanied or even oriented to the protection of the historical and cultural landscape, as main testimony of history and culture of the *mare nostrum* civilizations.

Chapter 1

Morphological and typological assessment of architectural heritage in historical Mediterranean ports

In the first step, the research discusses and describes the morphological and typological assessment of the architectural heritage of the most significant historic ports in the Mediterranean Sea. The aim is to create a knowledge framework in order to identify and classify maritime heritage and to understand the dynamics that lead to the ports transformations.

The assessment methodology is structured on three levels of investigation: morphology, architectural heritage and techniques construction of port structures.

In the *morphology assessment,* historical ports are analysed in terms of typology, number, dimension and shape of basins, function, morphology, and relationship with the urban area. *Architectural heritage* is described and classified in terms of typology, function and architecture, in relation to the geographical and historical context. Finally, the

construction techniques of port structures, such as piers and docks, are identified and analysed.
These levels of analysis refer to specific historical periods of ports evolution, identified comparing buildings technologies, innovations in the naval and urban field. Particularly: *ancient ports* (until the V century), *medieval and architectural ports* (between the VI and the XVIII centuries), *modern and technological ports* (since XIX century).

1.1 Ancient ports

1.1.1 Morphology

In ancient times, ports were settled in natural basins or bays where ships could be repaired and replenished. Pre-Roman ports, called *proto-ports*, were mostly natural harbours where the morphology depended strictly on ships security and protection. Phoenician ports were built with rocks overlapped to form vertical walls, filled with assorted materials inside them and without mortars. In the VI-VIII century BC, Etruscan started to build new ports, subsequently modified and enlarged by Romans.
The first artificial ports were built during the Roman Empire when the construction techniques of piers and quays was improved with the introduction of new materials, such as *opus cementicium* and *pozzolan*. Therefore, it was possible to realize port infrastructure regardless of the natural conditions of the site (Franco, 2006).
Morphologically, two sort of ports can be identified: river ports and seaports. In the first case, ports did not have the presence of docks and piers. In fact, the linear morphology of the river allowed the construction of quays and moorings on both sides, along which port structure and infrastructure were placed, such as the river port of Ostia (Figure 1.1), a maritime colony of Rome. It was located on the mouth of the *Tevere* and was the main port until the erection of the port of Pozzuoli (Figure 1.2).
Instead, piers - often fortified - quays and basins characterized seaports, as in Cesarea Maritima (Figure 1.3). Functionally, seaports had more basins, used for military or commercial functions. The inner basins could be circular, such as in Carthage (Figure 1.4), or hexagonal, as in Portus (Figure 1.5). Here, the main activities of the port took place: repair and construction of ships or loading and unloading of goods, for example. The

function of outer basins, however, was mostly related to the shelter of ships and fleets. The commercial organization of Rome provided several ports located along coasts and rivers immediately near the city. The goods were unloaded in seaports (through *naves onerariae*) and then moved to Rome, for inland waterways, at the Emporium (through *naves caudicariae*).

The main commercial seaports of Rome were *Puteoli* (Pozzuoli) and *Portus*, the port of Claudius and Trajan, while the principal river port was Ostia. Other ports near Rome (Anser Research Project: "Anciennes Routes Maritimes Mediterranennes" - I porti antichi del Lazio, 2003) were *Portus Cosanus* (Ansedonia), *Antium* (Anzio), *Centumcellae* (Civitavecchia), *Portus Misenum* (Miseno), *Torre Astura, Gravisca* and *Mandataria* (Ventotene). *Portus Cosanus*, which was one of the first ports of the Empire, represents a transition from the natural harbours to the artificial. In fact, it was located on a lagoon, linked to the open sea through a canal, excavated in the rock and protected by a stone breakwater, actually submerged (Franco, 2006). The port of *Misenum*, located on the West part of *Puteoli* bay, was one of the main military ports of Rome in the Augustan age. In effect, the roman fleet "*Classis Preatoria Misenensis*" used to stop in this large basin, until to fall of the empire.

The seaport of *Portus*, today in the archaeological site of Fiumicino, had two large curvilinear piers at the end of which was placed a monumental lighthouse. The inner basin was dug in the mainland, under Trajan. It was very similar to the *cothon*, characteristic basin of the Punic ports. In the ancient Carthage (Franco, 1996) (www.ancient.eu/carthage/, 2016), today a suburb area of Tunis, the function of the *cothon* was mainly military and had a circular shape with a radius of 300 meters with an island in the centre, where ships moored. The outer basin, instead, housed the commercial activities and had a rectangular form: 20 meters per 600 meters. The two basins were connected through a canal, and located in the proximity of the city.

Another important ancient port was *Leptis Magna*, in Libya. This roman seaport had one circular basin, in which all the main activities of the city took place. It was protected by two large piers, one of which with a lighthouse, and had a surface of 100.000 sq. m. (Report "World Heritage of the Archaeological Site of Leptis Magna", 1982). One of the biggest ports in the Mediterranean context, in ancient times, was *Alexandria* (Figure 1.6), in Egypt. The city had defensive wall 15 km long and the port was structured in two basins, divided by a big dam called *Eptastadium*, which connected the land to the island where the famous lighthouse took place.

1.1.2 Architectural heritage

Port facilities, in ancient time, were primarily related to the commercial and military activities (Table 1.1). The river port of Ostia has been identified as a commercial area because of the presence of archaeological remains of warehouses, called in Latin *horreum* (Anser Research Project: "Anciennes Routes Maritimes Mediterranennes" - I porti antichi del Lazio, 2003)(Simoncini, 1993), such as the *Horrea Epagathiana* (Figure 1.7) in Ostian port. These buildings had a series of stores arranged side by side on the port quays, or along the piers, as in the Roman port of *Cesarea Marittima* (Franco, 1996) in the Lebanon coasts, or in the port of *Leptis Magna* (Pucci, 2011). In fact, the progress of Roman construction techniques allowed the realization of buildings on large piers.
In Rome, the main warehouse was the *Porticus AEmilia*: the remains, nowadays in *Testaccio* district, show a building made of *opus cementicium* and bricks, 487 meters long and 60 meters large (Ministero per i Beni e le Attività Culturali - Soprintendenza per i Beni archeologici di Roma, 2015). This building was located on the docks of the Rome emporium and housed all the goods coming from *Ostia, Portus, Puteoli*.
The warehouses of Trajan (Figure 1.8) in Portus had colonnades and corridors for the distribution of goods. They communicated with the quays, where mooring bollards and ladders for the access on ships (Figure 1.9) were located (Ministero per i Beni e le Attività Culturali - Soprintendenza per i Beni archeologici di Ostia, 2015). Other buildings and spaces with commercial vocation were markets and squares, as the Court of Corporations, in Ostia site. Ship owners, merchants and officials traded goods in the arcaded square, with more of 60 stores around it.
Ancient ports also had workshops, fishpond, port offices, lighthouses, tanks, aqueducts, fortifications and in some cases thermal buildings, imperial palaces and temples, when the port had public relevance (Anser Research Project: "Anciennes Routes

Maritimes Mediterranenennes" - I porti antichi del Lazio, 2003). Furthermore, arsenals were specific military buildings for the construction and repair of fleets.

In Carthage *cothon*, there was an important military building, called Admiralty Palace (Figure 1.10). Based on the reconstruction made (Franco, 1996) the building had a monumental aspect, with large colonnades, stores and shipyards. It could house 200 ships. The Punic port, partially excavated in the coast, was protected by high walls, such as in the island of *S. Pantaleo*, near *Marsala* in Sicily.

1.1.3 Techniques construction of port structures

The main reference that can provide principles on the construction techniques of maritime works in the classical era is the *De Architectura* (Vitruvius, 2011), by Vitruvius, dated in 27-25 BC. In the chapter "*public works*", he describes three techniques for the construction of piers and moles (Figure 1.11, Figure 1.12 and Figure 1.13): with flooded or watertight formwork and with prefabricated blocks. The first technique (Figure 1.14, Figure 1.15) involved the use of *pozzolan* and, then, could be made in water. The formwork was made of caissons (*arcae*) of wood planks tied (by *catenae*) to pales (*pilae*) driven into the fund. Concrete and aggregates were thrown in that formwork. At the external side of the pier, stone blocks protected the structure from the waves. This technique was the most widespread, such as in the port of *Antium, Portus* and *Cesarea Marittima*. When there was not *pozzolan* near the site, Vitruvius suggested the use of watertight formwork (Figure 1.16), from which the water was extracted. This technique is likely to have been used to build *opus-pilarum* piers, such as in the port of Pozzuoli, whose piers were studied for centuries (Simoncini, 1993) (Salvatori, 2008). This typology of pier was made of pillar connected by arches. The first and second technique could be used both, in mixed piers, such as in *Portus Cosanus* and *Torre Astura* (Franco, 2006). The third method provided the use of blocks thrown in the sea, whenever it was very stormy. The Hellenic method of piers construction, used for *Leptis Magna* port, instead, used regular stone blocks overlapped without mortars.

<table>
<tr><th>Port</th><th>Basins</th><th>Area or length</th><th>Port Functions</th><th>Typology</th><th>Port Spaces and Buildings</th></tr>
<tr><td>Emporium (Rome)</td><td>Fluvial</td><td>about 2 km</td><td rowspan="8">Commercial</td><td rowspan="11">Port-satellite of Rome</td><td rowspan="8">Piers, quays
horrea (warehouses)
tabernae (workshops)
emporium, arcade, corporations square, market, fishpond,
tanks, aqueducts,
lighthouse</td></tr>
<tr><td>Ostia</td><td>Fluvial</td><td>about 1,5 km</td></tr>
<tr><td>Antium</td><td rowspan="5">1</td><td>250.000m^2</td></tr>
<tr><td>Torre Astura</td><td>15.000m^2</td></tr>
<tr><td>Gravisca</td><td>-</td></tr>
<tr><td>Ansedonia</td><td>-</td></tr>
<tr><td>Mandataria</td><td>11.000m^2</td></tr>
<tr><td>Centumcellae</td><td>2</td><td>150.000m^2</td></tr>
<tr><td>Misenum</td><td>2</td><td>1.000.000 m^2</td><td>Military</td><td>Arsenal, shipyards, tanks</td></tr>
<tr><td>Puteoli</td><td>2</td><td>500.000m^2</td><td rowspan="2">Commercial
Military</td><td rowspan="2">Piers, quays
horrea (warehouses)
tabernae (workshops)
arcade, square,
market, forum,
harbour office,
arsenal, shipyards,
tanks, aqueducts,
lighthouse,
fortifications,
inner basins,
imperial palace,
temples</td></tr>
<tr><td>Portus Claudius Trajanus</td><td>2</td><td>1.500.000 m^2</td></tr>
<tr><td>Cesarea Maritima</td><td>1</td><td>150.000m^2</td><td rowspan="4">Commercial
Military</td><td rowspan="4">Port-city</td><td rowspan="3">Piers with horrea,
tabernae,
fortifications, quays,
lighthouse, square,
arcade, aqueduct,</td></tr>
<tr><td>Alexandria</td><td>2</td><td>4.000.000 m^2</td></tr>
<tr><td>Leptis Magna</td><td>1</td><td>120.000m^2</td></tr>
<tr><td>Carthage</td><td>2</td><td>150.000m^2</td><td>Cothon,
admiralty island, piers
quays,
fortifications,
warehouses, arsenal</td></tr>
</table>

Table 1.1 Assessment of ancient ports until Vth century

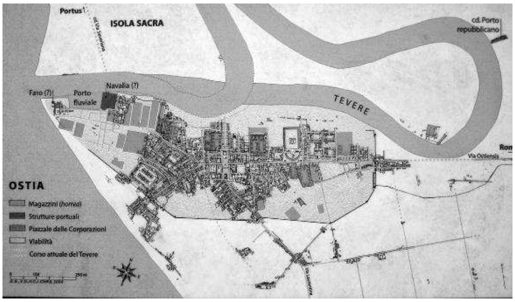


Figure 1.1 Reconstructions of the river port of Ostia (www.wikimediafoundation.org)

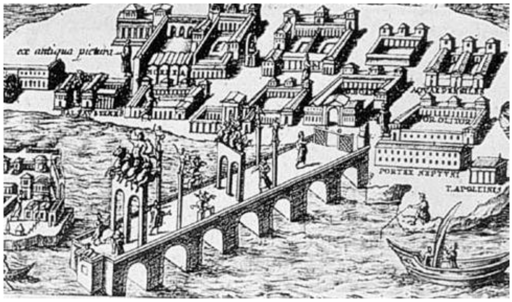


Figure 1.2 Reconstruction of the pier with pillars and arches in Pozzuoli (www.comune.pozzuoli.na.it)

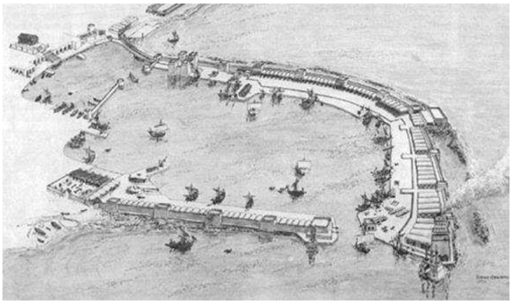


Figure 1.3 Reconstructions of Cesarea Maritima port (Franco, 1996)

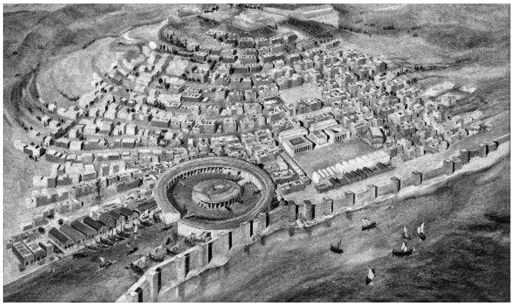


Figure 1.4 Reconstruction of the ancient Carthage (www.ancientimes.blogspot.com, Carthage Archaeological Museum)

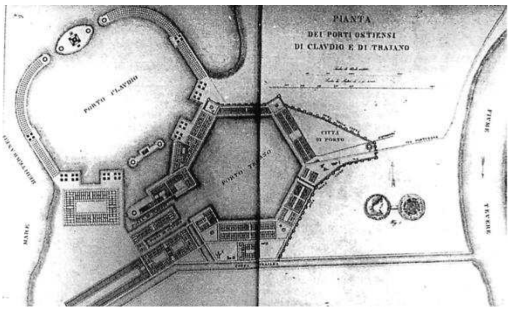


Figure 1.5 Reconstruction plan of Portus Claudius Trajanus (Simoncini, 1993)

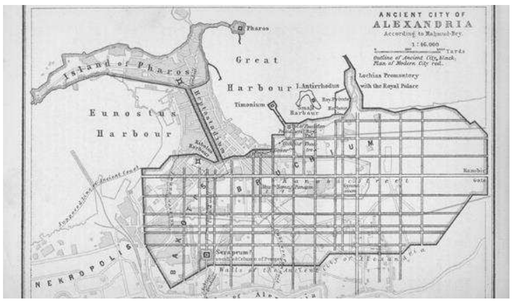


Figure 1.6 Plan of the ancient Alexandria, Egypt (Baedeker, Karl. "Egypt, handbook for travellers. pt. 1. Lower Egypt, with the Fayum and the peninsula of Sinai")

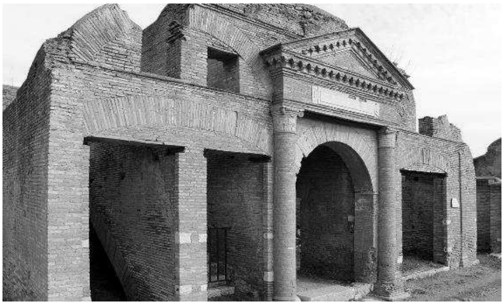


Figure 1.7 Horrea Epagathiana in ancient Ostian site (http://www.ia-ostiaantica.org/news/horrea-epagathiana-et-epaphroditiana/)

Figure 1.8 the remains of warehouses on the docks of the Trajan basin (www.google.map.it)

Figure 1.9 Remains of docks in Trajan port (http://www2.rgzm.de/Navis2/Home/FramesIT.cfm)

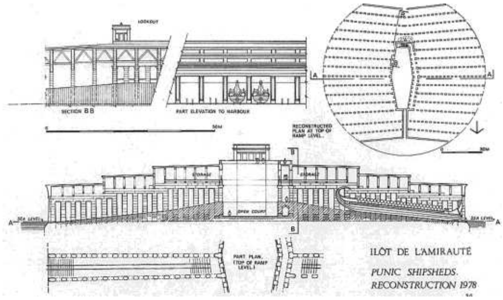


Figure 1.10 Reconstruction of the Admirality Palace in Carthage ancient port (Franco, 1996)

Figure 1.11 The remains of a pier and of wareouses in Leptis Magna port (www.livius.org)

Figure 1.12 Remains of a pier in the port of Leptis Magna (www.telegraph.co.uk)

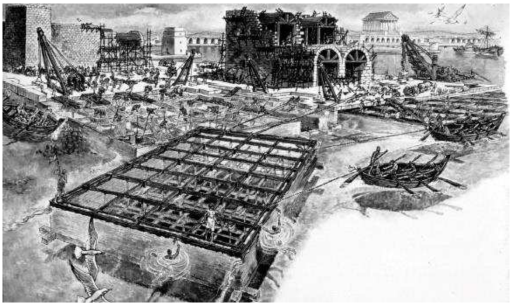
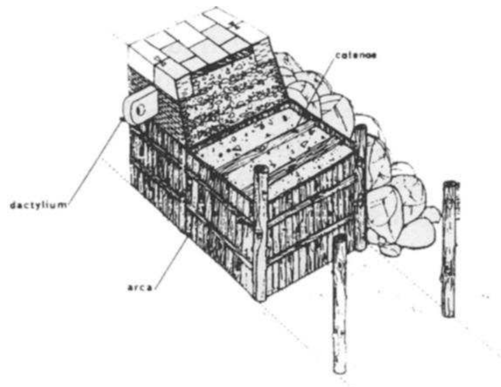


Figure 1.13 The pier of the Claudius port (http://www2.rgzm.de/Navis2/Home/Frame-sIT.cfm)

Figure 1.14 Representation of the methodology of construction of ancient port docks (Source: Franco, 1996)



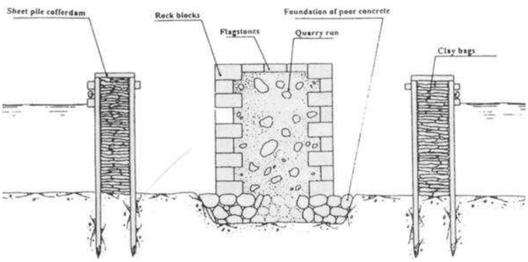


Figure 1.15 The methods of flooded formwork for piers construction (Source: Franco, 1996)

Figure 1.16 The methods of watertight formwork for piers construction (Source: Franco, 1996)

1.2 Medieval and architectural ports

1.2.1 Morphology

From the Middle-Age to Renaissance, two main trends can be identified in the design of port structures and in the relationship between city and port.
Firstly, during the XV century, the design approach of the ports became theoretical and architectural. Architects and theorists, such as L. B. Alberti and F. di Giorgio Martini, debated on the shape of the basins, the construction techniques and the wave movement, creating various treaties and studies.
The models were the Roman ports. In fact, Roman port facilities were studied through the Vitruvian Treaty and direct surveys. Particularly, Francesco di Giorgio Martini defined acceptable an access of the ports of 60-75 meters, as well as in the same area proposed to build fortress and towers to protect the port. The same theory was supported by Leonardo da Vinci and Giuliano da Sangallo (Simoncini, 1993). Architects thought that the circular and semi-circular basins were the best shape for ports, for the capacity and security.
Secondly, Mediterranean port cities were fortified because of the frequent Saracen raids on the west coasts. The centralized system of Rome and its satellite ports was replaced by isolated port cities within commercial traffics that crossed the whole Mediterranean, from East to West: the *emporium* cities. The main western ports of Mediterranean were Venice, Marseille, Genoa and Naples, who exchanged goods and products with the emporium of Acre, Istanbul, Aleppo, Damascus and Cairo, which were the last destinations of caravan routes.
Between IX and XV centuries, port cities were fortified with walls, towers and bastions, both on the seaside that on landside. Particularly, the ports of Naples (Figure 1.17), Barcelona (Figure 1.18) and Genoa (Figure 1.19) were protected by great maritime walls, as well as in the oriental emporium, massive fortifications were erected on the land front. Even the piers of the ports were fortified with high walls, leading to the displacement of the facilities towards the inner basins and giving them a more urban function and aspect.

The model of the *emporium* had five characteristic elements: access roads, defensive and military architecture, commercial building and spaces (Table 1. 2).

1.2.2 Architectural heritage

The emporium-city was placed in strategic points of the Mediterranean Sea. Port and urban functions were closely linked. In effect, new districts of merchants arose in the port of Naples, Genoa and Venice. These areas were located near the port, isolated and protected from the rest of the city. In Naples, the two main basin of the port were denominated Pisan and Genoese ports, where their merchants traded and stored goods. Genoa, instead, was colonized by Saracens, Orientals and Jews.

At the same time, Venetian and Genoese merchants resided in Acre (Kesten, 1993), Istanbul, Damascus and other oriental port cities (Fallanca De Blasio & Nazer Eslami, 2003) (Colletta, 2012). To confirm it, for instance, the Oriental city of Acre, between the XI and the XIII centuries, was divided in four main districts: the area of Genoese merchants, the Venetian, the Pisan and the crusaders one.

Moreover, in ports there were specific buildings and spaces for trade located on the docks, near the ships mooring. Particularly, the functions of storing and sorting of goods of the Greek *aphoteke*, the Byzantine *mitation* and the Roman *horreum* evolved in a new typology of port facility, used also for the rest of merchants and business negotiations. In Middle-Eastern cities, they were known as *karvansaray, hān* or *khan* (Concina, 1997) and date since the VIII century. These architectural complexes, with oriental origins, could be suburban or urban. In the first case, these buildings were located in the middle of commercial ways and had only the function of housing the merchants in their travel. Differently, the urban ones had also the function of place where storing and trading goods, because they represented the end of a maritime or caravan traffic. Thus, they were more complex structures located near the port or their boundaries. The *hān* had a central courtyard with arcades (Figure 1.20, Figure 1.21), where merchants stopped. Around the court, on the ground floor, there were warehouses and workshops. The upper floor was destined to the merchant apartments. The strategic role of these buildings often led to their fortifications, as the *Qasr* (Figure 1.22,

Figure 1.23), fortress widespread in Jordan (Urice, 1987), or *Ribat* (Figure 1.24), fortified outposts in North Africa. Other typology similar to the urban caravanserai was the *funduq* of the Maghreb, as in Tripoli, Algiers, Tunis and Cairo, where it was also called *wakala* (Figure 1.25), *dar* or *oukala* (Fallanca De Blasio & Nazer Eslami, 2003).
In Italian ports, it is worth to mention Venetian *fontego*, (Concina, 1997), built in XIII-XVI centuries. In the *Fondacus farinarius*, near Rialto Bridge, grain and cereals were stored and controlled. On the two sides of the building, structured in two levels, there were workshops, while in the front the dock for the mooring of the ships and for the loading/unloading of grain. The *Fontego de' Tedeschi* (Figure 1.26, Figure 1.27) is known since XIII century, but rebuilt in the XVI. It housed German merchants and their goods, and represented one of the main trade centres in the lagoon. It had around a central court with workshops, as the oriental khan, and a monumental facade. The *Fontego de'* Turchi had similar structure, plan and organization: storages, workshops, apartments, services and a *masgid*, religious space. In the Andalusian Peninsula, a commercial building, *Corral de Carbon* (Figure 1.28), was known as *Al-funduq al-Gidida* during the Arab domination in Granada. In Genoa, near the port, the presence of *stationes* and *hospitia* is witnessed by several sources (Poleggi & Cevini, 2003). They were similar to *karvansaray*, places where merchants stored and traded goods. In Barcelona, instead, there was a grain store called *Pallols* and a wide building used for business and trade, called *Llonja* (Figure 1.29)(Poleggi, 1989).
In Marseille, warehouses and merchants districts were located in the lower part of the city, on the *vieux port*, and they were known as *entrepot*. During the XVI century, these buildings were replaced by large architectural complexes: the *domaine*. In these palaces, merchants accumulated and deposited goods. Particle fractionation, dimension and facades were still similar to the urban fabric (Borruey, 1992). Other typology of port facility was the *lodge*, present in Naples (De Seta, 1991) and Barcelona (Museo Maritimo de Barcelona, 2016): an arcaded building where traders met and traded, as in the Neapolitan *Loggia dei Marsigliesi*.
These buildings were part of a complex urban area devoted to trade, known in Middle-East and North Africa as *souk, suk*, or *suq*, and in Anatolia as *çarçi* (Fallanca De Blasio

& Nazer Eslami, 2003). They were large commercial markets, with an urban dimension: narrow and vault-covered streets, with stores and workshops, ended in centralities, such as a caravanserai or a mosque. In Istanbul, the main commercial facility was the *çarçi*, such as the *Grand Bazar*, with 20.000 square meters of architectural structures, covered streets, urban caravanserai, as the *Eski Bedesten:* built in the XV century, it could count 124 shops inside and 72 outside. The central court was covered by 15 domes and 8 pillars. Urban structure similar to the oriental *suq* was the *Ripa Maris*, built in XII century in Genoa. It was a curtain of buildings (Figure 1.30) placed along the waterfront, about 900 meters long. It was organized in several floors (Figure 1.31, Figure 1.32): within the maritime walls, there was a narrow walkway whit warehouses on the sides; inside the curtain, there was the "*Sottoripa*" portico with merchant shops; on the upper floors, there were the apartment of merchants and nobles (Fallanca De Blasio & Nazer Eslami, 2003) (Poleggi & Cevini, 2003).

Ports had also military function, during this historical period. The major port cities built their fleets in shipyards and arsenals, known as *arsana* in Venice (Concina, 1988), *atarazanas* and *reials drassanes* in Barcelona, *tercenaux* or *arsenaux des galares* in Marseille. Arsenals were organized in one or more basins, for ship rest and repair. The Venetian Arsenal (Figure 1.33) was built in the early XIII century and expanded later in the XV. It could count of three docks: Canal of Old Arsenal (1206-1224), *Novo* Arsenal (1300-1450) and *Novissima Grande* Arsenal (1470-1510). Warehouses, called *magazzeni* or *squeri*, were built for the construction and repair of ships, which were also prepared for shipping, with weaponry and crews. Arsenals factories were organized according to the function and activity. The *Arsenal de Galeres* (Figure 1.34) was built under Louis XIV on the south shores of the *vieux port* of Marseille and had three functions: the rest, the repairing and the construction of the fleet. It was organized in secondary canals with warehouses. Subsequently, at the end of XVIII century it was decommissioned and substituted by a new urban area. The arsenal in Barcelona (Figure 1.35) were located on the west boundary of the *ciutadal*, while the commercial docks placed in the East part. In Naples, instead of Barcelona and Marseille, the arsenal had its own basin, protected by piers and walls (Figure 1.36). Furthermore, in Crete, venetian arsenals were built in the port of Candia and Chania: built in the crusade period, they were the most important shipyards in the East Mediterranean, before the Ottoman conquest (Concina, 1997).

1.2.3 Techniques construction of port structures

Roman construction techniques remained the current practise for centuries. Particularly, the study of ports and maritime facilities became important again in the XI century, because of the Saracen raids in Mediterranean Sea. The main innovation was the design and construction of new mechanical dredges and crane for materials movement. About in XVII century, the current techniques were mainly two: breakwater jetty or the vertical wall. In fact, after the restoration of the Port of Civitavecchia, it was preferred the first method: a jetty breakwater with a concrete superstructure. In Genoa, in 1638, De Mari designed a mixed pier, with a cliff foundation and a concrete structure above. Also in Venice a new pier was designed by the mathematician Zendrini: the Venetian Murazzi was a coating of stone blocks with an overall thickness of 12 meters (Franco, 2006). The docks were built upper than the sea level, in order to facilitate the loading/unloading of goods from the ships. In addition to these techniques, the opus-pilarum methodology continued to be studied in these centuries.

City	Access route	Defensive elements	Commercial and Port Buildings	Commercial and Port Areas
Marseille	Maritime	Fortification, walls, arsenal	Warehouse, entrepot, domaine	Square, piers merchants districts
Genoa	Maritime	Fortifications, maritime walls, arsenal	Stationes, hospitia, customhouse, lodges, warehouse, lighthouse	Ripa Maris, market, square, piers merchants districts
Naples	Maritime		Lodge, fondaci, warehouse, lighthouse	Square, piers merchants districts
Venice	Maritime	Fortification, arsenal	Fondaci, warehouse, officials palaces	
Granada	Caravan routes	Fortification, castle	Alhòndiga, funduq	Suq
Barcelona	Maritime	Fortifications, maritime walls, arsenal	Llotja, lonja, pallols, lighthouse	Square, piers
Crete			Warehouse	
Acre			karvansaray, hān, khan, fondaci, lighthouse	Bazar, suq, merchants districts
Istanbul	Maritime, Caravan routes		Bedesten, khan, hān, lighthouse	Bazar, çarçi, suq, merchants districts
Cairo, Tripoli, Tunis, Algiers, Alexandria	Maritime, Caravan routes	Fortifications, walls	Wakala, hān, khan, funduq, qaisariyya	Suq, merchants districts
Damascus, Aleppo, Bursa	Caravan routes		karvansaray, hān, khan	

Table 1. 2 Assessment of Medieval and architectural ports

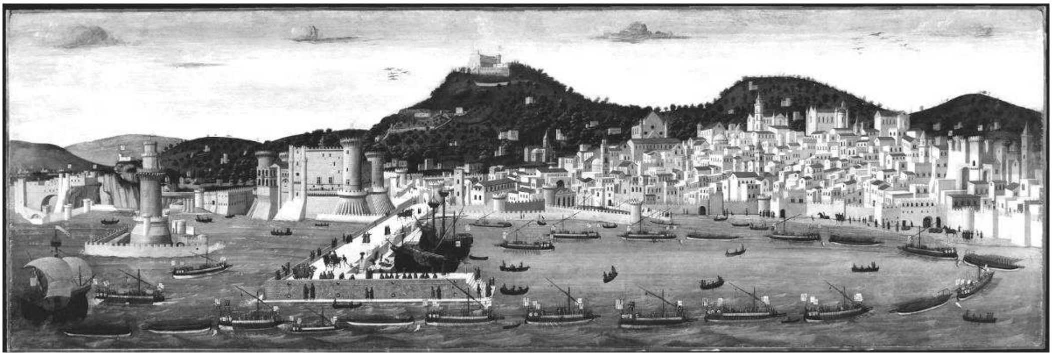


Figure 1.17 "Tavola Strozzi", oil painting with the reconstruction of Naples in the 1472 (www.tavolastrozzi.it)

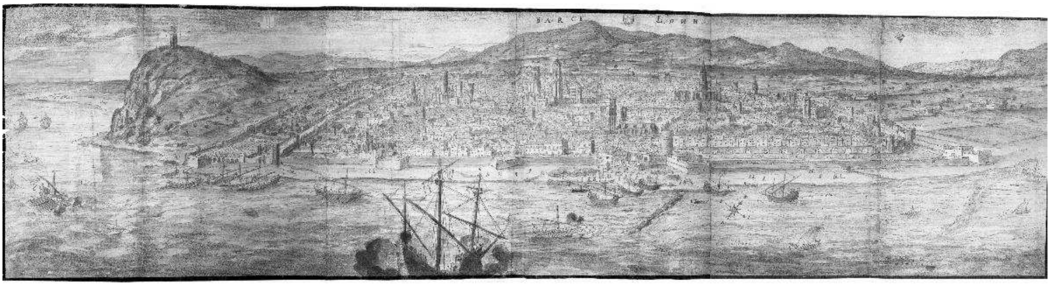


Figure 1.18 A picture of Barcelona in 1563, by A. van den Wyngaerde (Museu d'historia de Barcelona)

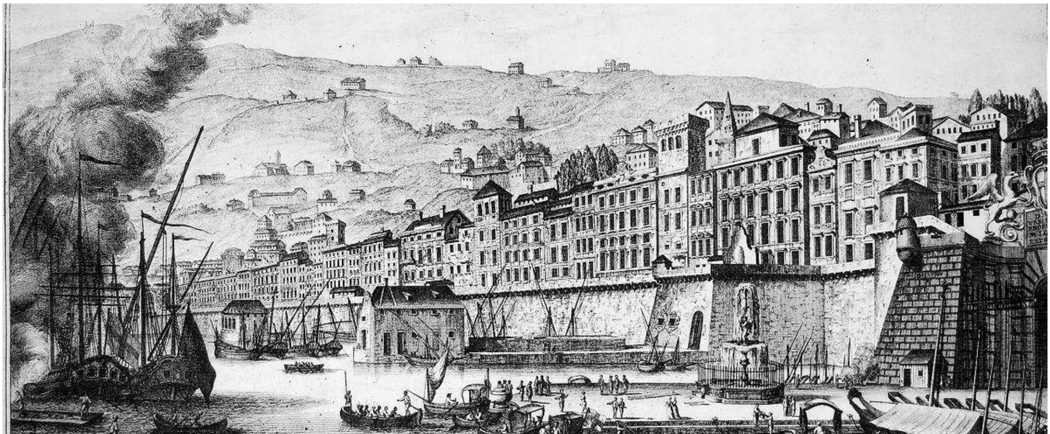


Figure 1.19 A picture of Genoa in the XVIII century (www.docsai.museidigenova.it)

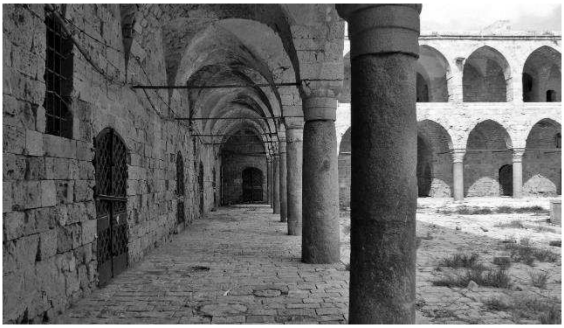


Figure 1.20 The courtyard with arcades of the Khan Al-Umdan in Acre (Report for the nomination of the OLD CITY of ACRE for the World Heritage List, 2001)

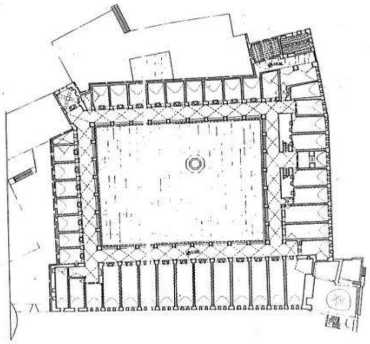


Figure 1.21 Plan of the Khan Al-Umdan in Acre (Report for the nomination of the OLD CITY of ACRE for the World Heritage List, 2001)

Figure 1.22 The fortified Qasr Haraneh, in Jordan (Source: Urice, 1987)

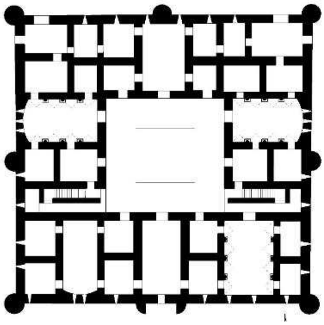


Figure 1.23 Plan of the Qasr Haraneh in Jordan (Source: Urice, 1987)

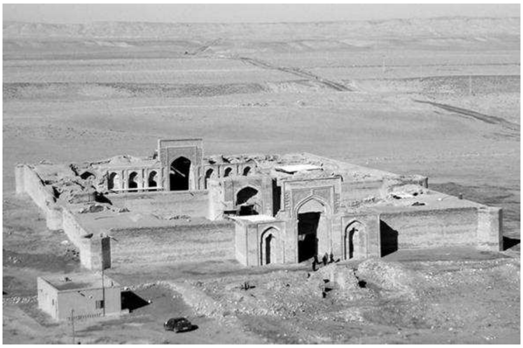


Figure 1.24 The Ribat Sharaf, a fortified outpost in Iran (www.archnet.org)

Figure 1.25 Wakala in Cairo, Egypt (www.archnet.org)

Figure 1.26 The Fontego de' Tedeschi today in Venice (www.archive.comune.venezia.it)

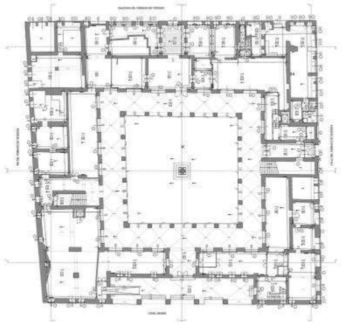


Figure 1.27 Actual plan of the building (www.studiobefana.it)

Figure 1.28 Patio of the corral de carbòn in Granada, Spain (www.granada.org)

Figure 1.29 View of the Lonja, building for commercial trade in Barcelona (Museu d'Historia de Barcelona)

Figure 1.30 The facade of Ripa Maris, commercial infrastructure of the port of Genoa since XII century (adapted from Fallanca De Blasio & Nazer Eslami, 2003)

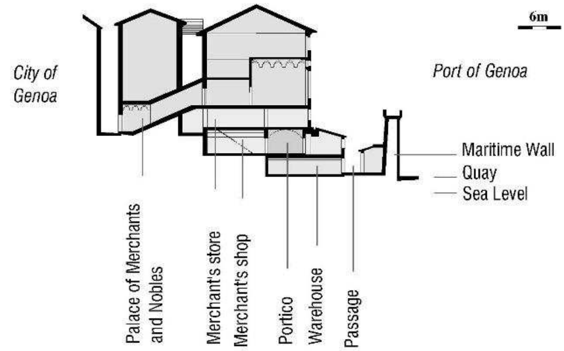
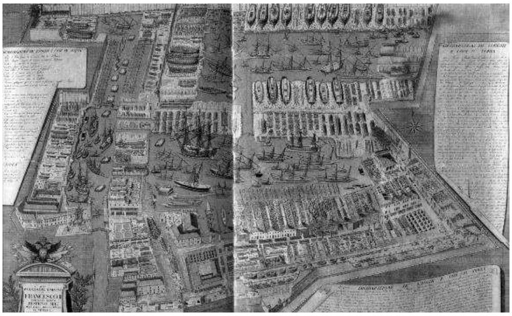


Figure 1.31 A section of Ripa Maris (adapted from Fallanca De Blasio & Nazer Eslami, 2003)

Figure 1.32 A historical photography of the waterfront of Genoa in 1880



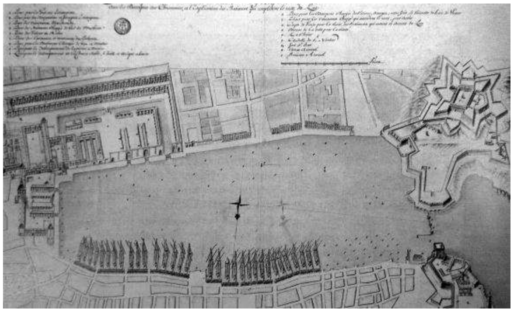


Figure 1.33 Venice Arsenal in 1797-98 (Concina, 1988)

Figure 1.34 Plan of Arsenal de Galeres, Marseille 1705 (Fallanca De Blasio & Nazer Eslami, 2003)

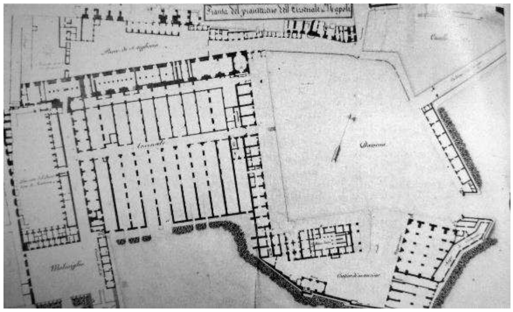


Figure 1.35 The Reial Drassanes, today Museo Maritimo de Barcelona

Figure 1.36 The Arsenal in the port of Naples, 1808-15 (De Seta, 1991)

1.3 Modern and technological ports

1.3.1 Morphology

At the end of the XVIII century, Mediterranean ports had obsolescence issues, such as silting of basins and decay of facilities. Furthermore, commercial traffics increased considerably, because of the opening of the Suez Canal in 1869, as well as the industrial development and the innovations in the transport system, such as steamers and railways. In effect, many piers and docks were built in series in port contexts, on which many warehouses were erected. Maritime rails linked them to the railway.

Considering London as a model in the port organization, the first Mediterranean city to expand its port was Marseille, since the early 19th. The inner port could no longer contain the heavy traffic of ships and then a new outer port - the *Joliette* - was built, starting from 1852. The new port was organized in three basins, with piers, docks and warehouses (Fallanca De Blasio & Nazer Eslami, 2003).

Even the port of Genoa was transformed sensibly: until the 1766 (Figure 1.40), the port conserved the high walls, the *Ripa Maris* and the basin intact, as represented in a plan made by Guidotti. Since the first decades of XIX century (Figure 1.41), maritime walls were demolished and substituted by new warehouses, on which top a promenade was realized, called "*Terrazze di Marmo*". In 1886 they were demolished and new wide docks were built, as well as railways and crane took place in the port, serving the warehouses and ships. The new port counted twelve piers and several quays, as designed by Eng. Parodi (Giaccone, 1891).

In the ports of Naples new docks were realized: the Bourbon port, after a series of works, was completed in 1920 with new piers, buildings and railways, bringing its basins from 620.000 sq. m. to 2.900.000 and its quays from 160.000 sq. m. to 1.700.000 (De Seta, 1991) (Benassai, 2014). The new interventions and plans led to the complete separation of the city from the port.

The port of Barcelona in the early XIX century was expanded with new basins, piers and docks, reaching an area of more than 2.000.000 sq. m. The first new piers have been realized, as shown in a port plan of 1881 (Figure 1.37), as well as the basin *de la Guerra*

and *de comercio.* Other important intervention (Figure 1.38) regarded the erection of the *muelle de España*, the *muelle de Cataluña*, a new dam, a port office, and the *muelle de poniente* (Archivio Historico Puerto de Barcelona, 1881, 1893, 1907-1910, 1911-15, 1926-29, 1953-57).
In the XX century, particularly between the two world wars and after the conflicts, Barcelona (Figure 1.39), Marseille, Naples, Genoa and other Mediterranean ports were significantly enlarged (Table 1. 3 *Assessment of modern and technological ports*), with the realization of industrial and process areas, which changed their historical morphologies. New basins, piers, docks and sheds were built in order to improve port capacities and development. In addition to this, during the World War, several military facilities were built in port areas, such as new arsenals and shipyards, navy and u-boat bases, among the others.

1.3.2 Architectural heritage

Innovation and industrialization induced morphological transformations of port areas. Firstly, docks were characterized by warehouses with a not more urban size. These large buildings were built on a "tabula rasa", e.g. artificial piers or quays built in series. The *Grand-Entrepot* (Figure 1.42, Figure 1.43) built in Marseille in 1860 was 600 meters long and divided in six floors with a capacity of about 150.000 tonnes of goods. Their techniques of construction were facing brickworks and masonries as vertical structures and wood or iron flats as horizontal. The buildings were located in the proximity of moorings and served by cranes for the loading and unloading of cargos from ships and to a railway line (Fallanca De Blasio & Nazer Eslami, 2003).
These typology of structures characterized also Genoa (Figure 1.44, Figure 1.45 and Figure 1.46) and, from 1888, they were built twelve new docks. Illustrative Album for the Exposition of Palermo of 1891 describes the port design, made by Eng. Parodi: masonry warehouses with two spans, an iron-wood coverage; iron sheds with two or three spans, 80 meters long; cranes and rails completed the system. On the top of each pier, a customhouse and a port office were located, in order to control the goods movement. Another large intervention in Genoa led to the erection of the Cotton Warehouses,

completed in 1889-1901 years. They had a 31.000 sq. m. surface displaced on four levels. As in Marseille warehouses, it had masonries and iron-wood roofs (Giaccone, 1891). Warehouses were constructed even in Barcelona (Figure 1.47, Figure 1.48 and Figure 1.49), as *Pabellon, Deposito Comercial* and *Tinglados* on port docks (Archivo Historico Puerto de Barcelona, 1881, 1893, 1907-1910, 1911-15, 1926-29, 1953-57). Other facilities built between the XIX and the XX century, were the maritime station and the customhouse, as in the port of Naples, Genoa and Barcelona. This typology of buildings had more architectural and urban aspect, often monumental, such as the *Aduana*, the *Estacion de Mercancias* or the *Embarcadero de Viajeros* in Barcelona, both in neoclassical style. The maritime stations of Naples and Genoa were even built at the end of XIX century. In Genoa, it dates from 1890, located in the centre of the port and contained customhouses offices, public security, post offices, shops and coffee, in addition to the spaces for passenger rest. The building roof was iron made on three large spans, with cast iron pillars (Giaccone, 1891). In several ports, also in Mediterranean Sea, during the Second World War, military structures were built, such as fortified navy and submarine bases, as well as arsenals and shipyards for their rest, maintenance and construction. Some important examples are surely the u-boat bases in the port of Bordeaux, La Rochelle, Brest, Lorient and Saint-Nazaire in France, which have been realized about in 1940-41 years by Germans. Today, these facilities can certainly considered as historical heritage of XX century.

1.3.3 Techniques construction of port structures

The expansion of modern ports led to the construction of dams, piers and docks. The current techniques were mainly two: the jetties breakwaters and the prefabricated blocks. The first was used in the late XIX century, both in Barcelona and Genoa, for the extension of the outer pier. While in Barcelona the *Dique del Este* (Figure 1.50) was a classic pier with scattered stones and upper wall (Archivio Historico Puerto de Barcelona, 1881, 1893, 1907-1910, 1911-15, 1926-29, 1953-57), in Genoa a new technique was experimented. The West pier, called *De Ferrari Galliera* (Figure 1.51), was prolonged to create the new outer basin. The works were built in three construction phases: firstly, the foundation stone; secondly, the substructure with artificial blocks; at last, the defensive wall and the moorings. The innovation was in the second step. In fact, while in the ports of Livorno and Marseille, the jet of the stones was random, in Genoa it was realized with a regular masonry. The great resistance shown by the dam in the following years led to the adoption of the technique in other ports (Giaccone, 1891). Finally, a prefabricated dam was realized in Naples for the piers called *Duca degli Abruzzi* and *Thaon de Ravel* (Benassai, 2014).

Port	XVIII-XIX Centuries P=Port area P/Q=Piers/Quays	XIX-XX Century P=Port area P/Q=Piers/Quays	Port Functions	Port Interventions
Marseille	P = 220.000m^2 P/Q = 130.000 m^2 (1700)	P = 1.100.000 m^2 P/Q = 960.000 m^2 (1872)	Industrial, Commercial, Military, Passengers	New port, docks, piers and quays, maritime railroads, warehouses, cranes, fisherman district
Genoa	P = 1.000.000 m^2 P/Q = 230.000 m^2 (1854)	P = 1.300.000 m^2 P/Q = 844.000 m^2 (1902)		Port enlarged, sheds, warehouses, maritime station, customhouse, maritime railroads, piers, docks, cranes
Naples	P = 620.000 m^2 P/Q = 160.000 m^2 (1800)	P = 2.900.000 m^2 P/Q =1.700.000 m^2 (1920)		Port enlarged, warehouses, maritime station, customhouse, maritime railroads, piers, docks, cranes
Barcelona	P = 1.360.000 m^2 P/Q = 160.000 m^2 (1870)	P = 2.560.000 m^2 P/Q =1.280.000 m^2 (1910)		Port enlarged, piers, docks, maritime station, customhouse, maritime railroads, port offices, maritime district, passengers facilities, merchants' station

Table 1. 3 Assessment of modern and technological ports

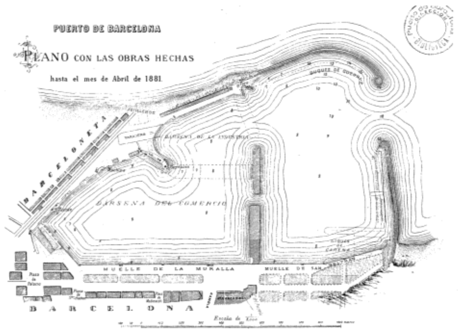


Figure 1.37 Plan of the Port of Barcelona in 1881 (Archivo Historico Puerto de Barcelona)

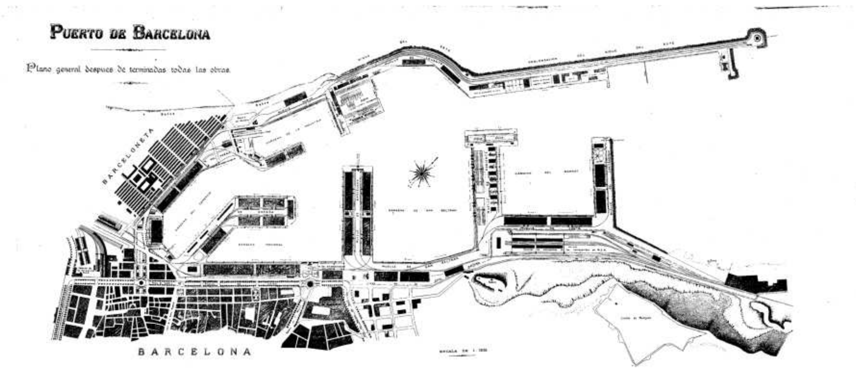


Figure 1.38 Plan of the Port of Barcelona in 1910 (Archivo Historico Puerto de Barcelona)

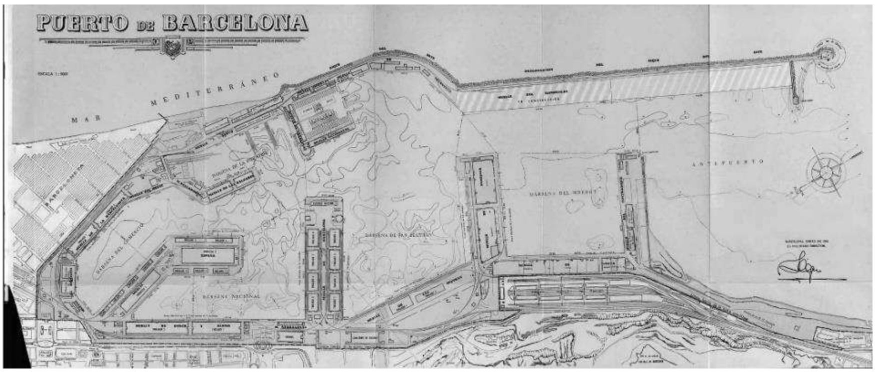
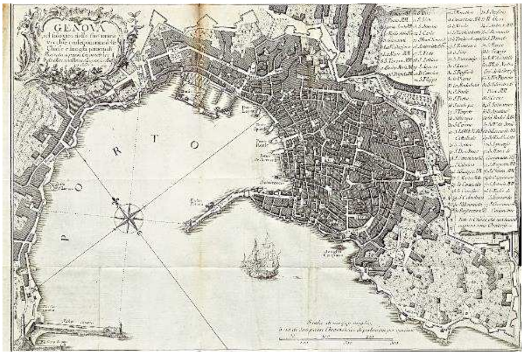


Figure 1.39 Plan of the Port of Barcelona in 1957 (Archivo Historico Puerto de Barcelona)



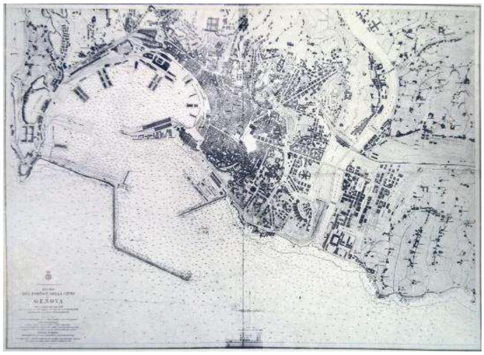


Figure 1.40 Plan of Genoa port in 1766, by Giacomo Brusco (Poleggi & Cevini, 2003)

Figure 1.41 Plan of the port and the city of Genoa, 1902 (Poleggi & Cevini, 2003)

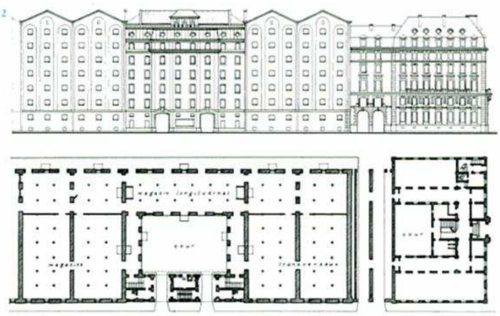
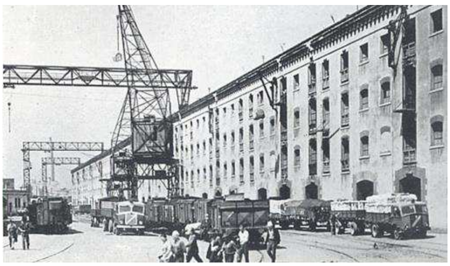


Figure 1.42 View of the Grand-Entrepot of Marseille in XIX century (Fallanca De Blasio & Nazer Eslami, 2003)

Figure 1.43 Plan and facade of a typical warehouse in Marseille (Fallanca De Blasio & Nazer Eslami, 2003)



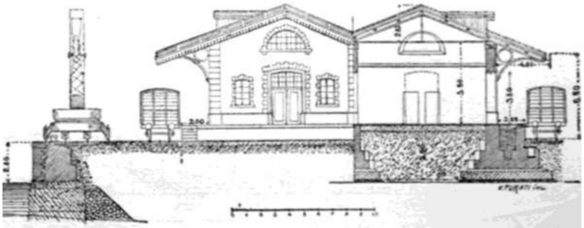


Fig. 82. — Capannoni

Figure 1.44 Cotton Warehouses in the early XX century, Genoa (www.irolli.it)

Figure 1.45 Sheds of XIX century in the port of Genoa (Giaccone, 1891)

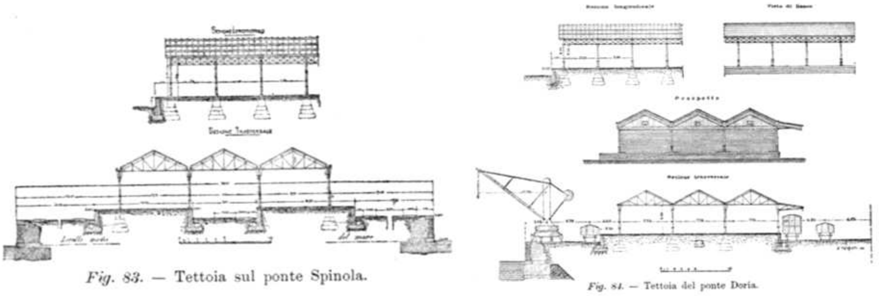


Figure 1.46 Iron sheds built in XIX century in the port of Genoa, located on the docks and served by mechanical cranes for loading/unloading (Giaccone, 1891)

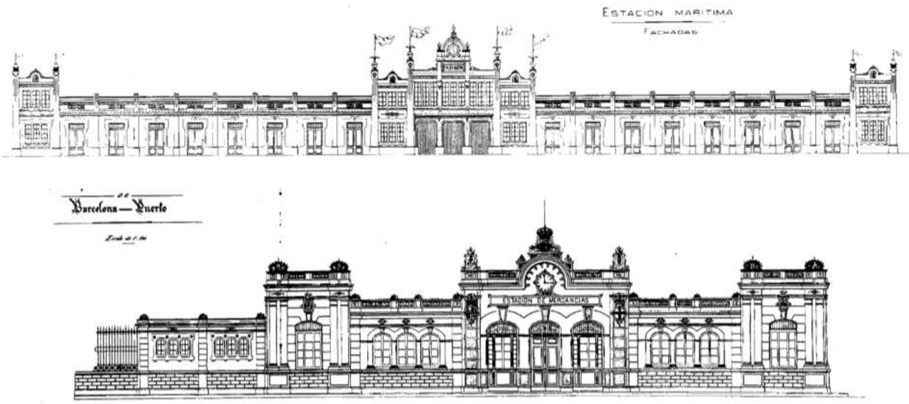


Figure 1.47 Drawings of Estacio Maritima and Embarcadero de Viajeros, Barcelona (Archivo Historico Puerto de Barcelona)

Figure 1.48 Deposito Comercial of the historical port of Barcelona at the end of XIX century (Archivo Historico Puerto de Barcelona)

Figure 1.49 The customhouse facility in Barcelona: the centre of the commercial traffics of the city in the early XX century (Archivo Historico Puerto de Barcelona)

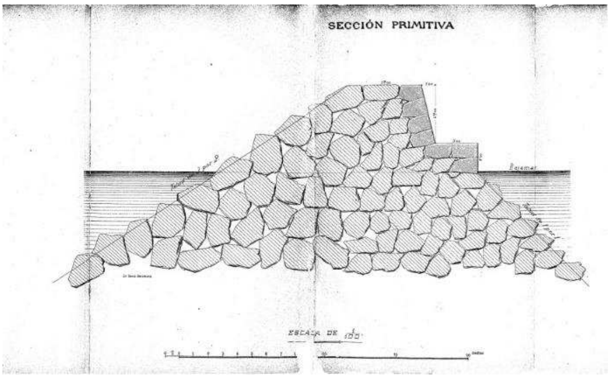


Figure 1.50 Section of the East pier in 1889 built in Barcelona port (Archivo Historico Puerto de Barcelona)

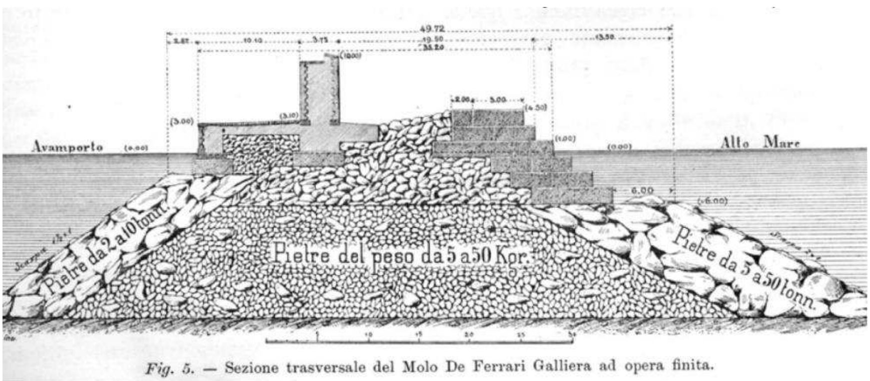


Figure 1.51 The project of West pier of Genoa in 1888 (Giaccone, 1891)

1.4 Classification of historical heritages of ports

The identification of different categories of heritage aims to the definition of specific strategies and guidelines for preservation and enhancement.
Firstly, ports have been analysed in terms of typology, function, number, type and shape of basin, dimension, surface, morphology, and relationship with the urban centre. Particularly, it emerges that ancient ports of Rome had many similarities with the modern ports: they were infrastructures often unrelated and independent from the urban centre. In effect, Rome had several ports on the Italian coastline, which were connected to the City through rivers or important commercial streets, such as the Appian or Trajan Way. In other cases, such as *Carthage*, *Leptis Magna* or *Alexandria*, instead, port-city system had a synergic relationship. Even for technological innovations, Roman ports and constructions could be compared to XIX-century ports, mainly for enlargement, long piers and large basins. From the Middle Age, ports and cities joined in a unique system, represented by the *emporium*. In this era, port facilities crossed the urban boundaries, leaving port quays and placing into the urban fabric.
Secondly, the potential historical elements of ports to preserve have been identified and described. This heritage is very heterogeneous and has different characteristics, in terms of history, materials, techniques of construction, morphology, typology, dimension, relationship with the context, among the others. Thus, the identification of categories depends on all these factors. As shown in Table 1.4, the heritages have been divided primarily in two main groups: buildings (B) and spaces or areas (S). The *buildings category (B)* counts different architectural elements, grouped in subcategories: productive and industrial archaeology (B_1), logistic buildings (B_2), commercial facilities (B_3), fortifications (B_4) and sacred architecture (B_5).
The *productive and industrial archaeology* (B_1) is composed of industrial facilities, warehouses and sheds, included shipyards. These buildings were built mainly in the XIX-XX centuries for the process, loading and storage of different types of materials, representing important facilities for the port organization. In the last century, they were abandoned because of their inadequacy in relation to the new transport system and industry process. Their techniques of construction are very heterogeneous: among the

vertical structures, there are stone masonries and iron, iron-concrete or wood pillars; the horizontal structures can be made of iron, iron concrete, wood or stone vaults.

Port logistic buildings (B_2) were also built since the middle of XIX century. Firstly, lighthouses, maritime stations, customhouses and offices represent the most frequent examples of port facilities. As well as the industrial heritage, these buildings are located on the docks of port because of their close relation to the ships activities. They are characterized by stone masonries or iron-concrete structures as vertical elements, and concrete-brick or wood flats as horizontal structures.

Mercantile and commercial facilities (B_3), in the majority of cases, were built previously, between the X and the XVIII centuries. These buildings and architectural complexes housed both the storage of goods, the negotiation and rest of the merchants. They have been located in the proximity of urban functions and, then, have traditional materials and structures: masonries with wood flats or stone vaults. This category of heritage can be characterized by decorative and artistic elements, rather than the previous ones. Their architecture and configuration depend strictly on the geographical location. In effect, in the East Mediterranean Sea *caravansary, funduq, walaka, bedesten* and *qasr* were the main commercial facilities, while, in the West, *fondaco (*or *fontego*) was the corresponding building. In both cases, the building have a central court with workshops at the first level, while apartments for the merchants are located on the upper one. Other facilities were represented by the market, the bazar and similar facilities, devoted to the retailing. Some examples are the *Fontego dei Turchi* in Venice, the *Eski Bedesten* in Instanbul and the *Ripa Maris* in Genoa.

Fortifications, castles and fortresses (B_4) have protected port cities since ancient times. At the end of the XVIII, jointly to the enlargements of ports, maritime walls were often replaced by new wide docks for ships mooring, because ports did not require a system defence. Castles and fortresses, instead, were preserved over the centuries. These massive and stone architectures have monumental and artistic features and, in most of cases, are actually not used and enhanced. The majority of Mediterranean port cities have one or more maritime fortresses: La Valletta, Brindisi, Rhodes, Dubrovnik, Naples, Marseille, and many others.

Sacred and religious architectures (B_5) were located in ports or near their boundaries, because the port and city relationship has been synergic between the X and XI centuries. In these emporium districts, it was very common finding churches and cathedrals in the West and mosques in the East. In some cases, churches were built by merchants' confederations. It is worth mentioning Marseille cathedral near the *Joliette* basin or Barcelona historical centre with *Santa Maria de Mar*, among the others.

The category of *spaces and areas of ports* (S) contains different types of heritage, which can be considered as spaces because of their territorial extension and can be traced back to different historical period: docks and piers (S_1), archaeological sites (S_2), maritime districts, historical centres and waterfronts (S_3), and military areas (S_4).

Port activities, such as the loading/unloading and storage operations, were executed on specific areas: *docks and piers* (S_1). These areas were active part of the port morphology and changed different times in the course of history. In effect, piers had very important functions: on the one hand, they protected the port basin and waters from the waves and winds, on the other they were also a defensive element against enemies' attacks. Furthermore, they also housed warehouses and facilities, as well as docks. Equipment (cranes for goods movement) can be actually present on docks, in some cases historically relevant. Technologically, they were built with vertical stone walls or jetty breakwaters until the XIX century, while with prefabricated and concrete blocks in the last century.

Archaeological sites (S_2) can be also present in port context, both on the coastline that submerged in port basins, with two types of heritage: movable, such as objects, ceramics or shipwrecks, and immovable with structures and surfaces. They can be remains of ancient docks and quays, or rests of warehouses and other facilities, as well as ceramics used for goods and food storage. Some important examples are the sites of *Leptis Magna* in Libya, *Portus Claudius Trajanus* near Rome, *Egnathia* in the Adriatic coast of South-Apulia and the rests of the ancient port of *Cartago* in Tunis suburb area.

Mediterranean port cities have typical *historical waterfronts or maritime districts* (S_3), which are a unique testimony of culture, history and sociality. In effect, as defined by the Venice and Krakow Charter, this heritage despite not monumental and artistic have a global value symbol of identity and memory that has to be safeguarded. Mediterranean waterfronts and maritime districts have unique characteristics: these curtains of buildings have facades with traditional materials, colours, morphologies and architecture. They often housed commercial activities and workshops on the first level, while merchants and citizens lived in apartments on the upper levels. In the majority of cases, they represent the main image of a historical port. The waterfronts of Marseille, Naples and Brindisi, such as the historical centres of Acre and Tyre, among the others, are some examples.

The last typology of historical areas, which can be located in ports, is represented by all the *military, navy and army areas* (S_4). They have been realized in ports particularly during the two World Conflicts, but previous facilities could be included. In this category arsenals and shipyards, official palaces, ship and submarine bases, among the others, are considered as historical sites. Significant examples are the arsenals in Venice, Taranto, and Genoa for instance, as well as *Reial Drassanes* in Barcelona.

Historical Buildings (B)	Historical Spaces and Areas (S)
B1. Productive and industrial archaeology*:** Warehouses, sheds and stores, etc. ***B2. Port logistic facilities: Customhouses, captaineries, port offices, lighthouses and maritime stations, etc. ***B3. Commercial and mercantile buildings:*** Fondaco, caravansary, palaces for trade and merchants, lodges, markets, stores, etc. ***B4. Fortifications:*** Castles, fortresses, bastions, towers, walls, etc. ***B5. Sacred Architectures:*** Cathedrals, churches, monastery and convents, mosques, etc.	***S1. Historical spaces of ports:*** Docks, piers, basins, promenades. ***S2. Archaeological sites:*** Submerged and on-land remains. ***S3. Waterfronts and maritime districts:*** Historical waterfront and curtains, maritime districts and centres. ***S4. Military areas:*** Arsenals, military buildings, army and navy bases, etc.

Table 1.4 Classification of architectural heritage of ports

The first task of the research work has led to define a knowledge framework about the history, the evolution and development of port cities. In the view of a definition of a methodology for the assessment of the risks affecting the historical and architectural heritages of ports, the classification aims to identify specific analysis and, then, strategies for each heritage category. Specifically, the morphological assessment aims to the understanding of the causes and dynamics of transformations and changes of the port areas and, then, of the hazard concept. The typological classification and assessment of heritage, instead, is functional to the preparation of specific forms for vulnerability analyses that are going to be explained in the next chapters.

Chapter 2

The risk assessment for the historical heritage of ports

2.1 Introduction

Nowadays, most of the port areas in the Mediterranean context could be considered as "landscapes at risk". In effect, considering all the anthropic environments, ports are certainly the most sensible areas. In contrast to the other territorial settings, where there is a very low level of interference, in port contexts all the urban and extra-urban functions can interface.

Moreover, they are very complex contexts, characterized by a heterogeneous mixture of components: productive, commercial, logistic activities and facilities are located in the closeness of relevant historical, cultural and natural heritages, as well as urban districts. Particularly in Mediterranean ports, the historical and cultural component has a higher relevance than in other international cases, representing a unique symbol and testimony of cultures developed in the course of thousand years in the *mare nostrum*

context. The specific multifaceted configuration of ports can justify their assessment and study, in order to identify the main risk factors affecting historical and cultural heritage and, then, to define sustainable lines of development.
First of all, the architectural and historical heritage of ports, which has been identified, described and classified in the Chapter 1, since the last decades has been characterized by several criticalities in the conservation, management and use.
The reasons of these issues can be summarized by the two main trends of ports (Gras, 2013) (Hoyle, et al., 1994), since the XIX century. Firstly, in order to house the new modern facilities, ships and activities, the original basin has been transformed, modernized and enlarged, generating impacts and pressures on built heritage, and changing significantly their relationship with the urban zone and the historical sites. Secondly, in other several cases, the ancient site was not appropriate and the activities were settled in the suburb areas, leading to the abandonment of historical spaces.
Actually, several port buildings and spaces, in the Mediterranean context, denote a high level of obsolescence, decay and abandonment, compromising the conservation of their cultural, historical and natural values. Some facilities, such as lighthouses, warehouses or customhouses, have lost their function in the port organization, due to the new integrated transport system, resulting now disused and decommissioned. In addition to the functional obsolescence, also the lack of maintenance can produce decay, especially if heritages are abandoned. Furthermore, some buildings and spaces do not respect the new performance requirements and normative standards, or they are handled by different ownership, management and control authorities.
Beyond the inner evolution and state of conservation of the architectural heritage, some further issues might rise from the relationship with the port system and the urban settlement. On the one hand, concerning the port system, the closeness to areas with low environmental quality - residual spaces, dismissed structures and infrastructures, operating production compartments - or with high protection and control level - industrial zones, military facilities and private premises - might compromise both protection and accessibility. On the other hand, concerning the urban settlement, decay of interface areas, shortcoming of connection systems and lack of cultural and social events for

citizens and visitors, might threaten the traditional role of the port for the local community and, thus, the continuity of life for historical places and buildings.
Finally, the dangerous propensity of the modern port activities – e.g. oil, gas and hazardous materials storage and loading/unloading – can lead to the occurrence of disasters and accidents, with potential severe effects, including the complete destruction of heritage. In effect, the handling of hazardous substances represents a high risk factor, potentially able to generate explosions and fires in sensible areas near natural or cultural assets. Even the concentration of activities increasingly directed towards industrial and energetic production in the port areas can contribute to deteriorate the environmental conditions, leading to deterioration of the constitutive materials of heritage.
According to all the above-mentioned aspects, ports can be certainly treated as contexts with the presence of high risk factors for natural, cultural and landscaping elements. The assessment and mitigation of those risks represent a challenge and opportunity for the development of sustainably port cities and preservation of landscape.

2.2 The risk for cultural heritage

The concept of risk, related to the historical heritage, awakes at the end of the 60s, with the Venice Charter of Restoration of the 1964, the Italian Charter of Restoration and the UNESCO Convention of 1972.
In effect, after the reconstruction of the cities damaged by the Second World War, the preservation and protection of monuments and generally of historical heritage become a significant goal and challenge for European countries, leading to the definition of several restoration guidelines.
In these years, the attention of institutions starts focusing on the effects and pressures that anthropic activities and territorial transformations produce on historical and cultural sites. Especially the methodologies of intervention on heritage have been regulated, with guidelines and strategies for the preservation and restoration, which are related to the typologies and characteristics of heritage.

In this view, the Venice Charter, as well as the Italian Charter of 1972, has a particular significance, because it recognizes for the first time as "heritage" a heterogeneous variety of buildings, spaces and elements: not only the monuments but also the architectural elements with a historical and cultural value. Specifically, in the art. 10 the definition of historical heritage regards "*both the isolated architecture both the urban landscape, which represents a testimony of a particular civilization, an evolution process and a historical event*". Thus, historical centres start to be acknowledged as heritage to protect and the submerged archaeological heritage is introduced in the Charter of 1972.

Furthermore, it becomes clear that some human activities, particularly industrialization, could compromise the state of conservation of cultural assets leading to the irreversible transformation of territory. In fact, it is realized that modern world produces pathological effects on cultural heritage, because of the progressive industrialization and the urban growth, which have completely changed the landscape of cities. A first mention is present in the Athens Charter of 1931, where it is recommended the protection of monuments, which are "*threatened in the modern world by the external agents*". The concept is again reported in the Italian Charter of Restoration of 1972, where the protection of heritage against the "*action of pollutants and of atmospheric, thermos-hygrometric changes*" is for the first time introduced.

Additionally, some risk factors starts to be recognized and studied in last decades: natural phenomena, such as earthquakes and floods, or disasters, as conflicts, explosions and fires, represent hazards factors for the historical environment, potentially leading to the damage or complete destruction of cultural assets. In fact, in the UNESCO Convention of 1972, institutions assume to "*develop scientific and technical studies* […] *as will make the State capable of counteracting the dangers that threaten its cultural or natural heritage*". Recently, an increasing attention is also being devoted to the so-called NaTech events, i.e. the simultaneous occurrence of both natural and technological events such as those of Tohoku (Japan) in 2011, when an earthquake and a tsunami damaged six refineries causing fires and explosions and damaging as well a nuclear power plant.

Relating to the dangers and threats, in the European Charter of Architectural Heritage (1975), the art. 6 reveals that "[…] *This heritage is at risk. It is threatened by ignorance, by any form of degradation and abandonment".* Sometimes the causes are addicted to urban sprawl, which "[…] *lead to destruction* […]" because "[…] *authorities give excessive attention to economic interests*".

Finally, in the Charter of Restoration of Krakow, adopted in 2000, it is clearly specified in the art.11 that "[…] *all the risks affecting the heritage have to be identified, also in exceptional case* […] *and specific systems of prevention* […] *as well as intervention and emergency plans* […]" have to be redacted.

In the last years, UNESCO has represented one of the most important institutions for the protection and safeguard of historical and cultural heritage, mainly through the programs "World Heritage List" and "Heritage at Risk".

According to the Convention of 1972, two typologies of dangers – or risk factors – are considered (Table 2.1): potential and ascertained dangers.

Ascertained Dangers	Potential Dangers
Serious deterioration of materials	Modification of juridical status of the property diminishing the level of protection
Serious deterioration of structures and/or ornamental features	Lack of conservation policies
Serious deterioration of architectural or town-planning coherence	Threatening effects of regional planning projects or town planning
Serious deterioration of urban or rural space, including natural environment	Outbreak or threat of armed conflict, calamites, earthquakes, floods, disasters
Loss of historical authenticity and cultural significance	Threatening impact of climatic, geological or other environmental factor

Table 2.1 Classification of dangers for historical heritage (UNESCO, 1972)

The ascertained dangers, as defined by UNESCO, could be several: serious deterioration of materials, structures and/or ornamental features, from the decay and damage

to the complete destruction; serious deterioration of architectural or town-planning coherence and of urban or rural space, including natural environment. Other significant risks can be the loss of historical authenticity and cultural significance. In this category, some other certain factors of risk may be the loss of cultural and historical identity of places, as well as the loss of landscaping features.
The potential dangers are considered as factors that indirectly could lead to ascertained losses: modification of juridical status of the property diminishing the level of protection; lack of conservation policies; threatening effects of regional planning projects or town planning; outbreak or threat of armed conflict; threatening impact of climatic, geological or other environmental factor.
In this category, they can be certainly included the effect of pollution, waste and contamination of environment and the probability of disasters, such as explosions and fires. Other hazardous phenomena could be related to the aggressiveness of the context within the heritage is located: criminality, social decay, abandonment, vandalism are some examples of risk factors for heritage in the modern cities.

In the view of a preventive control and management of risk and disasters, several methodologies have been developed, in recent decades. The most widespread and accepted methodology of risk assessment, used in several studies and researches, comes from the *UNESCO Report on the Landslides* (Varnes, 1984). The methodology provides concepts and function to calculate risk, considered with a specific value (R_s) and a global one (R_t). The global risk (R_t) - that means the loss of lives or properties or economic values - is function of vulnerability and hazard. Varnes defines vulnerability as "[...] *a degree of loss to a given element or set of elements at risk* [...]" and it can be expressed in a scale from 0 (no damage) to 1 (total loss). The hazard concept –related to natural phenomena - is defined as "[...] *probability of occurrence within a specific period of time and within a given area of a potentially damaging phenomenon* [...]". Finally, the risk value may increase with the presence of economic, cultural or social properties in the area, evaluated with the component "element at risk". The function (2.1) is the following

$$R_t = (E)(R_s) = (E)(H \times V) \tag{2.1}$$

where R_t is the total risk, R_s is the specific risk, V is the vulnerability, H is the hazard and E represents the elements at risk. The function has been applied in several research studies concerning the risk assessment, from the seismic to the hydrological risk and, subsequently, also to the cultural heritage.

From a methodological point of view, it is worth mentioning the research project "Risk Charter of the Italian Cultural Heritage" (Accardo, et al., 2003) (Cacace & Ferroni, 2003) (Badami, 2010) (CORCELLI, et al., 2008) directed by the Italian Restoration Centre (ICR). The ICR institute has started this project since 1992, when the methodology has been defined and applied on several historical and cultural heritages in all the Italian territory. In the Charter, the risk is defined as "*possibility that an event damaged an element with cultural value*", and, then, it can be considered as a potential loss of historical, cultural, artistic values for architectural heritage.
According to the Varnes definition, the ICR risk is a function (2.2) of vulnerability and hazard. The vulnerability is defined as "*level of exposure to damage*" and, then, is related to the physical state of conservation of the heritage. As well as the Varnes concept, vulnerability function is expressed in percentage (%). The hazard, instead, is defined as "*level of aggressiveness of the territorial context*". The methodology is considered in relation to three fields of application: environmental, structural and anthropic. For the vulnerability (V), in effect, the first component (V_1) deals with the surfaces and aspect; the second (V_2) one regards the constructive-structural components; the third (V_3) deals with the use and security. The hazard (H) function considers atmospheric changes and pollutants (H_1), earthquakes, floods, landslides, etc. (H_2) and social economics dynamics (H_3).

(2.2) $$R = V \times H$$

where R is the risk of losses for cultural heritage, V is the vulnerability of the heritage and H is the territorial hazard.

The risk assessment in the case of natural and anthropic disasters is also calculated through the Varnes formulation (2.1). Particularly, the study of the seismic risk

(Benedetti & Petrini, 1984) is another important contribution to the preservation of historical heritages and monuments. It is defined as "*extent of damage expected in a given time interval, according to the type of seismicity, the resistance of the buildings and of human activity*". In effect, Italian peninsula is a very dangerous territory from a seismic point of view. The main components of the function are the vulnerability, the hazard and exposure. The vulnerability is the "*propensity to damage*" of a building or, in general, heritage. The hazard component, in the seismic assessment, is function of the frequency of occurrence of the earthquake and its magnitude. Specifically it is the "*probability of occurrence of the earthquake*". The exposure is a concept, which summarizes the gravity of the risk: for instance, the number of people involved in the disaster, the importance of monuments or heritages damaged.

In the international scientific debate, developed since the first Charter of Athens, no reference has been focused on the criticalities in the conservation of historical port areas. Despite most of the articles in the international charters might be considered and applied for port areas, their complexity and sensibility should lead to confront in order to define specific strategies and guidelines, as well as a methodology for the assessment and mitigation of risks.

2.3 The risk assessment for historical heritage of ports

The main goal of the current research is the definition of a methodology for the assessment of risks affecting the different typologies of cultural and historical heritages of port areas. Particularly, the definition of the risk factors aims to the identification of strategies and guidelines for the preservation of port landscape and heritages, as well as for the integration of the port-city system.

In order to elaborate a methodology for the risk evaluation in the specific context of ports, it is important to define the concept of risk in the present research. Specifically, the risk is considered as "*occurrence of a damage on port heritage, which could lead to the loss of cultural, historical, architectural and artistic values*". Referring to the state of art previously described, this concept of risk is inherited from the definition given by ICR in the Risk Charter (Accardo, et al., 2003) and, then, it includes all the values owned by the heritage, from the material-constructive to the functional-anthropic and the cultural-landscaping point of view. In effect, the heterogeneity of the heritages potentially present in port areas and the different typologies of hazards of port activities forced to consider risk in a wide conception.

Defined the concept of risk which can affect the historical sites of ports, the methodology of assessment is going to be described. Particularly, according to the function (2.2) of risk introduced by ICR, the risk can be evaluated through the assessment of two key elements: the vulnerability of the historical heritage (V) and the impact of the port activities and facilities (H).

$$\text{Risk} = f\left(V, H\right) \tag{2.3}$$

The vulnerability of the historical heritage is considered as "*susceptibility and propensity to the damage*" or "*level of exposure to the damage*", and then is related to the state of conservation, use, management and with its relationship with the contest. In effect, vulnerability is considered as function of several indicators, which deals with the physical state of conservation, the functional properties and, then, the cultural features, in order to have a global and unique parameter of assessment.

The estimation of the impacts of the port activities on heritages is a complex process. In effect, first of all, two types of impact – i.e. hazards – are defined and evaluated: the stationary impact and the exceptional one. The stationary is an impact, which is continuously present in port areas and, in the majority of cases, has a middle-long effect. The exceptional impact, instead, is related to potential accidents and disasters that can occur in ports. It is produced with a very low frequency and it is characterized by a short duration and a high intensity.

Defined the hazard concept –described in details in chapters 4 and 5 – it is important to say that the typology of impact influences the methodology of the evaluation of the risk. In a stationary situation, the risk is calculated through the combination of the percentage of vulnerability with the level of aggressiveness of the port activities, estimated with specific indicators. In an exceptional condition, instead, other considerations are necessary to identify the level of risk. In effect, in industrial risk analysis, the risk is defined as the frequency of the accident multiplied by its consequences (generally, fatalities and losses) on the surroundings. Then, the frequency and the probability of the dangerous event have to be calculated. Secondly, the effect of the disaster on the heritage need to be estimated. Thus, combining the frequency and the magnitude of accident with the heritage vulnerability a level of risk is identified. The common units in risk assessment are fatalities/years (population losses) or € /years. However, these units are not at all the adequate ones for the estimation of damage and losses to historical and cultural heritages.

As previously enounced (2.3), the combination of vulnerability and hazard influences risk and, then, generates losses and damage on heritage. The main risks, which can affect historical sites in port areas, concern the material-structural damage, the functional obsolescence and the loss of cultural-landscaping values.

Firstly, the negative effects and damage which can be produced by port activities on the heritages are certainly related to the physical state of conservation of those buildings, spaces and areas with a cultural value. In effect, several causes can induce the material deterioration of heritages, as well as the damage of its constructive and artistic components: the lack of safeguard, maintenance and restoration; the abandonment or an incorrect use and usability; the hazardous impacts of port activities, such as pollutions and disasters; these are some examples which are going to be described and analysed subsequently in the research work. Thus, the “losses” in terms of materials and architectural values regard some decay phenomena, such as erosion, blackening and corrosion of surfaces, irreversible damage of constructive elements and, finally, the complete destruction and loss of the heritage. The deterioration of materials and structures of the heritage implies the loss of elements as testimony of civilization, evolution processes or historical events.

Besides the materials features, the functional characteristics of the heritage are equally important values to preserve and adapt. In effect, the transformation of port contexts in the last centuries leads facilities and spaces to be obsolete, because they do not respect the functional requirements and standards. In addition to this, some heritages have lost their original function in the port organization. Nowadays, the risk could awake

when cultural assets are incorrectly used, or especially when they are completely abandoned. The incorrect use and management can cause the loss of historical vocation, socio-cultural identity and significance for the local community, as direct effects. Thus, the effects of territorial planning, the excessive transformation of port areas, incorrect policies, as well as the abandonment and degradation of areas, are same reasons that might compromise the preservation of all the cultural properties of heritage and landscape. These are key factors for the monuments and, generally, for historical sites and areas, especially in a complex system like ports.
Finally, the effects of the risk factors can produce damage and losses in terms of cultural significance, historical authenticity and image of the landscape of ports. In effect, these cultural features in recent years have been increasingly threatened by industrialization, urban transformation and land exploitation, among the others. Specifically, in port areas the landscaping value at risk are principally three: morphological, visual and symbolic properties. The loss of the morphological characteristics in the port landscape regards the serious alteration of volumes, facades, relationship between full and empty spaces, as well as the introduction of materials, structures and equipment with a complete different aspect and dimension from the historical and cultural assets. The visual deterioration of landscaping areas, such as historical ports, can be caused by the erection of structures or infrastructures, which represent an obstacle, hiding heritages or changing their overall view. The symbolic change is one of the recent effects of port transformation, which has produced the loss of identity and of those historical values, layered over the centuries in the local traditions.
In the next chapters, the research work is going to describe and assess the vulnerability and the hazard in the specific context of ports, focusing on the concepts and methodologies for their evaluation, in the view of the preventive conservation and enhancement of their historical heritages.

Chapter 3
The vulnerability of historical heritage of ports

3.1 Methodology

The vulnerability is the first component of the risk function and, generally, refers to the intrinsic characteristics, state of conservation, use and management of the historical heritage, even for the port assets. As defined in the risk function (3), the vulnerability is the "*level of exposure to the damage*" of the heritages (Accardo, et al., 2003). In effect, more a building - or spaces - is damaged and more it is susceptible to deterioration. For instance, a stone surface of an architectural heritage, which is characterized by erosion and physical decay, is more attackable by atmospheric agents and pollutants, as well as a structural component which is damaged has a high probability to collapse. In this view, the vulnerability can be also considered as "*susceptibility or propensity to damage*" (Benedetti & Petrini, 1984). Furthermore, the concept of vulnerability, related to the cultural heritage, is broader than the material or structural meaning, as well as the concept of risk. In fact, three categories of vulnerability can be identified, analysing the state of art and the conservation issues for the port historical heritage: material and architectural (V_{mat}), functional and anthropic (V_{fun}), environmental and landscaping (V_{cult}) vulnerability.

Particularly in the current research, a simplified method for the evaluation of the vulnerability is proposed, in relation to the specific criticalities and conservation issues in the port contexts and to the heritage categories. The method is structured in two levels of investigation (Table 3.1): a “level 0”, which provides a general description of the heritage surveyed and a “level 1”, for the effective estimation of vulnerability. First of all, it is worth underlining that for a vulnerability assessment, the phase of the knowledge and the diagnostic process have a key role, as well as the direct or indirect survey of the heritage, in order to have the adequate scientific, architectural, historic and cultural framework.

Level 0	Level 1
Original name Actual name Location Documentation Typology of historical heritage Geometric information Date/period of construction Date/type of Survey	*Indicators of material vulnerability (V_{mat}):* State of preservation (diffusion, severity, urgency) of structural, artistic-decorative elements; criticalities and susceptibility of materials to damage. *Indicators of functional vulnerability (V_{fun}):* Accessibility, use, property, management, control and supervision, restoration and maintenance interventions/plans. *Indicators of landscaping vulnerability(V_{cult}):* Cultural identity, historical authenticity, promotion and diffusion of knowledge, level of protection and safeguard, connection to centralities and relationship with context.

Table 3.1 A scheme of the proposed methodology for vulnerability assessment

As previously announced, the L0 task reports all the main information and data about the heritage (Annexes 1.1, 2.1, 3.1, 4.1, 5.1), according to the “UE condition survey guidelines for heritage conservation” (CEN/TC 346/WG1/TG1 , 2010). Especially, the heritage is catalogued in terms of name (original and actual), category (B_n, S_n), location (city, region, state, geographical coordinates, urban zone), typology of documentation held, geometric information (length, width, height, gross surface, volume), use (original and actual) and historical period (date, period or year) of construction or transformation. In addition to these factors, it is reported the type of survey (complete or only external) and its date, because of the importance of dating the state of conservation and vulnerability.

The second part (L1) of the assessment, instead, leads to the identification of a global index of vulnerability for each heritage of the port, calculated as the weighted average value of three partial indexes, such as in the function (3.1): the material, functional and cultural components of the vulnerability.

$$V_{glob} = \sum(n_{mat}V_{mat} + n_{fun}V_{fun} + n_{cult}V_{cult}) \div (n_{mat} + n_{fun} + n_{cult}) \quad (3.1)$$

where V_{glob} is the global index of vulnerability, V_{mat} is the partial index of architectural and material vulnerability, V_{fun} is the partial index of functional and anthropic vulnerability, V_{cult} is the partial index of cultural and landscaping vulnerability, n_{mat}, $n_{fun,}$ n_{cult} are specific weights (at first considered equal to 1).

Therefore, the vulnerability is a parameter expressed in percentage, from 0 to 1, which depends on the three partial indexes, estimated through the evaluation of several indicators (from 11 to 20 for each heritage) for which a score (from 0 to 3) is assigned in relation to the characteristics and state of conservation, use and management of the heritage (Table 3.2). It is considered high vulnerability for values higher than 66%, while medium for 33-66% and low for 0-33%.

This method is widely used in several researches and protocols for the evaluation of values and properties, which cannot be assessed with a quantitative method (ICOMOS, 2011) (Benedetti & Petrini, 1984) (Accardo, et al., 2003) (Cacace & Ferroni, 2003). In details, it contains all the technical data of the heritage, from the material-constructive characteristics to the functional and cultural. While the L0 task is provided by reporting forms identical for each heritage category, the analytical forms (L1) differs in relation to the characteristics and element to evaluate and preserve. The calculation of the partial indexes of vulnerability is possible extrapolating a value in percentage from the average of the scores given to each indicator, as showed in the following function (3.2).

(3.2) $$V = \left(\sum P_i\right) \div \left(n \times P_{max}\right)$$

where V is the partial index of vulnerability, P_i is the single score assigned to an indicator, P_{max} is the max value assignable to an indicator (e.g. 3) and n is the number of indicators.

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="5">Categories of historical heritages of ports</th></tr>
<tr><th>B_n</th><th>S₁</th><th>S₂</th><th>S₃</th><th>S₄</th></tr>
<tr><td rowspan="3">Indicators of Vulnerability</td><td>Material Vulnerability</td><td colspan="3">Damage Class (structural damage, material decay)
Level of Damage (gravity, urgency, diffusion)
Vulnerability to fire and chemicals</td><td>Overall state of conservation of built environment, public spaces and paths</td><td>Overall state of conservation of built environment, public spaces and paths</td></tr>
<tr><td>Functional Vulnerability</td><td colspan="2">Level of accessibility
Level of use - use compatibility
Property - management
Conservation policies</td><td>Level of accessibility
Level of protection
Property
Management
Conservation policies</td><td>Level of accessibility
Historical vocation
Conservation policies</td><td>Level of accessibility
Historical vocation
Conservation policies</td></tr>
<tr><td>Cultural Vulnerability</td><td colspan="5">Safeguard laws
Socio-cultural identity
Historical authenticity
Diffusion and knowledge
Relationship with context</td></tr>
</table>

Table 3.2 The indicators identified for the heritage categories

Defined the vulnerability, as a global concept, and introducted the methodology for the estimation of the index, the research is going to focus on the three different components, previously announced: the material vulnerability, and the functional and the cultural. ones

3.2 Material vulnerability

The material-architectural vulnerability (V_{mat}) of the historical heritage of ports refers principally to the physical state of conservation of all their constructive components, as well as constitutive materials. The definition of the indicators for its calculation depends on the heritage category and, then, specific vulnerability forms are defined for buildings (Annex 1.2), docks and piers (Annex 2.2), archaeological sites (Annex 3.2), waterfronts (Annex 4.2) and military areas (Annex 5.2).

Firstly, for the B, S_1, S_2 categories, the material vulnerability concerns specifically the state of conservation of the main components. Particularly, it can be calculated with specific indicators, as defined by the ICR methodology used for the project “Risk Charter of the Italian Cultural Heritage” (Accardo et al., 2003) (Cacace et al., 2001). Two classes of damage are identified for the evaluation: the structural damage, such as partial or global losses with a potential or ascertained collapse, and the material decay, regarding all the phenomena as corrosion, erosion, blackening, biological attack, etc. as described in the UNI 11182 (Beni culturali - Materiali lapidei naturali ed artificiali - Descrizione delle forma di alterazione , 2006).

Each damage class is evaluated through three main indicators, which express the level of damage of the heritage components: gravity, diffusion and urgency. The gravity represents the magnitude of the damage, from the complete absence (score 0) to minor (score 1), average (score 2) and serious damage (score 3). The diffusion is an indicator which refers to the level of diffusion of the damage on the heritage and it is evaluated in percentage: for 0-25% of diffusion the score assigned is 0; for 25-50% it is 1; for 50-75% it is 2; for 75-100% it is 3. Finally, the urgency concerns the progression of the damage over the time: when the damage is not in progression, the score is 0; for a low progression it is 1; for a medium progression it is 2; for a rapid progression it is 3. The class and level of damage are identified for the two main typologies of components of the historical heritage of ports. For the buildings (B), the structural component and

the artistic-cultural one are considered. In the first category, there are vertical and horizontal structures, while in the second one all the decorative and artistic elements, if present. For docks and piers (S_1), the assessment of the state of conservation regards, on the one hand, the structures and spaces, on the other, the equipment, which can be located in these areas. Archaeological sites (S_2) are particular heritages, which can count both immovable that movable remains, also submerged: the immovable heritage concerns rests of surfaces, structures, columns and capital, inscriptions, paintings or mosaics, for instance; the movable one includes epigraphs, sculptures, shipwrecks, weapons, tools, numismatic finds, etc.
The partial index of material vulnerability, for these categories, considers also the susceptibility of materials to some widespread factors of hazard of the port contexts: the vulnerability to fire and to the chemical aggression. In effect, accidents and disasters involving hazardous materials such as hydrocarbons, gas and coal, occur with a certain frequency in port areas, sometimes near natural and cultural sites. Thus, the behaviour of buildings materials, attacked by fires, is different. Particularly, four main classes are identified: high (0), medium (1), low (2) and very low (3) resistance to fire, in terms of capacity of conserving the main physical characteristics, as well as functional and structural efficiency. For instance, a high resistance is assigned to the stone masonries, while metals and wood have to be considered with a lower value. The chemical aggression is another hazard which contributes to deteriorate construction materials and surfaces, particularly in industrial contexts, very common in modern ports. The level of resistance to chemicals, such as carbonic dioxide, sulfuric dioxide and others, is evaluated in a scale of four values, similar to the previous one used for fires: from the high resistance (0) to the very low one (3). In this case, the wood is one of the most resistant materials, while stone has a medium value. Metals and reinforced concrete are the most vulnerable structures.
A different assessment is carried out for the S_3 and S_4 categories, concerning both waterfronts, maritime districts, historical centres and military areas. In effect, they are architectural aggregates, wide built areas, open spaces and viabilities, including mon-

umental gardens and historic parks, among the others. These landscaping assets cannot be evaluated through punctual indicators about the state of conservation, because of their territorial extension. In addition to this, the values to consider in this case are different. Mediterranean waterfronts, despite the absence of monumental and artistic properties, have unique and specific characteristics in terms of global values, both tangible that intangible. Military areas can also include facilities and buildings, offices and warehouses, on the one hand, and open spaces and viability, on the other one.
Thus, the material vulnerability is evaluated through an overall state of conservation of three main components, as listed by the "International Charter of the Historical Towns of Washington" in 1987: built environment with buildings, architectures and monuments; public spaces, such as squares, gardens and parks; streets, pedestrian ways, and cultural and landscaping paths. Particularly, the vulnerability is estimated through a score linked to the percentage of the built environment, public spaces or paths, which are in good state of conservation: 0 for 75-100%; 1 for 50-75%; 2 for 25-50%; 3 for 0-25%.

3.3 Functional vulnerability

The functional vulnerability is a partial index, which summarizes all the criticalities in relation to the use and management of the historical heritage of ports (Annexes 1.3, 2.3, 3.3, 4.3, 5.3). In the port context, these factors often influence sensibly the possibility of enhancement and conservation of the heritages. In effect, having a different property, management and control is a very common trend in the port areas. Furthermore, the low accessibility and usability, as well as the lack of restoration intervention, can lead to abandonment and, then, to decay. To confirm it, some of the potential hazards listed by the UNESCO program "Heritage at Risk" (UNESCO, 1972) are the lack of conservation policies and the modification of the status of property, which can reduce the level of protection. The compatibility (original-actual), as well as the level of use (total, partial and disused) of the historical heritage represents another indicator, functional to the estimation of the vulnerability.

Specifically, for buildings (B), piers and docks (S_1), the functional vulnerability is function of accessibility, use, property, management and conservation policies.

The accessibility of a port building or spaces is estimated in relation to the amount and typology of users, which can access it: for a complete public access a score of 0 is assigned; for a public temporary access the value is 1; for an exclusive access to employers the score is 2; if the historical site is inaccessible the maximum value of 3 is assigned.

The use of the building or spaces is evaluated through the compatibility and the level of use. Particularly, the compatibility represents the relationship between the original and actual use: if they are compatible a score of 0 is considered; if the actual use is mainly acceptable the score is 1; 2 is the score when the function is just acceptable; for a use incompatible or for a heritage completely abandoned the score is 3. The level of use regards, instead, the percentage of heritage which is actually used: if the heritage is totally used the score is 0; for a partial use the value to assign is 1; if the heritage is unused since a period less than ten years the score is 2; finally, if it is abandoned since a period more than ten years the value to assign is 3.

The relationship between property and management through a compatibility/identity scoring: if they are compatible or coincident the score to assign is 0, while a value of 3 is assigned in the contrary situation.

According to the brief introduction, the absence of conservation policies is a key factor, in relation to the conservation of historical sites. In effect, punctual intervention on the heritage, as well as planning solution, is evaluated in terms of typology and progress: if the intervention or the plan is current or it has been finished since five years, the heritage is certainly is good state and the value to assign is 0; for an intervention realized since fifteen years, minor decay and damages is likely to be occurred and the score is 1; for a conservation policies not realized but programmed 2 is the value to assign; if it has not realized and programmed, finally, the heritage is very vulnerable and the value is 3.

A specific assessment has to be carried out for archaeological sites (S_2), because the re-use and use of these remains cannot be taken into account. In addition to the accessibility, property, management and conservation policies, the level of protection of the sites also has to be considered. In fact, the element of protection need to be identified, if present: for a site protected with structures, roofs, panels, and microclimate control, or if the site is underground, 0 is the score to assign; if there are only physical barriers, a somewhat protection is ensured and the score is 1; if the site is only protected by roofs, the level of protection is minimum and the score is 2; the complete absence of protection structures or strategies is hazardous and a score of 0.
For waterfronts, maritime districts and historical centres (S_3) three main indicators are estimated, in order to evaluate the vulnerability of these areas from a functional and anthropic point of view.
The first indicator regards the overall level of accessibility and usability of the historical area. In effect, more an area is permeable and accessible to population, tourists, employees and users, and more it maintains the social identity, the historical value and all their cultural properties. Particularly, if the port area is completely accessible, with adequate point of access, public and green transport systems, the vulnerability decrease and a score of 0 is assigned; for an area with the absence of one of the previous factors, such as the public transport or the high accessibility, the score grows to 1; if the area has a low accessibility, the transports are inadequate, a score of 2 is appropriate; a condition where the site is almost inaccessible, the viability inadequate and the transports absence, the maximum value of 3 has to be assigned.
The accessibility of military areas (S_4) is instead evaluated considering a value of 0 for permanent access to officials and employees, and free public access in specific areas, both with guided tours. A value of 1 has been to assign if the public access is possible only through limited guided tours. For a temporary and rare accessibility to the public a score of 2 need to be assigned and, finally, for a restricted and exclusive access only to employees the value to assign is 3.

The historical vocation, in terms of original use of buildings or spaces of the area, is evaluated similarly to the previous use compatibility and level of use of the other categories, as well as the conservation policies, which are clearly referred to the overall area and not to a single heritage.

3.4 Cultural and landscaping vulnerability

The third component of the vulnerability deals with the level of conservation of cultural and landscaping values of the historical heritage (Annexes 1.4, 2.4, 3.4, 4.4, 5.4). Particularly, the safeguarding and listing of the cultural sites can be considered as a priority, both for the real protection and preservation of them, both for the acknowledgment of the historic value of the heritage in the territorial system. The safeguarding is evaluated in terms of programs and strategies of protection on the heritage and its surroundings: if they are present, a score of 0 is assigned; for sites without any typology of safeguard the maximum score has to be considered, such as 3.

The conservation of the socio-cultural identity of historical places is another key factor for maritime and port areas. It is considered as the level of acknowledgment of the site by the local community. If the heritage is completely recognized as landmark by population and citizens, the score to assign is 0; for a partially, poor, naught recognition the values are respectively 1, 2 and 3. In this view, the historical authenticity also has to be preserved, in terms of sum of all the values layered in the course of history, as well as the social, cultural and historical identity. The level of conservation of all the cultural and historical properties is also analysed: if it is total, 0 is the score; if the heritage preserves the majority of the values it is 1; if the site preserve a low amount of values, the score to assign is 2; finally, for a building or space that has lost many values, the vulnerability is maximum, with a score of 3.

Another factor of risk, related partially to the concept of safeguarding and protection laws, could be the lack of dissemination of values and of acknowledge within the territory. The promotion of the historical value influences the vulnerability differently if it is absent (the score is 3), local (2), regional (1), national and international (0).

In relation to the landscaping value, the characteristics of the immediate context in which the heritage is located, as well as the level of connection with the main social and cultural nodes of the city are considered for the estimation of the vulnerability index. In effect, for a cultural site the assessment requires the assignment of a score of 0 if the context is adequate and enhances the heritage. If the context does not affect the value of the heritage, 1 is the opportune score, while it decrease to 1 and 0, if the context needs redevelopment intervention or if it is inadequate. The distance and connection between the heritages and the other important nodes of the territory are evaluated in order to calculate the partial index of vulnerability. In fact, if the heritage is good connected to the urban functions (adequate transports and viability) the score is 0; for a medium (1) and low (2) connection the vulnerability grows; if the site is completely isolated and disconnected the maximum vulnerability is considered (3).

Chapter 4

The stationary impacts of port activities

4.1 Port activities and facilities

A port could be located on the seafront (seaports) or on a river (river ports) which could be linked to the sea (inland ports). Ports are infrastructures important for countries and cities, because a lot of goods and people move through them. In effect, they are very complex areas where several typologies of activities take place. Furthermore, they are also important from a social and cultural point of view, because they are part of the history of maritime cities. For these reasons, it is clearly important to predict and control their impacts on people, environment and landscape, including cultural and historical heritage. From the literature and research projects (Casini, 2015) (Darbra, et al., 2004) (Puig, et al., 2015) (ESPO-European Sea Port Organization, 1994) (CERTEC, 2013), a list of activities of ports has been defined, as well as the main port functions. Ports could have mercantile (including commercial, industrial, energetic), logistic, urban (or touristic) and cruiser functions. The most common activities are classified in three main categories, subsequently listed: general port activities, handling/storage of materials and port-based industry.

Port Activities	
General activities: *Administrative services* *Bunkering, dredging* *Marine-based cargo transport (shipping/navigation)* *Land-based cargo transport (Truck, train, car, etc.)* *Passenger transportation* *Deposal of dredge materials* *Fishing & aquaculture* *Maintenance of port installation and infrastructures* *Maintenance of port vehicle and equipment* *Ship, building, repair and maintenance* *Port development* *Pilotage, towing and mooring* *Marinas, yacht club and water sports* *Ship and port waste management*	**Cargo handling and/or storage of:** *Containers* *Dry bulk* *Oil, gas and petroleum products* *Hazardous cargo (non-oil)* *Liquid bulk* *Perishable goods* *Vehicles/trade cars* *Ro-Ro* **Port based Industry:** *Aggregate industry (sand, gravel, cement)* *Chemical & pharmaceutical plants* *Fish market and processing* *Agro food Industries* *Metal ore processing and refining* *Oil refineries, Power stations, Steel works*

Table 4.1 Classification of port activities (Puig, et al., 2015)

Among the general activities, there are administrative services, including staff working on the financial and commercial departments, as well as shipping and navigation, bunkering, pilotage, towing and mooring. Bunkering is the action of supplying a ship with fuel. In case of small vessels, bunkering is carried out from shore, using facilities similar to normal petrol stations. On the other hand, ships are bunkered from one or more dedicated barges. Bunkering is generally performed by hoses. The fuel could be fuel oil or diesel. Pilotage, instead, regards the action of the captain guiding the ship into the port. A harbour pilot provides local navigation advice to the captain, since he/she knows the channels and how currents and winds affect ships.

When the ship is entering in the port basin, pilots usually use a boat to get on board, although in some places they may use helicopters. Since ships are often slow to turn and take a long time to stop, it could be a risk of damaging docks and ships. Thus, they need towing operation, which is assisting a ship by one or more tugboats, which bring it towards the dock, so that it can berth safety. Mooring is the action of making safely a vessel, secured to the wharf, by the cable or an anchor.

Shipping involves the action of transporting cargo by sea with any type of vessel. This activity, generally called marine-based cargo transport, involves the shipping operations that carried out within the port. Land-based cargo transport, instead, includes every type of transport on land within the port, such as by trucks, cars, train.

One of the main activities in port is the passenger transportation. They can be classified in ferries (designed to carry primarily passengers and sometimes also vehicles and cargo, with a regular and frequent services) and cruisers (designed to take passengers on short holidays or longer voyages all over the world).

Other port activities could be fishing & aquaculture and marinas, including water sports. Fishing is the activity of catching fish and aquaculture is the cultivation of freshwater and marine resources, both animal and plants, for human consumption or use. Marinas are located in basins or docks with moorings and supplies for yachts and small boats; it differs from a port because it does not handle a large number of passengers or goods. Finally, there are a lot of number of sports that could be made involving the water within the port boundaries: motorized vehicles, barefoot skiing, boat racing, or water skiing.

Ports also have some maintenance activities, regarding buildings and spaces, infrastructures and equipment, ships and basins. For instance, dredging consists of removing a certain amount of sediment from the bottom of the basin in order to keep the navigation depth of a waterway (maintenance dredging), make it deeper (capital dredging), sell the material (commercial dredging) or to improve the environmental quality of a waterway (remedial dredging). Related to dredging it is usually the disposal of dredge materials. If dredge material cannot be used it should be placed in existing areas or on upland sites where levees can be used to contain the material.

The maintenance of port infrastructures and installations includes buildings, gardens, roads, docks, equipment, such as harbour cranes, containers, and straddle carriers, among the others. Finally, port could house ship construction, repair and maintenance, in specific areas: dockyards refers to the operations of maintenance while shipyards are associated to the construction of ships.

Another activity regards port development: operations carried out on land and on sea that involve the construction of maritime works. On-land activities include construction or demolition of buildings, infrastructures for transferring cargo (e.g. wharves and berths), cargo transfer facilities (e.g. gantry cranes), storage facilities (e.g. silos), rails, pipeline, roads, installation or removal of pavement and utility constructions. At sea, instead, they include installation or replacement of navigation marks, piles, lights, vessel traffic schemes, flood defence and wave screens, among the others.

Related to the most of the port activities is the waste management. It refers to the management of the waste generated within the port.

A particular activity within the port could be the handling or storing of materials that can produce specific impacts and involve environmental aspects or accidents. Several types of cargo could be stored in ports, such as containers, solid or liquid bulks, oils and petroleum products, cars and vehicles.

A container is a large steel or aluminium vessel that may be filled with many types of small goods. It should have the strength enough to resist shipment, storage and handling. They are stored on the top of each ship's hold and on deck and in the port context on large empty spaces near the docks.

Other type of good are the bulk, which can be solid or liquid. Dry bulk, for instance, is a solid cargo that is transported unpacked in large quantities: iron ore, grain, coal, phosphates and bauxite are some examples, as well as cement, gypsum or sulphur. Liquid bulks are liquid cargoes moved unpacked in large quantities, excluding hazardous materials: cooking oil, fruit juices, rubber and vegetable oil.

Instead, oil, gas and petroleum products are transported and stored in tanks; crude oil is often transported from oil-producing countries to other refineries. Similar to oils are also other hazardous cargo (non-oil). They are substances or materials that can harm

people, properties or environment; they include chemical products, minerals, products of animal or vegetable origin and radioactive materials; although oily products are hazardous materials, they have been considered as a category. Perishable goods are goods that can decay and then they need a specific conservation, for example refrigerated. Moreover, in ports could be handled vehicles and trade cars, which include transportation and storage of commercial vehicles.
Another common port activity is the Ro-Ro (Roll-on/Roll-off). It is a wheel cargo, such as automobiles, trucks, semi-trailer trucks, or trailers that are driven on and off ship on their own wheels or using a platform vehicle.
Furthermore, port areas are often characterized by the existence of industries and processing plants. Particularly, they can count industries for aggregates, chemical products, foods, oils and others. Aggregate industry is a broad category of particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and other aggregates. Chemical & pharmaceutical plants are an industry that manufactures or processes chemicals on a large scale; the general aim is to create new material wealth via the chemical and biological transformation and/or separation of materials. They use specific equipment, units and technology in the process.
Fish markets and processing refers to all the activities regarding fish, from the time when it is caught or harvested to the final delivering to the customer. Agro food Industries is defined as large-scale production, processing and packaging of food using modern equipment and methods. Metal ore processing and refining deals with the separation of commercial valuable minerals from their ores. It consists in a purification of the impure materials, in this case metal.
Oil refineries are industrial process plants where crude oil is processed into useful products such as petroleum naphtha, gasoline, diesel fuel, asphalt base, heating oil, kerosene and liquefied petroleum gas. Power stations are industrial facilities for the generation of electric power; most of them burn fossil fuels (oil, coal, natural gas) to generate electricity. Others can use nuclear power or cleaner renewable resources such as solar, wind, wave and hydroelectric. Steel works is the business of processing iron ore into

steel, which, in its simplest form, is an iron-carbon alloy. This industry is also responsible for turning it into partially finished products or for recycling scrap metal into steel.

4.2 Environmental aspects in port areas

Modern port areas, since last decades, have been transformed in productive, logistic and commercial clusters with a large movement of passengers, cargo and transports. These activities generate impacts and pressure on the port environment, including population, natural ecosystem and landscape. In fact, in most of cases, port areas are located near urban centres, historical sites or natural landscape, leading to their impairment and deterioration.

The environmental impact of port activities can be considered, in relation of their nature, stationary impacts. In fact, although they occur both in ordinary and accidental conditions, their effects on environment are produced in middle-long period and continuously. In order to prevent damages and losses, as well as to reduce port impacts, since 1994 the European Sea Port Organization (ESPO) promotes a sustainable management of ports, with the Environmental Code for Industrial Ports. In last decades several other implementation have been developed, such as the new Code of Practice, published by ESPO in 2003, recommending specific environmental practices to improve port performance (Puig, et al., 2015). Furthermore, ECOPORTS foundation starts its activities, producing the Self Diagnosis Method (Darbra, et al., 2004), followed by TEN-ECOPORT (De Fino , et al., 2015). UE Regulation 1836/1893 promote and invite industrial companies to apply and implement an "Environmental Management System (EMS)", including modern ports. According to these, the "ISO Standard 14001" (Kuhre, 2007) provides guidelines and elements for the environmental management, which ports are invited to develop.

Particularly, port activities and their impacts have been studied, in relation to the scientific literature and research projects already carried out, in order to define a methodology for the identification of significant environmental aspect for the conservation and preventive maintenance of historical and architectural heritage in this specific context. In the process of identifying impacts of port activities on the environment, it is worth define some important keywords: *environmental aspect and environmental impact*. The ISO standard 14001 defines an environmental aspect as "*element of an organization's activities, products or services that can interact with the environment*" and, particularly, a significant aspect (SEA) as "*environmental aspect that has or can have a significant environmental impact*".

Differently, an impact is the resultant change of environment that concerns the SEA: for instance, if emission to air is the SEA, the global warming is the impact. Thus, the main aspect of the environmental policy of ports have been identified (Table 4. 2) in the ECOPORT activities (APAT - Agenzia per la protezione dell'Ambiente e per i servizi tecnici, 2008) (Darbra, et al., 2004).

Some of the significant environmental aspects of port areas
• *Emissions to air (air quality and dust)* • *Discharges to water* • *Releases to soil due essentially to industrial activities* • *Releases to marine sediments and activities affecting the seabed* • *Noise, with its potential impact on population and fauna* • *Waste generation and dredging disposal* • *Loss/degradation of terrestrial habitats* • *Changes in marine ecosystems* • *Odours* • *Resource consumption* • *Port development (land and sea occupation)*

Table 4. 2 Significant environmental aspects (APAT, 2008; Darbra, et al., 2004)

The emission to air includes substances (gas or solid) and energy released from fixed sources (materials clusters, chimneys and others) and mobile (transport and treatment of materials). The presence of these products in the atmosphere and their interaction (chemical-physical) can create air pollution, with implication on local climate, surfaces

of buildings and human health. Common sources are outdoor deposit of materials, treatment and spill of bulks, emission of combustion processes.
The discharge to water concerns every type of discharge that can generate pollution of the port water. For instance, it could be a loss of products during loading/unloading and storage of goods or a discharge of ballast water and bilge.
Soil contamination refers mainly to industrial activities (past or current). In fact, contaminants include liquids dispersed on the ground, the disposal of solid bulk, residues and waste. A common source is represented by underground tanks, chemical batteries, heavy metals, scrap metal, materials abandoned or chemical and organic products. They can be absorbed by soil, groundwater, rivers, etc.
Other aspects are the releases to marine sediments and activities affecting the seabed. It could refers to all types of spill of liquids (fuel) or solid products (waste) on the sea bottom. They can produce negative effects on the ecosystem. They are involved in the dredging, bunkering, trade and navigation.
Waste generation and dredging disposal relates to any substance or object to be disposed: oil products and water containing them; hazardous liquids and solids, sewage and garbage. They are produced by transport, storage, maintenance, waste management. They give a negative image to the port and influence the landscape perception.
The resource consumption refers to the consumption of non-renewable energies (such as electricity, fuels) or natural resources. The first one implies the release of CO_2, SO_2 and other substances in the atmosphere producing acid rains, for instance.
Finally, a significant environmental aspect is the port development, which could be referred to land or sea side of the port basins.
In the first case, port development on land occurs because of the lack of spaces and the growing number of activities localized in ports lead to the progressive enlargement. It can also lead to the destruction of naturalistic areas and biodiversity, to the erection of industrial areas near urban zone and, then, to impact on the landscape. Secondly, whenever the space on land is not available, new infrastructures and spaces are built on the sea. Port development on sea can lead to the change of maritime currents, waste and erosion of the coastline, including damage to marine ecosystem.

4.3 Environmental impacts on the historical heritage of ports

In the environmental assessment of ports, protection and preventive maintenance of historical heritage and cultural identity is not one of the top-priority, as shown the several reports and methodologies (ESPO-European Sea Port Organization, 1994). Most of their aims are related to the population health and natural environment.

However, in most of cases ports are located close to historical sites, as well as urban areas. In this context, modern port activities – nowadays represented by industrial, logistic and commercial functions- produce impacts and hazards, leading to a potential risk of loss and damage of heritages.

The loss of cultural heritage could be compared to human health risk, because cultural and historical values are unique and irreplaceable, in most of cases. Furthermore, they are an important part of the social awareness and culture. According to this, port authorities and stakeholders should consider in port management and planning these aspects. Particularly, two are the main questions: *What are the parameters and environmental aspects in relation to historical heritage of port? And what are the impacts on heritage, related to these aspects?*

4.3.1 Identification of impacts on heritage

In order to understand which environmental aspect is relevant for historical and architectural heritage, it is necessary to define the impacts, in terms of loss or damage that port activities and installations produce. In fact, three main typologies of damage can be considered: the material and pathological decay (MAT), the impact on use and function (USE), the impact on landscape (LAN).

Table 4.3 shows the impacts that port activities produce on historical heritage, related to the environmental aspect, such as identified by ISO standard 14001.

Firstly, it is worth notice that 5 of the 12 environmental aspect and, then, the impacts related to them affect the material and physical state of conservation of buildings and spaces: air emission, discharge to water, pollution of soil and water and waste production. In fact, the EA of air emission could lead to pathological effects and decay of surfaces. The consequences are the possible loss of materials of the surfaces, both for

stone and metal structures. The erosion is a deterioration specific of stone materials, such as corrosion of iron and other metals. These effects are mainly related to the pollution present in the atmosphere, due to the relative humidity, the acid rain and the concentration of CO_2, SO_2, HNO_3 and of particular matter (PM). This pollution is also responsible of the blackening of stone surfaces that can produce loss of materials in advance state. All these pollutants, including the aggressive marine condition, in certain climatic condition could lead to the physical stress of the materials of historical architectures. Furthermore, water discharge can represent also a source of hazard for heritage, especially submerged sites and architectures in direct contact with the water in ports. Considering the case of submerged archaeological remains, the presence of pollutants, as chemical or oil products, can affect structures and materials, producing loss of materials or erosion, as well as the presence of contamination of soil and water. In fact, archaeological sites are often located in permeable grounds.
Secondly, it points out that the impacts related to 4 of 12 of the EA produce effects on function and use of historical heritage. Particularly, waste production does not affect directly the heritage but can regard the context and the surroundings, generating an insane environment, discomfort for users and, then, the abandonment. Similar to this is the effect of noise and odours, which can affect the potential users or the visitors of the heritage. These conditions could lead to a general decrement of comfort or habitability. Port development, instead, can lead to progressive transformation, generating physical limit and boundaries and, then, inaccessibility of some spaces of port areas.
Finally, in relation to the landscaping impacts of port activities, 5 of 12 EA have been taken into account. Air emission and water discharges can produce deterioration of materials and structures, generating a change of the image of historical heritage. Waste production, associated to the port development, leads to the deterioration of the image of heritage and its context. For instance, the presence of garbage stores or landfills near historical sites causes negative effects on the optical cone of the landscape. Port development (on land or sea) in the same way leads to spatial aggressive transformation that change significantly the landscape. It could be cause of loss of identity of a historical site, producing social consequences and abandonment.

	Impact on the conservation, use and enhancement of historical heritage		
	Material (MAT)	Use and function (USE)	Landscaping (LAN)
Emission to air	Corrosion Erosion Loss of material Blackening	-	Image deterioration
Resource consumption	-	-	-
Discharge to water	Erosion Loss of material	-	Image deterioration
Contamination of soil	Erosion Loss of material Blackening	-	-
Contamination of sediments	Erosion Loss of material	-	-
Odour	-	Insanity, discomfort, abandonment	-
Noise	-	Insanity, discomfort, abandonment	-
Change in marine ecosystem	-	-	-
Change of terrestrial habitat	-	-	-
Waste	Erosion Loss of material	Insanity, discomfort, abandonment	Image deterioration Loss of identity or authenticity
Port development on sea	-	-	Image deterioration Loss of identity or authenticity
Port development on land	-	Inaccessibility, abandonment	Image deterioration Loss of identity or authenticity

Table 4.3 Individuation of effects on heritage, related to the ISO 14001 environmental aspects

According to the above-mentioned aspects, the Significant Environmental Aspects for historical Heritage (SEAH) have been identified: air pollution, discharge to water, soil and sediment contamination, noise and odours, waste production, port development on sea and on land. They are environmental aspect with a significant impact on the historical and architectural landscape of ports.

4.3.2 Identification of a relationship between heritage and SEAH

The identification of the effects on the historical and architectural heritage leads to the understanding of the influence of the several environmental aspects in ports. Particularly, it also aims to the identification of the heritage with the highest factor of risk.

	Effects on heritage (MAT, USE, LAN)			
	Buildings (B)	Docks and piers (S_1)	Archaeological sites (S_2)	Waterfronts (S_3)
Emission to air (AirE)	MAT, LAN	MAT, LAN	MAT, LAN	MAT, LAN
Discharge to water (DW)			MAT, LAN	
Soil contamination (SoilC)			MAT	
Sediment contamination (SedC)			MAT	
Noise (N)	USE	USE	USE	USE
Odors (O)	USE	USE	USE	USE
Waste (W)	USE, LAN	USE, LAN	MAT, USE, LAN	USE, LAN
Port development on sea (PDS)	LAN	LAN	LAN	LAN
Port development on land (PDL)	USE, LAN	USE, LAN	USE, LAN	USE, LAN

Table 4. 4 Relationship between environmental aspects, the effects and historical heritage in ports

Table 4. 4 points out that the heritage category with the highest number of environmental aspects involved is represented by the archaeological remains, with 9 SEAH.
According to the high vulnerability of these sites, the major effects are related to the physical-material damages: emission to air, as well as the soil contamination or waste

production, can produce erosion, loss of materials and blackening of structures of sites on-land; discharge and contamination of waters, instead, may affect the state of conservation of submerged sites, in terms of aggression on surfaces and materials.
In relation to soil and sediment contamination, archaeological sites not protected are potential areas of deposit of particles and other contaminants, for their permeable characteristic. Other effects caused by port activities are related to the usability of these historical areas: noise, bad smells, waste presence in the surroundings could produce insanity, discomfort and abandonment by users and visitors.
Finally, like the other types of heritage, some of the SEAH can change and influence the image of the historical or natural landscape. The other types of historical heritage, as buildings or areas, are subjected principally to air pollutants in terms of physical damage. Waste deposits or production, smells and noisy activities can affect the usability and image of historical places, such as the development of port spaces.

4.3.3 Identification of a relationship between SEAH and port activities

The next step of the assessment refers to the correlation of the port activities to each environmental aspect significant for heritage (SEAH). An environmental aspect is produced by different activities; thus, the main goal of this step is the calculation of the most frequent SEAH aspect in ports. The Table 4.5 shows the main activities producing impacts in ports, summarizing their influence on the environmental aspects.
The assessment of port activities has been carried out through the scientific literature, analysis of reports of port authorities and the TEAP (the tool for the identification of environmental aspect) on the site www.eport.cat. Analysing the relationship between activities and environmental aspects, it is worth underlining that the aspect “emission to air” is the most frequent with 24/26 port activities involved, followed by the “discharge to water” with 19/26 and “noise/waste” with 17/26.

	Significant Environmental Aspects for Historical Heritage (SEAH)								
	AirE	DW	SoilC	SedC	Noise	Odor	Waste	PDS	PDL
Bunkering	X	X			X				
Shipping	X	X			X		X		
Land transports	X		X		X		X		
Passenger transportation	X	X			X		X		
Dredging and deposal		X	X	X	X		X		
Fishing & aquaculture		X	X	X	X	X	X		
Maintenance of installation/infr.	X	X	X	X	X		X		
Ship, building repair	X	X			X	X	X		
Marinas	X	X			X		X		
Waste management	X					X			
Mooring, pilotage and towing	X	X							
Containers handling	X	X			X			X	X
Dry bulk handling	X				X		X		
Oil gas handling	X	X	X	X		X			
Hazmat (non-oil) handling	X	X	X	X			X		
Liquid bulk handling	X	X	X	X					
Perishable goods handling	X	X				X	X		
Vehicles handling	X				X			X	X
Ro-Ro	X	X			X		X		
Aggregate Ind.	X	X			X			X	X
Petrochem. Ind.	X	X	X				X	X	X
Agro food Ind.	X	X			X	X	X	X	X
Metallurgic Ind.	X	X			X		X	X	X
Oil Refineries	X	X	X	X			X	X	X
Power station	X							X	X
Port and coastal engineering	X				X		X	X	X
Number of activities involved	24	19	9	7	17	6	17	9	9

Table 4.5 Relationship between port activities and environmental aspects

4.3.4 The consequences of stationary impacts on heritage

The environmental consequences of port activities and operations do not lead to the direct destruction of buildings but produce pathological effects, in terms of decay and damage of the surfaces, structures and artistic elements, on one hand, and disuse and decrement of the performance of buildings, on the other one. The obsolescence process could be considered to be based in two main phenomena: the physiological decay, which is a factor of the natural aging of architectures elements; and the pathological deterioration, which is, instead, a result of a faster process due to the external factors (pollutants, climate change, disasters and other) or incorrect project and construction, among several causes.

The pathological component of the process of obsolescence is, then, related to human and anthropic activities, such as industry or transport, that are nowadays relevant elements of modern ports. The effects of environmental and stationary impacts on heritage could be structured in three main categories: physical-material (MAT), use-functional (USE) and landscaping (LAN).

Firstly, port activities produce environmental hazards, such as waste, emissions or discharges, with consequences on buildings and materials. The most frequent impact in ports is represented by air pollution and emissions, as shown in Table 4.5. Other causes could be water discharged, soil-sediment contamination and waste, for instance. These last aspects are difficult to estimate in terms of decay, instead of air pollution, which is present in several research projects and scientific contribution.

Air pollution, nowadays, is an ascertain factor of physical decay for buildings, architectures and monuments (APAT - Agenzia per la protezione dell'Ambiente e per i servizi tecnici, 2006) (Bonanni, et al., 2010) (United Nations Economic Commission for Europe (UN ECE), 2010) (Community Research and Development Information System - European Commission, 2010) (De la Fuente, et al., 2011) (Lipfert, 1989). Particularly, port areas could represent an important source of air pollution, with the great amount of productive activities, transportations and energetic industries.

The main pollutants in the atmosphere are the carbon dioxide CO_2, sulfuric compounds (such as the sulfuric acid H_2SO_4), nitrogen oxides NO_x and the particular matters. The

CO_2, despite it is a natural compound of the atmosphere, could become an aggressive factor for materials if it reacts with water and the calcium carbonate $CaCO_3$, producing disintegration on the stone surface, for instance. The main causes of its emissions are combustion, in processes or in transport.

The sulfuric compounds, instead, are present in atmosphere mainly in terms of sulfur dioxide SO_2 and hydrogen sulphide H_2S. These compounds are responsible of the sulfation of stone and bronze elements, leading to the loss of material. They are produced in the combustion of solid and liquid fuels (coal and oil) and in processing of metals (not iron) such as copper. The aggression on stone, for instance, occurs when sulfuric compounds react with water and calcium carbonate, producing gypsum ($CaSO_4 2H_2O$) that is easily to loss.

Nitrogen oxides produce nitric acid NHO_3 in the atmosphere, which is a corrosive substance when it deposits on surfaces, because of the crystallization. These pollutants are produced in high temperature combustions.

Finally, the particulate matter is one of the most dangerous pollutants for monuments and architectures. It is the main cause of the process of blackening of stone materials in open-air, for instance. It can be considered in two main categories, as a function of particles size: PM_{10}, if the diameter is less than 10 μm, and $PM_{2,5}$, if it is less than 2,5 μm. Another classification identifies primary and secondary particles. The primary ones are released directly into the air, while the secondary are produced by next reactions in the atmosphere.

The sources of the air pollutants are, generally, three: processes of combustion, vehicles traffic and manufacturing and processing of materials. The main effects on built heritage are the erosion/corrosion of materials, maybe called loss of materials, the blackening process and the physical stress.

The loss of material or erosion is due to the relative humidity, the acid rain, the concentration of CO_2, SO_2, HNO_3 and particular matter (PM) in the atmosphere. The marine aerosol, moreover, produces an additional erosion of materials and surfaces. In effect, hydrochloric acid reacts with calcium carbonate (for stone materials) and produces calcium chloride.

Another type of decay for stone materials is the blackening, caused by the air pollution and, mainly by the particular matter in the atmosphere. It is related to different types of particles: PM_{10} or $PM_{2,5}$. The exponential model is the most common for representing this phenomenon (Community Research and Development Information System - European Commission, 2010).
Another phenomenon to consider is the physical stress, related to the interaction between the materials and the environmental condition, such as temperature, humidity and others. Several thermo-hygrometric conditions can produce damages on heritage. For instance, the thermal expansion or the freezing could produce deterioration of stone materials. Thus, the thermo-hygrometric conditions have to be monitored and, then, evaluated in terms of frequency of humidity higher than 80% in a year, of oscillation around 0° C of the temperature and wind intensity (APAT - Agenzia per la protezione dell'Ambiente e per i servizi tecnici, 2006).

The significant environmental aspects with an impact on the function and usability of the historical heritage are noise, odours, waste and port development. Particularly, these components, despite not affecting directly heritage with a deterioration process, could produce negative conditions for the usability of it. Waste production can generate an insane environment, discomfort for users and, finally, abandonment and disuse of historical sites. Similar to this is the effect of noise and odours, which can disturb the potential users or the visitors of the heritage. These conditions could lead to a general decrement of comfort or habitability. Port development, instead, can lead to progressive transformation, generating physical limit and boundaries and, then, inaccessibility of some spaces of port areas.
In order to estimate these components, an assessment of port activities has to be carried out. In effect, specific sources of noise, odours and waste need to be identified in the port, defining causes and consequences on the surroundings. Regarding the "port development", the following elements have to be analysed: port plans and programs; interventions current, programmed or already carried out. These aspects need to be related to the port masterplan and to the location of the historical sites, as well as the frequency of them in the port has to be assessed.

Ports have been enlarged and transformed significantly in the last century and this process of development is still going on, in most of cases. Consequently, port landscape has changed progressively, housing new infrastructures, activities and facilities. In a context such as the Mediterranean Sea – where ports have been located close to historical urban areas – modern port development could generate an aggressive action on the landscape, from a natural, historical and socio-cultural point of view. The landscaping component is part of port environment as well as of the urban areas, especially when they are part of a unique territorial system. According to the Charter of Krakow, as well as the UNESCO programs and the Convention on Landscape 2000, landscape represents a cultural heritage as result of a historic layering of cultural and natural values and attributes. It characterizes the evolution and the interaction between humans, nature and environment.

The environmental aspects of port management, promoted by ESPO and other several port authorities in Europe, often have not considered landscape aspect as a priority, with some exception. The Port Authority of Livorno, at first, introduced an indirect environmental aspect called "visual impact" (Port Authority of Livorno, 2012). This indicator represents the impact of port development, activities and operation on the landscape. For instance, an industrial plant could damage the image of a naturalistic or historical area. Other environmental research studies consider landscape preservation as a priority in the assessment of ports (Peris-Mora, et al., 2005) (Casini, 2015), although in the majority of cases it is not included in the list of top aspect of the management. However, it is worth saying that landscape aspect is not always an important element, because the port-city system would have historical and landscaping characteristics. The impact on landscape can regard several environmental aspects, such as waste production, emission to air or discharge to water that produced an image change of heritage and its context. Nevertheless, the most significant aspect is the port development, which can transformed sensibly landscape.

The authenticity of a monument or historical heritage means the sum of all its substantial features, historically checked, from the origin to the present, as a result of the historical layering over the centuries. The meaning of the term identity, related to the heritage, is its common present value within a community, summed to the past value inherited from the authenticity of the monument. These characteristics could be damaged with the intense transformation on the port context, for instance.

A methodology of assessment of the impacts of projects on landscape is provided by the "Environmental Strategic Assessment" (European Directive 2001/42/CE) and "Environmental Impact Assessment" (European Directive 337/85/CEE), regulated in Italy by the Legislative Decree no. 152/2006. The methodology have been introduced in order to demonstrate the compatibility of a project or a plan with the natural, cultural and historical landscape. Particularly, three typology of aspect can have an impact on landscape: morphological, visual and symbolic. The morphological one regards the alteration of the volumes, facades, relationship between full and empty spaces, among the others. In the same way, another impact could be the use of techniques of constructions far from the traditional local ones. The heritage affected in this case could regard elements of natural interest, historical and cultural.

The visual impact, instead, concerns landscape when an activity or project represents an obstacle, hiding natural or historical sites, or changing their overall view. The elements at risk are panoramic landscape, potential natural-cultural paths, for instance.

Finally, the symbolic impact occur when activities or projects interfere with symbolic places: for example sites that population and, generally, citizenship consider important for their social and cultural identity, or because they are linked to religious or historical events or literature.

4.4 Methodology for the estimation of stationary hazards in ports

In order to identify and quantify the stationary impacts on the historical landscapes of ports, a simplified method for the estimation of a level of hazard is proposed. It is carried out through specific hazard forms.

The first part of the form (Annex 6.1) contains all the general information about the port object of investigation. In effect, as defined by the Self Diagnosis Method (Darbra, et al., 2004), ports can count several types of morphology: bay, river, estuary, artificial port or natural harbour, among the others. In addition to this, the location (city, province, region, state), the dimension (gross surface), the historical data (foundation and relevant transformation), the authorities involved (port authority, municipality, state, navy, other), the function present (commercial, industrial, cruiser, touristic, urban, etc.) are some information to insert in the form. Other specific characteristics that have to be included, regards the boundaries of the port area, which denote the relationship with its surroundings: urban areas; urban areas with cultural and historical values; protected and unprotected natural parks, industrial area, and others.

The second step of the assessment (Annex 6.2) deals with the estimation of the activities and facilities located in the port. Considering the list of activities present in Table 4.1, they have to be identified in the port and, then, evaluated in terms of extension and frequency. The extension of the activity, or its area of influence, consists in its gross surface (square meters) in the port masterplan. If the activity has a surface wider than 10 ha, the score to assign is 3. For activities with surfaces between 5 ha and 10 ha, the score is 2. Finally, the low value of 1 is assignable to activities with a surface less than 5 ha. The frequency is a concept related to the effective execution of the activity in the port basin. Specifically, if the activity is carried out continuously or more than once a day, the score to assign is 3. For activities, which are performed about once a day, the value is 2. The value to be assigned in the case of activities with a frequency of once a week or less than once a day is 1.

The valuation of the extension and frequency leads to calculate a global score for each activity in the port. As defined in the previous part of the chapter (Table 4.5), a relationship between the port activities and the significant environmental aspects of heritage (SEAH) has been identified. This leads to the calculation of the scores generated for each SEAH, starting from the values just estimated for the activities (Annex 6.3). Thus, relating these scores to the typology of impact (MAT, USE, LAN) potentially generating by the environmental aspects (Table 4.3, Table 4. 4), a final value concerning the effects on heritage is calculated summing the SEAH scores, both for impact on materials, on use and function, and, then, on landscape.

The last step of the assessment (Annex 6.4) deals with the identification and evaluation of the partial indexes and the global one representing the potential hazards of the port for historical sites. Particularly, the indexes are calculated in percentile, comparing the score estimated with the maximum value assignable, which represents the highest hazard. The partial indexes are the impact on materials (H_{mat}), on use and function (H_{use}) and on landscape (H_{lan}). Finally, the global value of the potential hazard (H_{glob}) is estimated with the average value of the partial indexes.

Chapter 5

The accidental impacts of port activities

5.1 Accidental impacts in ports

Nowadays, ports are associated to environmental issues, such as pollution, waste, hazardous substances and materials, representing a potential risk for the surroundings. In addition to this, severe accidents can occur producing potential negative effects on environment, people and properties. They are known as major accidents.

In effect, in port areas several dangerous operations and activities take place (Ronza, 2007): chemical plants and other process plants; oil and chemical depots; road and rail transport; oil and gas pipelines. Industrial ports also house ships, carriers, cruises and tankers, most of them containing and transporting hazardous substance or materials. All ships are propelled by fuel or diesel and this represents a potential hazard. Furthermore, other types of transportation of hazardous materials could be present on-land, such as trucks, trains and lorries, including pipelines and hoses.

A major accident is defined (Council Directive 96/82/CE , 14 January 1997) (Casal, 2008) as "*an occurrence such as a major emission, fire or explosion resulting from uncontrolled developments in the course of the operation of any establishment* […] *and leading to serious danger to human health and/or the environment, immediate or delayed, inside or outside the establishment and involving one or more dangerous substances*". Especially it involves the release – instantaneous or over a relatively short period – of significant amounts of energy or of one or more hazardous materials. It can occur both in industrial processes and during the transportation: for example, some major accidents involved train or road tankers, ships or carriers. The effects of accidents can include principally three phenomena:

- Thermal: related to the thermal radiation;
- Mechanical: blast (pressure wave) and ejection of fragments;
- Chemical: release of toxic materials.

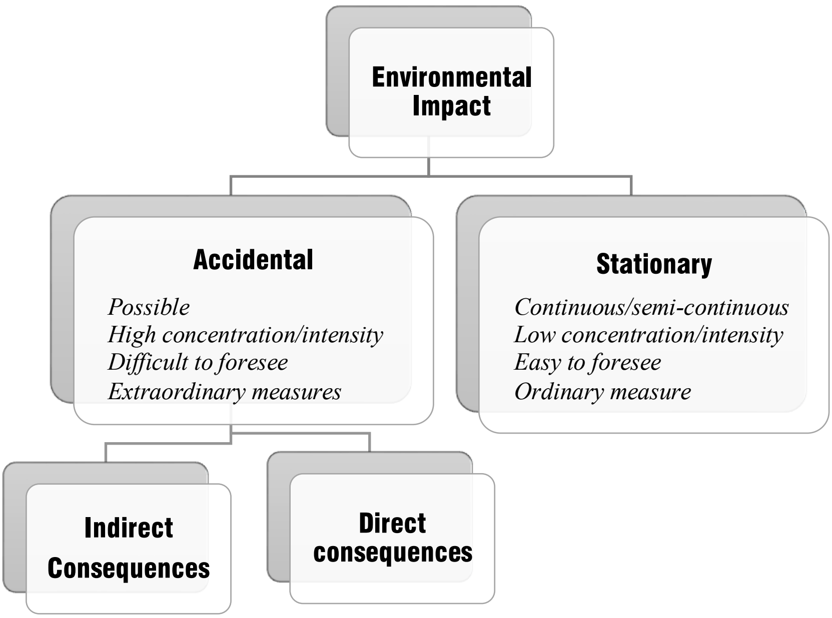


Figure 5. 1 Characteristics of the stationary and accidental consequences of environmental impact

The features of the environmental impact of these accidental events are different of those corresponding to the stationary impact analysed in the previous chapters, as represented in the Figure 5. 1.
Major accidents can affect people, property or environment. Human consequences can be physical (fatalities of injuries) or psychological and can regard both the employees of the establishment and the population or people surrounding it. Damage on property can be serious: the partial or global destruction of the buildings or equipment. The environmental consequences regard the release of hazardous substances. Finally, major accidents could produce economical loss and damage to the image of the port.
Generally, major accidents are associated to the occurrence of fires, explosions or atmospheric dispersion of hazardous materials (Casal, 2008). An accident, moreover, can produce one or more of these phenomena through the domino effects: an explosion can produce a fire, which can cause the explosion of another vessel, etc. All these phenomena occur usually in a short time period and for the failure of one of the several aspect of a port activity.
Fires accidents can be classified into the following categories: pool, tanks, jet and flash fires and fireballs.
A pool fire (Figure 5.2) is a steady state of combustion of a pool of flammable liquid (hydrocarbon) with a given size and shape, determined by the presence of a dike or by the ground slope; most pool fires occur in open air; combustion is poor and large amounts of black smoke are released; large pool fires are turbulent with variable flame length (intermittency). A pool fire can also take place when a flammable, non-miscible, liquid is spilled on water. Tank fires (Figures 5.4, Figure 5.5) are similar to pool fires but usually with a circular shape, where the diameter is determined by the tank size; the flames are located at a certain height above the ground.
The jet fire (Figure 5.3), instead, is a steady state turbulent diffusion of flames with a large length/diameter ratio, caused by the ignition of a turbulent jet or flammable gas or vapour. The combustion is much more efficient than in a pool fire due to the better mixing of the fuel air. The shape and position of the jet is mainly determined by the jet velocity influence (particularly in the case of high-speed jets) and buoyancy effects

are observed at the jet tip. Pool fires, tank fires and jet fires, can produce very high heat fluxes, although this effect is limited to a shorter distance than the one in the explosions.

Flash fires are intense fires in which flames propagate through a mixture of air and flammable gas or vapour within the flammability limits. They are associated with the atmospheric dispersion of gas/vapour under certain meteorological conditions: when the cloud meets an ignition source, the flame propagates through the flammable mixture. In certain conditions, mechanical effects (blast) can also occur. If the vapour comes from a liquid pool, the flash fire will lead to a pool fire.

Finally, fireballs (Figures 5.6, Figure 5.7) occur for the ignition of a mass of liquid/vapour mixture that is typically associated with the explosion of a vessel containing a superheated flammable liquid such as, for example, liquefied propane. Since there is no oxygen inside the cloud, the fire only burns on the outside of the fireball. The density of the mixture decreases and the diameter of the fireball increases. Large (but short duration) fireballs can also occur in tank fires in the event of a boil over.

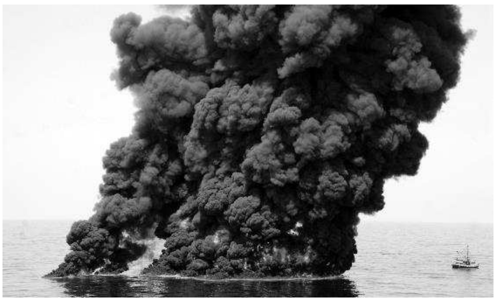


Figure 5.2 Images of a pool fire in the open sea

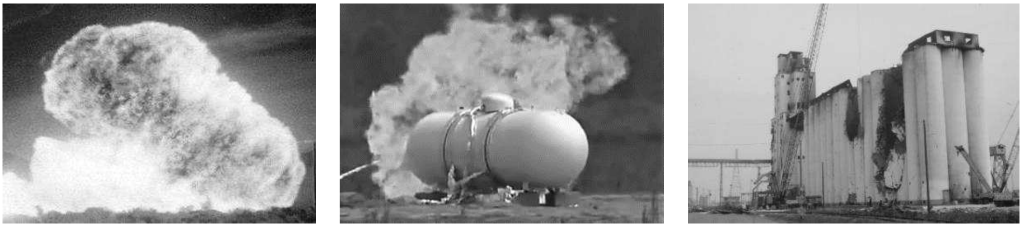
Figure 5.3 Image of a jet fire

Figures 5.4 – 5.5 Images of tank fires


Figures 5.6 - 5.7 Images of a fireball

Explosions are associated with major accidents involving mechanical phenomena. They can occur when there is a rapid increase in volume due to the expansion of a pressurized gas or vapour, the sudden vaporization of a liquid (physical explosion), or a fast chemical reaction (often combustion). Explosions can be classified in three main typologies: vapour cloud explosions (VCE), vessels explosions and BLEVEs, and dust explosions. Firstly, vapour cloud explosions (Figure 5.8), known as VCE, are produced by chemical products involving a significant amount of a flammable gas or vapour mixed with air. They are usually associated with the release of a flammable liquids or vapour-liquid mixtures. A vapour cloud explosion is always accompanied by a flash fire and the severity of the mechanical effects (blast) is determined by the mass involved and the characteristics of the environment (confinement/congestion): there are confined, partially confined and unconfined explosions.
The vessel explosions (Figure 5.9), instead, are physical explosions caused by the sudden failure of a vessel containing a pressurized gas or a superheated liquid (i.e. a liquid at a temperature that is significantly higher than its boiling point at atmospheric pressure) in equilibrium with its vapour. Under certain conditions (currently under discussion), this type of explosion may be referred to as a BLEVE (Boiling Liquid Expanding Vapour Explosion).
Finally, dust explosions (Figure 5.10) are the effect of the fast combustion of finely divided oxidizable particulate solids (such as flour, sugar, cork, aluminium, aspirin and coal) when dispersed in air. Dust explosions are determined by particle size and solid concentration in air and very difficult to model. They occur in confined environments,

commonly inside equipment (silos, cyclones). An initial explosion often generates strong turbulence, which disperses a large amount of dust; it is then followed by a second, much stronger explosion.



Figures 5.8 - 5.9 - 5. 10 Images of a vapour cloud explosion, a fireball during a BLEVE and a silo after a dust explosion

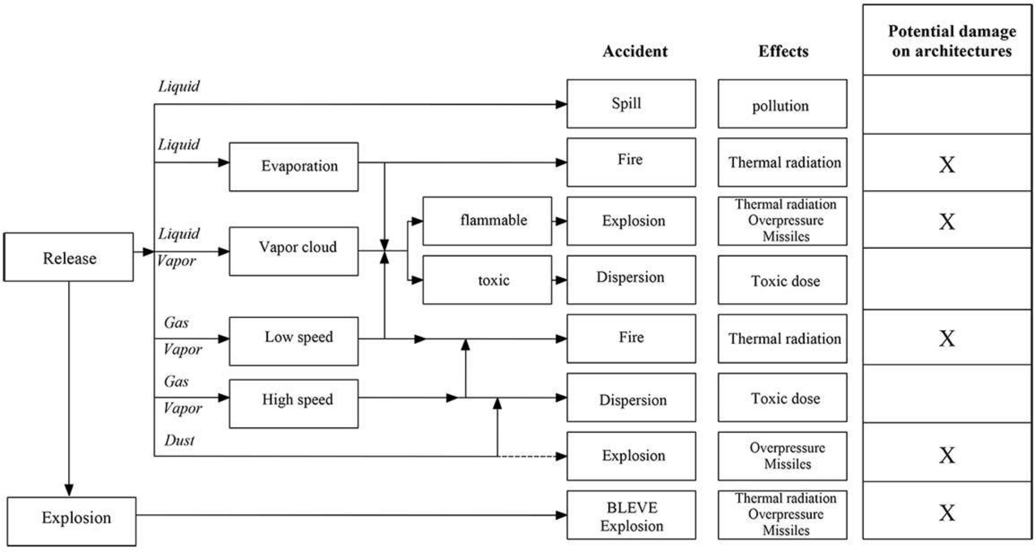


Figure 5.11 Simplified schematic representation of the accidents that can occur following a loss of containment, their effects and the potential damage on historical heritage (adapted from Casal, 2008)

Finally, the release of a toxic material can produce a toxic cloud. Depending on the density of the cloud and on the meteorological conditions, the cloud is either dispersed quickly into the atmosphere or evolves close to the ground and moves at wind speed. Major accidents are often caused by the loss of containment of a hazardous material or of energy, as consequence of an impact, a failure of a piece of equipment (pipe or

tank) due to heating, pressure increase, the effects of corrosion, for a human error during a loading or unloading operation or by various other factors. The loss of containment can be also a consequence of an accident, for instance an explosion. Once released, the evolution depends on the physical state of the substance spilled and can waste both soil, water and air. These phenomena could occur in sequence (Figure 5.11): pool fire can generated toxic clouds, which ignited can produce flash fires or explosions. Particularly, wind and meteorological conditions may encourage the formation of toxic or flammable clouds. These gas clouds, if ignited, can produce flash fires and explosions.
Dust and powder, instead, can produce dangerous clouds when dispersed inside equipment and explosions when it is dispersed in air. These explosions do not follow a loss of contaminant but usually occur inside equipment (silos, dryer or cyclone) or inside a building, although their effects may be felt over a significant area.
Pressurized tanks can explode because of the increase of pressure or temperature. These explosions can produce a blast with effects over large distances. If the material is flammable, the explosion (often a BLEVE) can produce a subsequent fireball. The damage depends on many factors. Specifically, the mass or energy involved in an accident is proportional to the amount of material present in the plant. The effects are inversely proportional to the time during which a given amount of energy or hazardous materials is released: the intensity of the phenomenon at a given distance will be higher. The degree of exposure can have a considerable effect on the consequences of an accident on people in the vicinity. For example, a building can provide very efficient protection for thermal radiation or a toxic cloud, but the short distance to the source can influence the effects.

5.2 Statistical data and historical surveys

Several studies have been developed in order to understand the accidents in port contexts, their causes and consequences. Particularly, a historical analysis (Darbra, et al., 2004) (Darbra & Casal, 2004) has been carried out for accidents in seaports, using data and information contained in the Major Hazard Incident Data Services (MHIDAS) developed and managed by the Safety and Reliability Directorate (SDR). This database, created in 1980, includes incidents occurred from the early 1908s to 2006 in 95 countries of the world. Focusing on “accidents in seaports” the database gives 471 cases. Firstly, the study categorized and classified accidents in relation to the historical period. It points out that the number of accidents increased significantly in the last three decades (84%). This trend could be caused by two factors: firstly, the number of information on accidents increases in the last decades, then we have less information of past events; secondly, the notable growth of the industrial activities in ports has led to higher risks. Other relevant classification was made by typology of accidents occurred. MHIDAS database defined four types of accidents (Figure 5.12): loss of contaminant, fires, explosions and gas cloud. Particularly, it points out that the common incident is represented by the fire phenomenon with 60%, explosions with 35% and gas cloud with 5%.

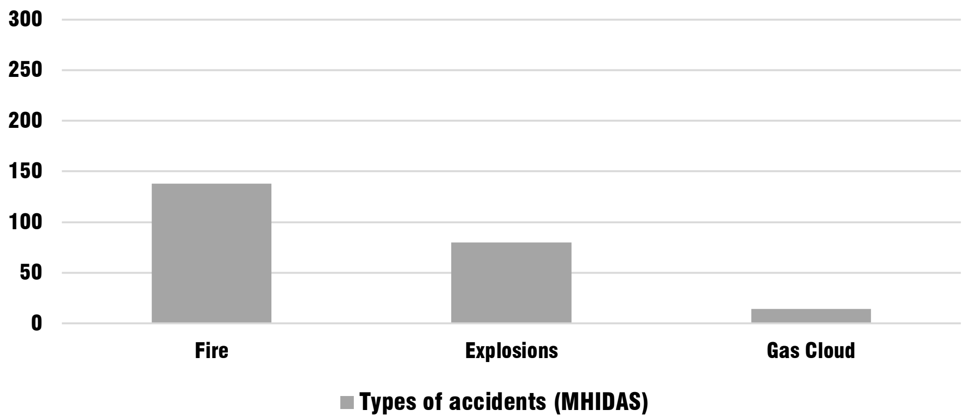


Figure 5.12 Statistical data on the typology of accidents (Darbra, et al., 2004)

In order to individuate the probable causes of the accidents, these authors carried out a classification of the activities involved in the accidents in the MHIDAS database. The database identifies 7 types of activities or places in which accidents took place (Figure 5.13): transport, process plants, storage, load/unload, waste, domestic/commercial and warehouse. On the 471 accidents in seaports, only 1.1 % of them has unknown origin. Regarding the rest of them, transport is the most frequent category (56.5%).

Specific origin	No. of accidents	% of category
Transport		
Ocean going vessel	173	65
Pipeline	31	12
Portable transport containers	26	10
Barge	14	6
Road tanker	12	4
Rail tanker	7	3
Tank container	3	1
Loading/unloading		
Ocean going vessel	24	34
Pipework	10	14
Hose	10	14
Not defined	6	8
Barge	5	7
Portable transport containers	4	6
Road tanker	4	6
Solid conveyance	2	3
Pipeline	2	3
Tank container	2	3
Pumps/compressor	1	1
Rail tanker	1	1
Storage		
Atm. press. storage vessel	31	56
Portable containers	9	16
Solid storage	5	9
Not defined	5	9
Small commercial tanks	1	2
Pipework	1	2
Pressurized storage vessels	1	2
Solid conveyance	1	2
Barge	1	2
Process		
Not defined	19	37
Pipework	7	13
Process vessel	6	12
Reactor	5	10
Pumps/compressor	6	12
Fired process equipment	4	8
Heat exchange	3	6
Process machinery drives	1	2

Table 5.1 Specific origin of accidents in seaports (Darbra et al., 2004)

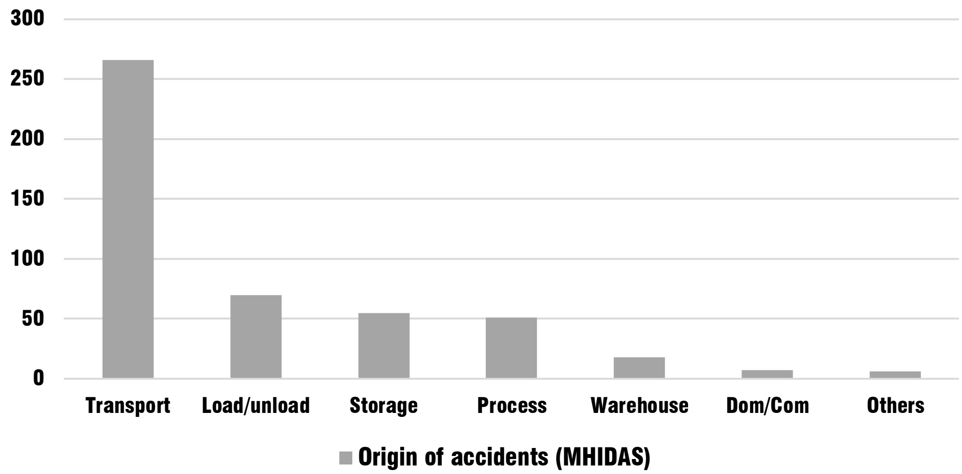


Figure 5.13 Statistical data on the origin of accidents (Darbra et al., 2004)

The most critical aspects of port activities are the transport, the movement and the storage of materials or products, with hazardous potential. Particularly, the transport category includes the movement of ships within the port basin (entering or leaving), of trucks and trains transporting goods. The specific origin of the accidents was assessed for the 4 main categories (Table 5.1): transport, process, loading/unloading and storage. Regarding the transports, the common origin concerned vessels/ship for 65% in this category, followed by pipeline (12%), portable transport containers (10%), road and rail tankers (7%). In the loading/unloading of materials, the highest risk derived from ships (34% of category), pipework (14%), portable transport container, road and rail tankers (13%). The storage was represented mainly by atmospheric pressure storage vessels (56%), portable transport container (16%) and solid storage (9%). In the process category, several cases had not a defined origin (37%). Subsequently, a classification regarding the hazardous materials involved in these accidents was developed. It points out that the majority of cases occurred with oils (59%), followed by chemicals products (4%), acids (3%) and natural gas (3%). In the 40% of cases, others substance were also involved. Thus, an analysis of causes was carried out for major accidents in ports. The database takes into account four types of causes: impacts, mechanical, external, human and others. Particularly, results of statistical analysis point out that impacts are the most common reasons, with 43% of cases.

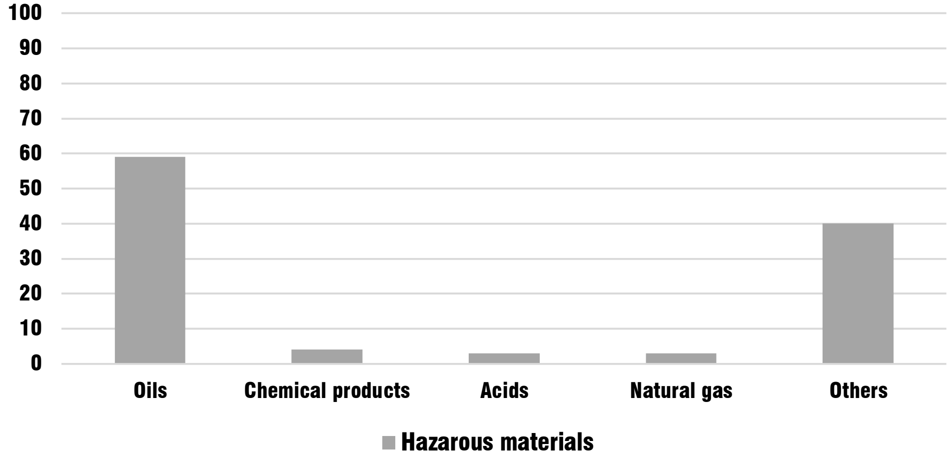


Figure 5.14 Statistical data on the hazardous materials in accidents (Darbra et al., 2004)

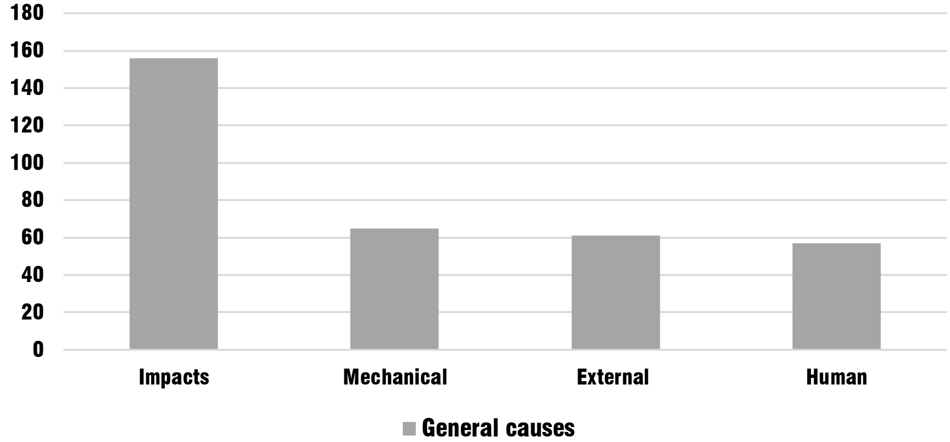


Figure 5.15 Statistical data on the causes of accidents (Source: Darbra et al., 2004)

As shown in the Table 5.2, in the impact category the most relevant factors are collisions, which involved ships, rails and vehicles.

Specific cause	No. of accidents	% of category
Collision		
Ship-land impact	79	45
Ship/ship impact	45	26
General operation	8	5
Heavy object	8	5
Rail accident	7	4
High wind	7	4
Other	20	11

Table 5.2 Specific causes of collisions in seaports (Darbra et al., 2004)

5.3 Assessment of frequencies and probabilities

The assessment of the statistical data and historical accidents is necessary to understand their causes and typologies. For the estimation of the accidental risk (5.1) it is necessary to evaluate both the frequencies of the accidents and the magnitude of the effects on the surroundings.

(5.1) $$\text{Risk} = (\text{Frequency, Potential Effects})$$

The assessment and calculation of the probable frequencies of the accident scenarios is usually carried out through an event tree. An event tree analyses all the sequences in an accident, from the initial event to the outcomes, giving a probable frequency to each possible event. It is important to know or assign a frequency to the initial event (for example ships collision) and, then, to the probabilities, which appear in the sequence of events. These data are obtained from research projects, historical data and from expert judgements. Particularly, in Table 5.3, the probabilities of the accidental sequences and, thus, the frequencies of the common port accidents are listed (Ronza, et al., 2003) (Ronza, et al., 2007).

If no data are available for ships failure, the calculation of frequency of ship collision could be carried out with a generic failure frequency (De Haag & Ale, 1999) (National Institute of Public Health and the Environment - RIVM, 2009):

(5.2) $$f_0 = 6{,}7 \times 10^{-11} \times T \times t \times N$$

where
T is the total number of ships per annum in the port
t is the average time of loading operation for each ship
N is the number of loading operation per annum

Type	Frequency	Units
Ship-ship collision in port water + release	$1{,}0 \times 10^{-5a}$ $4{,}8 \times 10^{-4}$	Harbor movement^{-1} Ship^{-1} x year^{-1}
Collision of two fuel oil tankers, one moored + release	$1{,}48 \times 10^{-7}$	Harbor movement^{-1}
Collision of two LPG carriers, one moored + release	$1{,}48 \times 10^{-8}$	Harbor movement^{-1}
Impact with a jetty while loading, fuel oil tanker	$8{,}16 \times 10^{-5}$	Harbor movement^{-1}
Impact with a jetty while loading, LPG carries	$8{,}16 \times 10^{-6}$	Harbor movement^{-1}
[a] *single hulled ship.*		

Table 5.3 Frequencies of port accidents (Ronza et al., 2003)

Thus, the scenario of ships failure could regard gas tankers, semi-gas tankers (refrigerated), double containment liquid tankers and single containment liquid tankers, as in Table 5.4.

Scenarios	Frequency
Gas tankers:	
Continuous release of 180 m^3 in 1800 s	
Continuous release of 90 m^3 in 1800 s	$0.00012 \times f_0$
	$0.025 \times f_0$
Semi-Gas tankers (refrigerated)	
Continuous release of 126 m^3 in 1800 s	$0.00012 \times f_0$
Continuous release of 32 m^3 in 1800 s	$0.025 \times f_0$
Double containment liquid tankers	
Continuous release of 75 m^3 in 1800 s	$0.0015 \times f_0$
Continuous release of 20 m^3 in 1800 s	$0.006 \times f_0$
Single containment liquid tankers	
Continuous release of 75 m^3 in 1800 s	$0.1 \times f_0$
Continuous release of 30 m^3 in 1800 s	$0.2 \times f_0$

Table 5.4 Scenarios for loss of containment for external impact of ships in ports (National Institute of Public Health and the Environment - RIVM, 2009)

Analysed the frequency of the initial event, it has to be estimated a probable sequence of events, which depends on the type of accident on the hazardous material and on diverse specific circumstances.
The Figure 5.16 shows a generic event tree for a flammable material spill. The first step is the release. Subsequently, an immediate ignition could occur, producing a pool or jet fire, for instance. If the ignition is delayed, there is the possibility of the occurrence of different phenomena: an amount of gas can produce a cloud, which could ends in an explosion. Thus, the other step to be taken into account is the blast wave generation, referring to the different types of explosions. Finally, the best scenario refers to the possibility of no outcome, in terms of major accident.

Especially, two types of ignition were evaluated: immediate and delayed. For petrol and light hydrocarbon fractions the ratio delayed/immediate is 1 (both 50% of probability), such as for LPG. For diesel/kerosene/crude oil, a value of 1/10 (10% and 90%) is considered for immediate and delayed ignition (Casal, 2008). The probability of each of the events has been defined from historical analysis.

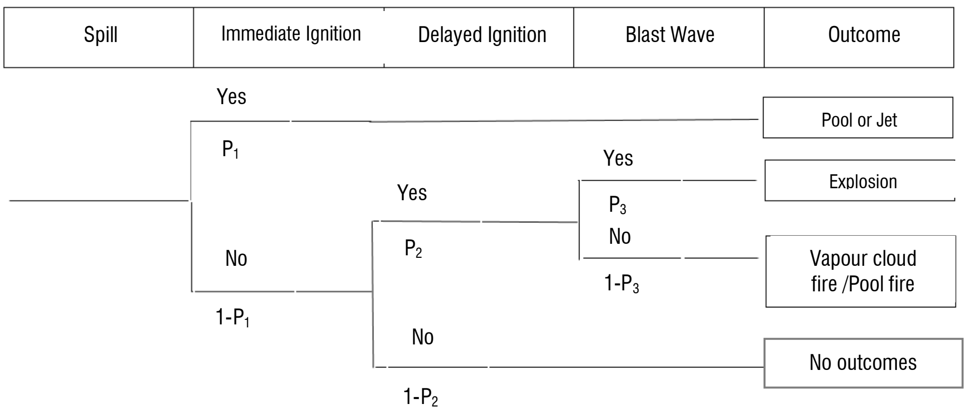


Figure 5.16 General event tree for flammable material leaks (Casal, 2008)

Figure 5.17 shows the event tree for a LPG spill (Ronza, 2007). Different scenarios could follow the initial event. Firstly, an upwards or downwards release can be produced. Subsequently, if an immediate ignition occurs, the higher probabilities regard the fires outcomes, such as jet or pool fires. If the ignition has a delay, instead, there is the possibility that a certain amount of gas cloud is produced in the atmosphere and, then, other phenomenon could be generated: jet and flash fires or a vapour cloud explosion, if flames acceleration occurs. If the ignition does not occur, just a gas cloud will be released. Each of these events has a specific probability of occurrence, calculated by statistical and historical surveys of past accidents.

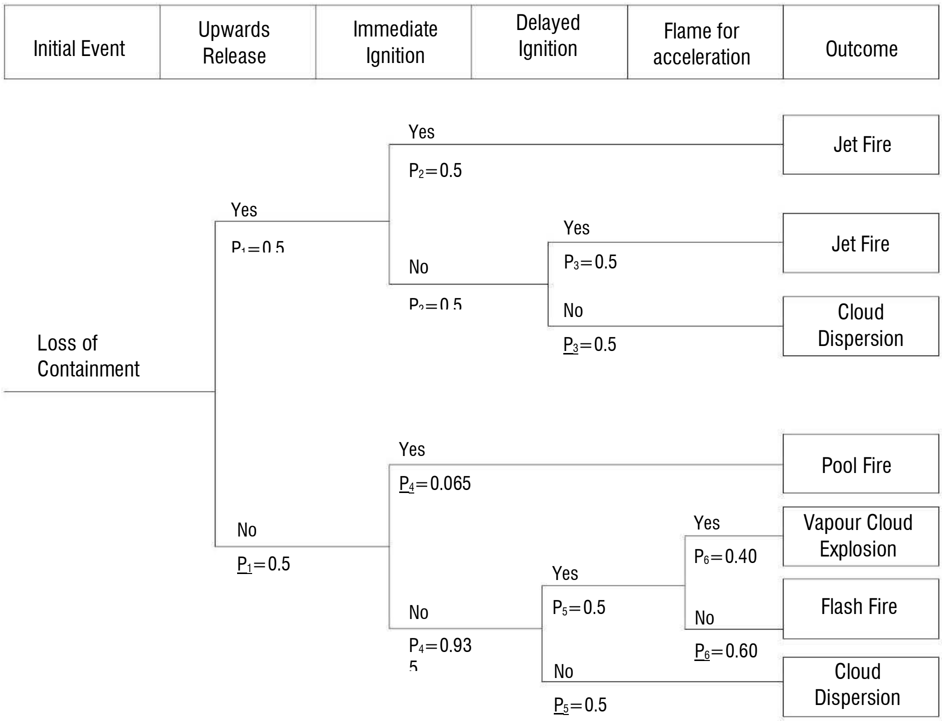


Figure 5.17 General event tree for LPG spill (Ronza et al., 2007)

The event-tree methodology provides the calculation of the frequency (5.3) of the outcome (explosion or fire) through the multiplication of the initial frequency of the first event or failure with the probabilities of the subsequent events (Casal, 2008):

(5.3) $$F_{outcome} = F_{initial} \times P_1 \times P_2 \times .... \times P_n$$

where

$F_{outcome}$ is the frequency of the outcome of the accident

$F_{initial}$ is the frequency of the initial event
P_i is the probability of the possible event in the scenario

In Table 5.5, the calculation of the probabilities from the event-tree in Figure 5.16 has been carried out and listed.

Outcomes	Probabilities
Jet Fires	0,375
Vapor Cloud Fire	0,140
Explosion	0,094
Cloud Dispersion	0,234
Pool fire	0,033
No outcome	0,125

Table 5.5 Probability of accident for a LPG spill (adapted from Ronza., 2007)

5.4 Main features of fires

Most of accidents in modern ports are represented by fires. They could be relevant because of the thermal flux produced or because they can lead to other catastrophes, as explosions. In fact, in most of the accidents occurred in industrial plants, fire is the initial stage, followed by a release or an explosion. The probable sequences of accident could be: fire + larger fire, fire + explosion, fire + gas cloud and fire + BLEVE and fireball.

The combustion is the chemical reaction in which a fuel reacts with an oxidant, yielding various products and energy release. Combustion can occur also in gas phase, when a liquid fuel become vaporized due to the heat of the flames and reacts with oxygen. The main releases are smoke, which also contain unburnt fuel, and the thermal energy. For a combustion to be possible three simultaneous elements are required: a fuel, oxygen and an ignition source.

Different models are used to predict the thermal flux of a fire, in terms of intensity, and then to estimate the effects on people, environment and buildings; amongst them: the point source model and the solid flame model are widely used. The first is the simplest model and it can be used to predict the intensity of fires at a large distance. For the nearness of fire source the second model is much more efficient, which associates a fire to a solid model (Casal, 2008).

5.4.1 The point source model

The simplest method to predict flames intensity is the point source model (Casal, 2008), which associates to a point the source of a fire. Particularly, this point is located at the centre of the flames and it is assumed that the energy is radiated in all the directions, such as a sphere. It is proportional at the inverse of the square distance between the source and the target.

(5.4) $$I = Q_r \div \left(4\pi\ L^2\right)$$

Where
I is the intensity of the heat flux (kW m^{-2})
Q_r is the heat released as thermal radiation per time (kW)
L is the distance from the target

The radiant heat flux, for pool and jet fires, can be calculated as:

(5.5) $$Q_r = \mu_{rad}\ m\ \Delta H_c$$

Where
m is the burning rate (kg s^{-1})
ΔH_c is the heat of combustion
μ_{rad} is the radiant heat fraction

For a pool fire (with a diameter D) the radiant heat fraction can be calculated with the following expression:

(5.5) $$\mu_{rad} = 0{,}35\ e^{-0{,}05D}$$

Considering the absorption of the heat by the atmosphere and the position of the target the formula becomes the following:

(5.6) $$I = \left(\mu_{rad} m \Delta H_c \tau \cos\phi\right) \div \left(4\pi\ l^2\right)$$

where

τ is the atmosphere transmissivity

ϕ the angle between the horizontal and the distance source-target

5.4.2 Flame solid model

The flame solid model (Casal, 2008) is the one commonly used to estimate the thermal radiation from fires, being much more accurate than the flame point model.

The flame solid model assumes that fire is a still, grey body encompassing the entire visible volume of the flames, which emits thermal radiation from its surface. The irradiance of the smoke plume above the flames (much lower than of the flames) can be partially taken into account. The shape of the flames depends on the type of fire: for a pool fire, the pool shape is essential; if it is circular, the fire will approximate to a cylinder. About the shape and size of the fire, it is worth saying that they could change with time due to the turbulence of the phenomenon, for instance, or due to the existence of wind. The model considers an average and maximum values. Thus, the thermal radiation intensity reaching a given target is:

(5.7) $$I = \tau \, F E$$

Where

I is the intensity of the radiation (kW m^{-2})

τ the atmospheric transmissivity (-)

F the view factor (-)

E the average emissivity power of the flame (kW m^{-2})

Particularly, the flame solid model calculates the intensity of the thermal effect in relation to the type of fire: the components of the expression (5.7) are different for pool, flash, jet fires and fireballs, for instance. The calculation depends on the solid shape, which will vary with the type of fire.

5.4.3 Effects on building and equipment

The damage on buildings caused by thermal flux can vary according to the thermal radiation intensity and the exposure time (Table 5.6). According to the distance between the source and the target (in this case a building or an equipment), the materials of the architecture and the intensity of the heat flux, several effects could be produced. Firstly, a potential consequence could be the damage of the surfaces, which can become discolored or peeled off; this is the most common effect and can regard all the materials of buildings. Another effect, more severe, could be the ignition of combustible materials, such as wood. It could lead to the whole collapse and loss of the building. In case of iron-concrete or metal structures, the deformation and, then, failure of them can occur. Other possible damage is the breakage of glasses and other finishing elements.

Effect of thermal flux on architectures
• surfaces or paints of buildings become discolored or they pills off; • deformation and failure of structural elements, such as they are iron or concrete-iron made; • ignition of combustible materials, such as wood; • breakage of glass

Table 5.6 Damage to buildings and structures (Casal, 2008)

The damage depends on the heat flux, on the properties of material and on the physical characteristics of the element (thin or thick). Particularly, among the combustible materials there are plywood, particleboard, hardboard, polystyrene, polycarbonate, carpet, polyester and others. According to the characteristics of construction materials, it is possible calculate the temperature of ignition (Casal, 2008). The ignition of solids depends on materials and thickness. In fact, for thin (5.8) and thick (5.9) materials the ignition time is:

(5.8) $$t_{ig} = \rho\ c\ L\ \left(T_{ig} - T_0\right) \div I$$

(5.9) $$t_{ig} = 2\rho\ c\ L\ \left(T_{ig} - T_0\right) \div 3I$$

Where

t_{ig} is the ignition time (s)

c is the specific heat at constant pressure (KJ Kg^{-1} K^{1})

L is the thickness of the material (m)

T_0 is the initial temperature of the material (K)

T_{ig} represents the temperature of ignition (K)

I is the intensity of the heat flux (kW m^{-2})
ρ the density of the material (kg m^{-3})

5.5 Main features of explosions

Explosions are frequently present in industrial accidents. In effect, in an analysis of 5325 accidents, the 36% of them were explosions. In a recent analysis of transport system accidents, one in 9.5 cases led to an explosion and one in every 15 accidents was a combination fire-explosion. A survey on port accidents pointed out that one in 6 release-fire events produces an explosion (Casal, 2008). They are relatively important because their effects are destructive on people, environment and equipment.
Explosion can be modelled in order to understand the consequences and effects, in relation to the characteristic of the accident and the material involved. Particularly, different types of explosion can be identified as a function of the degree of confinement or whether the involved material is in the cloud or inside an equipment, as in Figure 5.18.

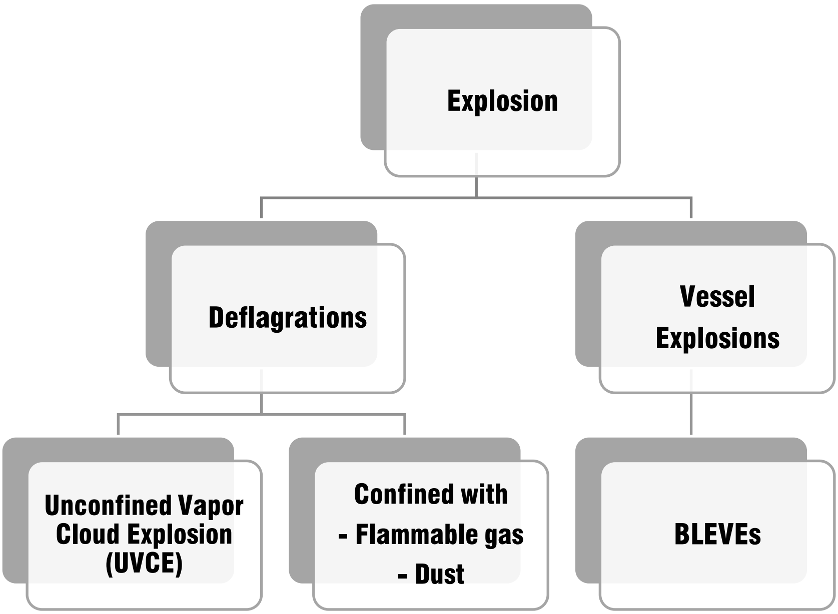


Figure 5.18 Typologies of explosion (Casal, 2008)

5.5.1 Vapor Cloud Explosions

Vapor cloud explosions are produced by the loss of containment of a flammable gas/vapor or liquid. This gas/vapor can be originated from a spill of liquid evaporated from a pool, from a release of gas or vapor or from a release of a superheated liquid. Under certain conditions, a flammable cloud may form. If ignited, the cloud can produce a flash fire. In addition, it is possible that flash fire and a mechanical explosion will take place both. For the occurrence of an explosion, some condition have to be present: the presence of a flammable substance; a delay in ignition; a cloud limited to a minimum size, and the presence of turbulence (release mode or presence of obstacles) or partial or total confinement.

If these conditions occur, it is possible the development of an explosion with blast effects on the area surrounding it. The energy released is a function of the amount of flammable substance. The most important feature of an explosion is the blast, which occurs when the energy involved in the explosion (originated from the heat of combustion) is partly converted into mechanical energy.
When an explosion occurrs, the initial condition is P_0 (atmospheric pressure). After the blast, the pressure increases instantaneously to a value $P_0 + \Delta P$ and afterwards it rapidly goes to a negative value and finally to the initial pressure. This is called *overpressure wave.* The overpressure wave has a positive phase and a negative one. The peak of overpressure is ΔP and it is the parameter used to evaluate the effects of a blast.

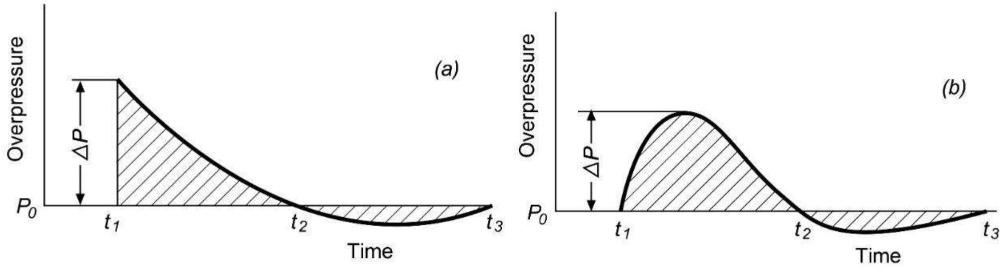


Figure 5. 19 Shape of the overpressure wave for a) detonation and b) deflagrations (Casal, 2008)

Explosions can be divided in two categories: detonations and deflagrations. In the detonation, the blast wave develops at supersonic velocity. It has a characteristic shape with a practically instantaneous increase of pressure. Instead, in the case of deflagrations the wave travels at a speed lower than the speed of sound and, furthermore, the increase of overpressure, even if very quick, is slower than in the case of a detonation. Due to this different behavior, for the same amount of explosive detonation are more destructive than deflagrations.

In vapor cloud explosions, because the volume of the vapor-air mixture is large and the rate of energy release is relatively slow, the explosion is practically always a deflagration. Vapor cloud explosions are characterized by a large amount of vapor-air mixture released slowly; the wave is smoother and propagates at a subsonic velocity. When the explosion occurs in open spaces, the shape of the blast wave is spherical (free-air explosions). If an explosion occurs near a surface, the blast would have a hemispherical shape (ground explosions) (Casal, 2008).

One of the most common models to evaluate the effects of blast and explosions is the TNT model. It consists in estimating a "TNT equivalency" of the phenomenon or accident (Casal, 2008). In vapor cloud explosions, the equivalent mass of TNT is calculated using the following formula:

(5.10) $$W_{TNT}\,(kg) = \mu\, M\,(\Delta H_C \div \Delta H_{TNT})$$

Where
M is the mass of fuel in the cloud (kg)
ΔH_C is the lower heat of combustion of the fuel (kJ kg^{-1})
μ is the explosion yield factor (0,03)
ΔH_{TNT} the lower heat of combustion of the TNT (4680 kJ kg^{-1})

The yield factor depends on the reactivity of the fuel and the confinement of the cloud. Once evaluate the equivalent mass of TNT, the scaled distance has to be calculated:

(5.11) $$d_{sc}\,(m) = R \div (W_{TNTz})^{1/3}$$

Using the following function, the scaled distance is associated to the peack of overpressure at a specific distance:

$$\Delta P\,(bar) = 1 \div d + 1 \div (d)^2 + 1 \div (d)^3 \quad (5.12)$$

Peak Overpressure (kPa)	Damage	Peak Overpressure (bar)
0.15	Annoying noise	0.0015
0.2-2	Beyond it no serious damage, only windows	0.002-0.02
3	Limited minor structural damage	0.03
3.5-7	Windows and frames shattered	0.035-0.07
5	Minor damage to house structures	0.05
7	Collapse of a roof in a tank	0.07
8	Partial demolition of houses, made uninhabitable	0.08
7-15	Corrugated iron covers and panels shattered	0.07-0.15
15	Partial collapse of walls and roofs houses	0.15
15-20	Unreinforced concrete or cinderblocks walls shattered	0.15-0.20
18	Lower limit of structural damage; 50% destruction of brickwork buildings	0.18
35	Most buildings destroyed, except concrete-reinforced-walls buildings	0.35
35-50	Near-complete destruction of houses	0.35-0.50
50	Brick walls, 30 cm thick, collapse	0.50
70	Probable total destruction of buildings	0.70

Table 5.7 Damage to buildings, structures and equipment (Casal, 2008)

Once defined the peack of overpressure, a level of damage could be associated to it, using the Table 5.7. The damage caused by an explosion on the surrounding buildings depends on the peak of overpressure and the context morphology. Particularly, for overpressure less than 3 kPa, the damage on buildings is not serious, regarding only the breakage of windows in most of cases. Peaks of overpressure from 5 to 18 kPa, instead, can produce severe damages on structures, although not the complete destruction of them. If the ΔP has a value from 15 to 18 kPa 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 18 kPa overpressures, serious structural damages are likely to occur on buildings and equipment: at 35 kPa most of buildings are destroyed, while from 50 to 70 kPa the destruction of the most resistant structures is possible. Another simpler classification of damages defines four macro-levels of damages (Stephens, 1970): light ($\Delta P > 3.5$ kPa), moderate ($\Delta P > 17$ kPa) and severe damages ($\Delta P > 35$ kPa) and total destruction ($\Delta P > 83$ kPa).

5.5.2 BLEVEs and vessel explosions

BLEVEs are vessel explosions involving superheated liquid, i.e. a liquid which is contained in the vessel at a temperature significantly higher than that its boiling temperature at atmospheric pressure. This accident is one of the most severe that can occur in an industrial plant or in the transportation of certain hazardous materials. Particularly, BLEVEs produce both mechanical and thermal effects on the surroundings. In fact, if the material contained in the vessel is flammable, after the explosion a fireball could also occur. An analysis of 70 accidents between 1970 and 2004 led to the determination of the principal causes of BLEVEs, shown in the Table 5.8.

The most frequent materials involved were the LPG and propane, followed by gasoline. BLEVEs have two main characteristics: firstly, the significant superheating of the liquid (LGP, ammonia, chlorine etc.) and secondly, an instantaneous depressurization, related to the failure of the vessel.

These explosions occur when there is a superheated liquid in a tank. This heat could be produced also by an external accident, as a fire affecting (flames impingement, strong radiating flux) the vessel. Particularly, this fire produces the boiling of the liquid, which starts evaporating thus increasing the pressure. In the vessel, then, there will be both vapor and liquid at high pressure and temperature. A failure of the vessel, for example of the decreased resistance of the walls due to the excessive heating, produces the release of vapor and an instantaneous depressurization at a high temperature. The liquid increases in volume when evaporates instantaneously (about 1400 times for water, about 400 times in the case of propane or butane) and originates the explosion of the vessel. If the substance is not flammable, only pressure wave and missiles are produced (this would be the case of a boiler or steam generator, when the water is involved). In the other case, flammable liquids can burn and produce a fireball [3]. The effects of a BLEVE are summarized as follows:

- Pressure wave;
- Flying fragments or missiles;
- Thermal radiation (only for flammable substances).

Cause	Materials
Train derailment 33% External fire 17% Loading/unloading 16% Road tanker accident 14% Overfilling 4% Runaway reaction 4% Other 12%	LPG Propane Gasoline Chlorine Water Vinyl chloride Hydrogen, Ethylene, Acroleine

Table 5.8 Most frequent causes and materials involved in a BLEVE (Casal, 2008)

The blast wave can be evaluated by the TNT model, estimating a "TNT equivalency" of the phenomenon or accident (Casal, 2008). In BLEVEs, firstly, the vaporization fraction f has to be calculated, with a function depending on the specific heat of the liquid (C_{pl}), the temperatures (T,T_0) and the liquid vaporization heat (ΔH_{vT0}). The following formulation is obtained from a heat balance:

(5.13) $$f = C_{pl}\ (T - T_0) \div \Delta H_{vT0}$$

where
c_{pl} is the specific heat of the liquid, kJ kg^{-1} $^{o}C^{-1}$
T is the temperature insede the vessel just before the explosion, ^{o}C
T_o is the boiling temperature of the substance at atmospheric pressure and
ΔH_{vTo} is the liquid vaporization heat at T_o, kJ kg^{-1}

After that, it is possible to estimate the volume of the vapor generated in the vessel (V*), which is the cause of the BLEVE. It has two contribution, one depending on the vapor previously existing inside the vessel (V) and the other one the amount of vapor generated in the explosion due to the vaporization of the liquid. It can be calculated with the following expression:

(5.14) $$V^* = V + V_L \text{ x } f(\rho_{Liq55} \div \rho_{vap55})$$

Tehn, once obtained the volume of vapor involved in the BLEVE, the TNT equivalent mass is possible to estimate:

(5.15) $$W_{TNT}\,(kg) = 0.021(P \times V^*)/(\phi - 1) \times [1 - (P_0 \div P)^{\phi - 1/\phi}]$$

where
P is the pressure in the vessel (bar)
P_0 is the atmospheric pressure (bar) and
ϕ is the ratio of specific heats (-)

Since a fraction of the energy released in the explosion is devoted to break the vessel and to eject the resulting fragments, a correction must be made. Therefore, the amount W_{TNT} is reduced by the factor β=0.5 (this meaning that only half of the energy released is invested in creating the overpressure wave). Then, the “scaled distance” can be calculated.

.(5.16) $$d_{sc}\,(m) = R \div (\beta \times W_{TNTz})^{1/3}$$

Using the following function, the scaled distance is associated to a pick of overpressure at a specific distance:

(5.17) $$\Delta P\,(bar) = 1 \div d + 1 \div (d)^2 + 1 \div (d)^3$$

Projectiles are one of the effects of a BLEVE and are difficult to evaluate, because of their random behavior. They can induce domino effects if they hit other vessels, for instance. These elements could reach high velocities and cover large distances (Casal, 2008). There are two types of projectiles:

- Primary projectiles, which are major pieces of the container;
- Secondary projectiles, which are generated by the acceleration of nearby objects (pipes, bars, bricks, others).

The number of projectiles depends on the type of vessel, its shape and the severity of the explosion, among others. For instance, a fragile failure –not common- could be more severe and its projectiles could reach larger distances. Typically, vessels have a ductile failure and, then, less energy is involved, even though their effects can still be very serious. In the case of spherical vessels the number and size of fragments can not be predicted; instead, for cylindrical vessels often two fragments are generated: one bottom and the rest of the vessel (this second one with a somewhat aerodynamic shape, which allows reaching higher distances), which are ejected following approximately the vessel major axis direction.
The distance reached by the projectiles, considering a cylindrical vessel, can be estimated with the following functions, where M is the mass of the fuel in the vessel:

(5.18) $$d = 90 \times M^{0.33} \quad (\textit{for tanks} < 5\ m^3 \textit{ of capacity})$$

(5.19) $$d = 465 \times M^{0.1} \quad (\textit{for tanks} > 5\ m^3 \textit{ of capacity})$$

These functions consider a tank with the 80% full of LPG at the time of failure and the fragments are launched with an optimal angle of 45° on the horizontal. In most of cases, there are not these perfect conditions, but, at 80%, it could be assumed that they would have these characteristics. Other guidelines for estimating the range of projectiles are:

- 80-90% of fragments fall at 4 times the fireball diameter;
- Extreme fragments may travel 15 times the fireball radius;
- In very severe accidents, they can travel 30 times the fireball radius.

5.5.3 Dust and powder explosions

Finally, the third typology of explosion that could occur in ports is caused by fine dust or powder. Particularly, they refer to confined spaces, such as silos, pneumatic conveying lines, cyclones, etc. and involve particulate solids, as flour, grain, sugar or coal, among the others.

The phenomenon can be represent with a pentagon model, such as fires are related to a pyramid. There are five elements necessary to produce a dust explosion: the presence of a combustible dust in a finely divided form; the availability of oxidant; the presence of an ignition source; some degree of confinement; mixed reactants (Casal, 2008).
The industries or facilities prone to dust explosion are several. Among them, there are grain elevators, bins and silos; wood storage and process; manufacturing of aluminum and magnesium, of chemical and plastic, sugar and cocoa, coal and pharmaceutical products. Dust explosion can be caused by different types of activities and equipment, such as storage, cyclones, driers, packing and other operations. The ignition sources could be flames, heat, contact with incandescent materials, hot surfaces, electrical/impact sparks, static electricity, lightening and shock waves. The phenomena of a dust explosion can structure in different steps: a primarily explosion, with a blast wave; it produces a dust cloud, which often generates a second stronger explosion. Both explosion occur in confined spaces, such as vessels or silos and others. The effects of secondary explosions can go outside the equipment/building, with a sometimes very strong overpressure wave. In a survey conducted by the Berufsgenossenschaftliches Institut fur Arbeitssicherheit (BIA), 1120 explosions were identified in USA and Germany during the period 1900-1956. The 48% of them (536 explosions) involved industries handling grain, feed and flour. Among the very severe explosions occurred, theone in Ingeniero White premises (Port of Bahìa Blanca, Argentina) was quit important.

Events	F, P
Ignition in a silo cell	1×10^{-5} year^{-1}
Ignition in an over-cell gallery or handling tower	1×10^{-4} year^{-1}
Propagation to a direct neighboring module	10%
Propagation to a remote neighboring module	1%
Propagation outside the group	0%

Table 5.9 Frequencies and probabilities of various events (Van der Voort et al., 2007)

The high frequency of explosions involving grain occur because it generated very fine dust which can ignite and propagate flames easily. The source of heat required is small (Abbasi & Abbasi, 2007). According to scientific literature (Van der Voort, et al., 2007)

(Demontis & Cremante, 2012), dust explosions could produce several typology of effects on the surroundings. Firstly, debris and fragment are thrown at long distances, as well as a blast wave. Secondly, flames are produced. Finally, the bulk is released in the atmosphere. These effects could be lethal for people, buildings and environment.

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}

Table 5.10 Expected frequencies of obtained from grain explosions in USA (Demontis et al., 2012)

Particularly, some statistical studies (Demontis & Cremante, 2012) point out that the "expected frequency" of a dust explosion is function of the million tons handled per years and of the "operative hours" of the grain storage facility. For facilities with more than 1.5 tons of grain handled, the higher frequency has obtained. In fact, the expected value has an order of magnitude of about 10^{-5} (op. h)$^{-1}$, which is a limit value between probable and remote probability (Table 5.10). Despite grain storage explosion are more frequent in USA or in Germany, the following data can be consider valid for other European countries, such as Italy [13].

Probability per operating hours in Europe	Numeric Probability per operating hour	Probability per operating hours in USA
Frequent Reasonable probable	$1 – 10^{-3}$ $10^{-3} – 10^{-5}$	Probable
Remote Extremely remote	$10^{-5} – 10^{-7}$ $10^{-7} – 10^{-9}$	Improbable
Extremely improbable	Over 10^{-9}	Extremely improbable

Table 5.11 Descriptive probability scale for Europe and USA (Demontis et al., 2012)

The modelling of the effects and consequences of dust/powder explosions is 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, several 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. It was 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 involve a large area surrounding the silo. Particularly, fragments and projectiles were founded at a distance of 500m from the source, producing damages to dwellings (the closest ones were 230 m far), especially broken windows. The main damages were recording at a distance less than 100 m, in terms of projectiles (Masson & Lechaudel, 1998).

Chapter 6

Guidelines and strategies for preservation

6.1 Conservation criticalities in port areas

Ports, since ancient times, have represented very dynamics areas, where innovations, technological progress and engineering continue to upgrade and transform spaces, activities and organization. In effect, port basins with their docks, piers and facilities have been used over the centuries for commercial and military functions. In fact, until the end of the XIX century, port areas have been periodically modified or integrated with new structures and infrastructures because the innovations in navigation, architecture and engineering led to their improvement and to a higher security. Despite these interventions, between the VI and the XVIII century, ports and cities have preserved a synergic relationship. Particularly, ports have represented a central node of development for urban zone. Their facilities and spaces were part of the urban fabric of coastal cities and they were built with traditional techniques constructions, as well as the urban buildings, preserving a homogeneous image of the port-city and a balance between productive activities and urban life. According to these aspects, the environmental conditions in which historical heritages of port areas were located in this period have contributed to preserve the majorities of their architectural, material and cultural properties.

Since the 19th century, instead, historical ports have gone through the transformation and integration of spaces and functions, resulting in industrial and commercial areas with no more urban size. In effect, new docks and piers were erected producing large expansions of port basins and separating them definitively from the city. The new structures, which have been built in XIX-XX centuries, were characterized by new construction techniques and materials completely different from the urban fabric - iron, iron-concrete and bricks - mixed to the traditional ones. Furthermore, the large dimension of the new warehouses, forced to locate them on piers, connected to the railway through high mechanical cranes. These changes were principally caused by the evolution of the transport systems, such as the introduction of steamers as ships and trains as land carrier, among others. The industrial propensity of port activities in the XX century has produced a deterioration of environmental conditions with serious effects on built heritage, such as materials decay and losses of artistic and cultural properties. Besides the pathological consequences, also a functional obsolescence has characterized historical facilities of ports. In effect, the new activities required different typologies of buildings and spaces, with other dimensions and morphology, contributing to the abandonment and decommissioning of most of ancient structures.

This trend, which has produced a very wide amount of decommissioned historical facilities and spaces, was confirmed since the 60’ of XX century. In the last decades, in fact, ports have gone towards industrial and energetic production and commercial activities have completely changed, with dynamic functions and flexible and no more static storage. The separation from the city has been realized definitively with the transition from a segmented system to the integrated transport: the use of containers, transported on ships, trains or vehicular transport. The hangar becomes the new architecture of modern ports, a simple storage for transit commodities, which have increased even more the gap between urban and port environment. Actually, port areas are often characterized only by flattened asphalt, on which are deposited hundreds of containers, waiting to be deployed elsewhere.

According to the mentioned aspect, the conservation and management of historical facilities of ports has become critical. In effect, today, several ports in Mediterranean context have a heterogeneous heritage with a very low state of conservation and, generally, characterized by obsolescence from a material, functional and technological point of view. In addition to this, the main threaten for Mediterranean ports is the potential loss of historical authenticity and socio-cultural identity, which depends on the tangible and intangible values that are a unique cultural testimony.
Firstly, the physical and material obsolescence is produced by different factors of deterioration, which involve the architectural elements and the constitutive materials of the historical heritage. Specifically, it is caused by several hazard factors present in ports, which generate a progressive and rapid state of decay. As described in the previous chapters, port activities can generate negative effects, in terms of chemical aggression of buildings materials as well as of abandonment and lack of maintenance of heritage, which lead to decay and deterioration. In effect, it is commonly accepted, since the Venice Charter of 1964, that one of the main factors, which contribute to preserve a monument or a historic building is the continuity of use. In port context, the functional obsolescence is a very widespread deficiency, considered the several transformations in ports organization in the last two centuries. Exactly, it occurs when a building or a space no longer guarantees the execution of the functions for which it was designed. Thus, many ancient structures or spaces are today inadequate to be used for port activities and need to be reconverted and adapted for a new use, which need to be compatible with their conservation. The reasons of these inefficiencies can regard the dimensions or the spatial morphology of heritages, for instance. Another progressive process that often characterizes port heritage is the obsolescence, which appears when it does not respect the new standards and regulations, in terms of technical and technological performance. For these reasons, in the last decades, ancient facilities and

structures have been decommissioned and abandoned, resulting in a consequent decay process.

Nowadays, historical ports and waterfronts need to be regenerated, redeveloped and enhanced in order to give back these areas to the cities and to the citizens. However, this process has to be oriented to an integrated and sustainable development, in the view of the preservation of cultural, historical and social values of ports.

6.2 Guidelines for conservation and enhancement of historical ports

The necessity to regenerate port areas awoke in the middle of the XX century in USA (Vigarié, 1991) (Charlier, 1992) (Hoyle, et al., 1994) (Marshall, 2004) (Gras, 2013). The reasons of this trend concern principally the decommissioning of several ports after the II World War. From the first experiences of waterfront regeneration of the second half of 20th century to the actual policies for sustainable redevelopment of ports, different approaches have been experimented with not always positive results.

The first approach of waterfront conversion took place in USA in the '60 with the interventions in the port of Boston, Baltimore and San Francisco (Hoyle, et al., 1994) (Rodrigue, 2003). Particularly, in San Francisco a regeneration project of a wide decommissioned urban area has been effectuated. The urban plan provided the reconversion of a port area between the Pier 39 and the Hyde Street Pier, which were reopened with public functions and commercial, cultural and touristic activities. In effect, the *American approach* often proposed the transformation of port spaces into functions able to attract tourists and population, such as cultural, recreational and commercial activities with luxury hotels or congress centres. This is the case of Baltimore, which was characterized by the reconversion of the Inner Port with a global touristic project, composed by an aquarium, a congress centre, marinas, restaurants and several luxury hotels. These projects immediately had a great success but suddenly some criticalities came out in the port-city relationship. In effect, the interventions of reconversion focused only on waterfront areas neglecting the areas immediately behind, leading to a separation to the other urban contexts and generating differences between rich and poor clusters.

The second generation of port reconversion was the "*service industry approach*", specifically applied between '70 and '80 in London, Sidney and Brisbane, among the others. The main model was London, with the Docklands (Charlier, 1992) (Michon, 2008): the decommissioned river docks were transformed into tertiary spaces, with several offices palaces, business centres, high-tech lofts and luxury apartments. As the American approach, also the British and Australian models showed subsequently some further issues: firstly, the housing crisis of '90 and, secondly, the speculation process. Furthermore, the first approaches described have led waterfronts to lose their historical, cultural and social identity, with imbalances between city and ports and the generation of separated clusters.

The third experience involving waterfront regeneration concerned mainly Mediterranean port cities at the end of '90, such as those of Genoa, Barcelona and Marseille (Lorente, 1996) (Monclùs, 2003) (Jauhiainen, 1995) (Bruschi, et al., 2011). The "*South-Europe approach"* tried to preserve the traditional and maritime vocation of port cities, giving them a new image with innovative projects. This trend is also known as *event approach* because the waterfront enhancement has been carried out thanks to the organization of an international event, such as the Olympic Games, the Expo and others. The main goal of these projects was to recompose the relationship between port and city, the waterfront representing a showcase to exhibit their potentiality and innovations. The public space was the essential dimension of the regeneration process: maritime promenades, squares and pedestrian paths.
Particularly, the regeneration of Barcelona in 1992 has given to the town a rebirth of the historical waterfront: the railroad, which separated the city from the port for decades, has been relocated, opening the urban historical district to the sea. Furthermore, new cultural, social and touristic activities were located in the *Port Vell* - the ancient port- giving to warehouses and port facilities public functions: museums, offices, an aquarium, commercial centres were located in strategic points of the port-city system. Despite the new functions and transformations introduced, the historical vocation and identity of the city, including monuments and historic landscape, was preserved and enhanced, giving to the city a new renaissance. Significant examples of good-practise

are certainly the restorations of the ex-*deposito commercial*, today Museum of the History of Catalunya and of the *Reials Drassanes*, the ancient arsenal of Barcelona, today Maritime Museum of Barcelona. In the first case, the historical structure, placed on the ancient docks of the *Port Vell,* has been decommissioned since the post-war period and it was in a very low state of conservation in the first years of '90. The restoration project, included in the port redevelopment, has given to the building a new function respecting and enhancing the local traditions and history. In the second case, instead, the ancient arsenal was transformed into a centrality for the city, housing an exposition of the history of ports, navigation and shipping referred to international, national and regional cases.
In addition to this, the restoration project of the port of Genoa in 1992 also represents a good-practise example for the reconversion and redevelopment of historical waterfronts. One of the reasons of success of the project of Renzo Piano was the innovative governance. In effect, in order to make possible this reconversion, as well as the management of the ancient port areas, a new company was founded, with limited participation: the 51% by Municipality of Genoa, the 43.44% by the Chamber of Commerce and the 5.56% by the Port Authority. As in the case of Barcelona, in the restoration of the waterfront the open space is the key factor. In fact, the restored ancient docks actually house several public spaces, touristic and commercial activities. The decommissioned port facilities have been reconverted and restored, such as the Cotton Warehouses, a 300 meters long building of 4 floors. Since the '92 the warehouse houses a congress centre dedicated to conferences, expositions and other activities, representing a central node of Genoa, together with the aquarium and other maritime buildings.

Another approach of port regeneration is known as "*Saint-Nazaire style*" (Lecardane & Tesoriere, 2013) (Saunders, 2001). This French city represented an important military port in the II World War, housing a large fortified U-boat base built by the Germans. For this reason, during the war, the port was bombarded and destroyed by Britain fighters. After the war, in the '90, Saint-Nazaire went through an economic and demographic depression and the municipality decided to modernize the port in order to redevelop the city. The central point of the project was the reconversion of the U-boat base, transformed in a 3 floors public building with a wide green terrace and completed in 1998. This approach gave a relevance to the maritime and naval architecture of ports, from a military to a public and touristic dimension. The submarine base, thanks to this project, has reached an international acknowledgment and has been honoured as "heritage of the XX century". Other cases, similar to Saint-Nazaire, can be Plymouth and Portsmouth (UK), where the military docks of the port have been converted in public spaces, with the restoration of decommissioned military ships and open to population and tourists (Hoyle & Wright, 1999) (Ricaud-Dussarget, 1999).

In recent years, the energetic crisis and the industrialization contributed to sensitize the international attention to the sustainability of human activities, which has involved port areas too. In effect, the most current trend is certainly the "*sustainable and ecologist approach*" (Wakeman, 1996), also in reconversion projects: Vancouver is surely a pioneer in the green waterfront field (Bunce & Desfor, 2007) (Hutton, 2011) (McManus, 2007).

This Canadian city, since many decades, is recognized as ecologist, because of the environmental policies carried out, avoiding the mistakes made by several USA cities. In effect, nowadays, the waterfront of Vancouver has no highways disfiguring the coastline but it houses pedestrian and green paths, soft mobility and public transport. Despite the fact that the decommissioned areas have been substituted by several skyscrapers, they are placed in a large green territory, where the natural landscape prevails. It is worth mentioning that the green redevelopment of Vancouver has been effectuated also thanks to the "event approach": specifically, the Expo and the Winter Olympic Games.

Other cases of ecologic approach have been effectuated in Europe (Daamen, 2007), such as those in for Stockholm, Oslo or Santander, for instance. Another innovative approach, which can be included in the "Sustainable and Ecologist Approach", considers the "Historic Urban Landscape", local culture and traditions as primary resources for the port cities sustainable development (Fusco Girard, 2013).

Waterfront and Port Areas Reconversion and Redevelopment			
Approach	**Period**	**Strengths/Weakness**	**Examples**
"American"	1960-70	*Strengths:* Waterfront redevelopment; tourism; business *Weaknesses:* Loss of identity and local traditions; creation of separated clusters; port-city fragmentation	Baltimore, San Francisco, Boston, New York, etc.
"Tertiary and Residential"	1970-80	*Strengths:* Waterfront refurbishment; urban areas expansion; business *Weaknesses:* Loss of identity; housing crisis; speculation	London, Rotterdam, Brisbane, Sidney, etc.
"Event"	1990-2000	*Strengths:* Port-city system renovation, enhancement and integration; public spaces; tourism; business *Weaknesses:* Tourism and event as threats for local community and tradition; management after the event	Barcelona, Genoa, Marseille, Valencia, Bilbao, Sidney, Vancouver, Liverpool, etc.
"Saint-Nazaire"	1990-2000	*Strengths:* Enhancement of maritime and naval architecture; local tradition and history preservation	Saint-Nazaire, Bordeaux, Portsmouth, Swansea, Santander, etc.
"Sustainable and Ecologist"	2000-2010	*Strengths:* Environmental quality; public spaces; green and soft transport; port-city balance; enhancement of natural and cultural landscape	Vancouver, Stockholm, Oslo, Santander, etc.

Table 6. 1 Waterfront and port areas approach of reconversion

Nowadays, the "integrated" development of port-cities is a priority and a challenge for European and Mediterranean countries. From the experiences of port reconversion, some guidelines can be identified in order to respect natural, cultural, social and economic dimensions in the management of port cities. The strategies and intervention for historical ports preservation and development can be divided in two main categories: strategies on heritage ($I_{n,n}$) and on port-city system and sub-systems ($P_{n,n}$).

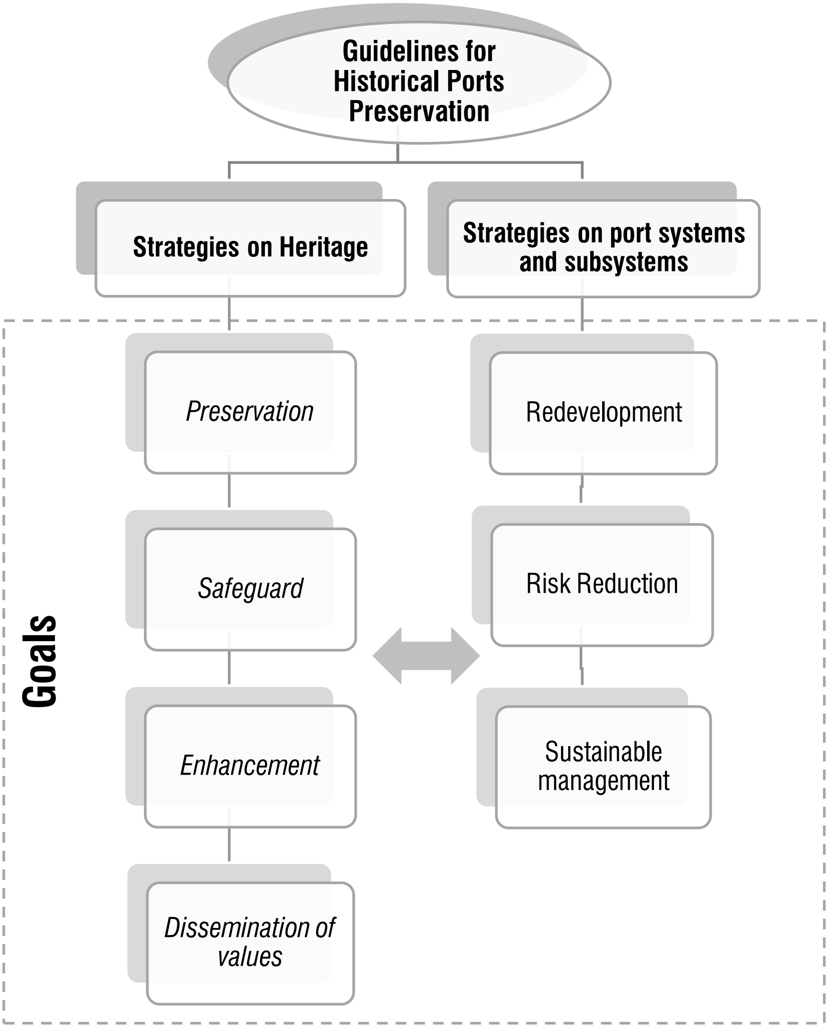


Figure 6. 1 Schematic representation of main strategies and goals for historical ports preservation

6.3 Strategies for historical heritage conservation and enhancement

The centre of all the waterfront and port regenerations is represented, firstly, by the "*heritage*" and, secondly, by the "*adaptive reuse*" (Gras, 2013). In effect, the reconversion of port areas is based on the concept of reusing the existing built heritage and spaces for a new function. The majority of Mediterranean and European ports actually have a very wide amount of decommissioned architectural heritages: a significant example can be the port of Liverpool, with about 10.000 square meters of abandoned warehouses, among which there is the biggest brick building in the world: the Stanley Dock warehouse, built in 1901. Port heritages, when abandoned, practically always need a functional adaptation and, generally, a restoration project able to preserve and enhance all their historical values and to guarantee the execution of new activities identified in relation to their characteristic and vocation. In addition to the Cotton Warehouses in Genoa, the *Reial Drassanes* and the *Deposito Comercial* in Barcelona, previously described, some other restoration in last years can be considered as best-practise for port heritage reconversion: the *Warehouse 26* of Trieste and the *Grand-Entrepot* of Marseille. The first one is the biggest ancient silos in Europe, a relevant example of industrial archaeology of the XX century. The restoration project has been carried out preserving strictly the historical, materials and architectural values of the warehouse, giving it a cultural and economic function. In effect, it actually houses expositions, events and exhibitions, representing a very aggregative pole for the ancient port and the city. In the second case, the warehouses, today known as "*Les Docks de la Joliette*" located in the XVIII *port* of Marseille, have been magisterially restored in the last years and they are a centrality for citizens and tourists. The mercantile vocation of the building has been preserved with new commercial activities, as well as cultural events, restaurants, etc.

In addition to the identification of the specific technical intervention and of a new use for preservation, also safeguard policies and enhancement strategies play a relevant role in port heritage regeneration, especially in the case of historical heritage: this is the case of castles, waterfronts and other assets with a particular tangible or intangible cultural value. Specifically, the strategies for the port heritage conservation can be divided into categories (Table 6.2) with the following goals: intervention ($I_{1,n}$) and plans ($I_{2,n}$) for heritage preservation, safeguard policies ($I_{3,n}$) and, finally, enhancement, promotion and dissemination of cultural values ($I_{4,n}$).

The interventions for the preservation of heritage – considered as punctual sites - count different levels of actions, starting from the securing work ($I_{1,1}$), which are necessary for buildings or sites in a very low state of conservation or likely to collapse: several heritages in ports are actually unused and are characterized by very advanced deterioration processes, as well as structural damage. In the view of future intervention for heritage restoration, the first operative action with an immediate necessity is certainly represented by the securing intervention, with temporary structures and supports able to protect assets, also from atmospheric agents and pollution.

The second level of intervention is represented by the maintenance, defined as combination of actions for preserving heritage in acceptable conditions. This is an important policy for the conservation of historical heritage, as enunciated by the Restoration Charters, considered in three typologies of strategies: preventive and programmed ($I_{1,2}$), curative ($I_{1,3}$) and ameliorative ($I_{1,4}$). The programmed and the preventive maintenances, as defined by Giovanni Urbani, are interventions executed periodically, on a statistical basis, in order to prevent the occurrence of damage and deterioration. The curative maintenance, instead, aims to restore a damage occurred. The ameliorative strategy is carried out for eliminating the causes, which can produce decay. The maintenance intervention depends on the material and technical properties of the architectural element, as well as the state of conservation. The maintenance interventions have to preserve strictly the original materials and the artistic, architectural and cultural elements of the port heritage, enhancing their historical image and aspect.

The third level of action on the heritage concerns adaptive interventions on built heritage. Particularly, as described previously, historical facilities often need to be adapted in order to be reused and preserved, from a functional to a structural point of view: ancient buildings can be obsolete for the progression of technical regulations. Thus, structural retrofit ($I_{1,6}$) on existing buildings aims to upgrade the resistance to the seismic actions, for different constructive systems: masonry-vaults, masonry-wood/iron/concrete flat, reinforced concrete, wood and metallic structures, including mix techniques of construction. Innovative interventions and materials should be used in order to give a more efficient level of security to the assets, respecting all the historical values actually present. Nowadays, it is common that historical sites in ports do not have the characteristics to house new activities, in terms of internal dimension and space organization, of technological systems and security requirements. Particularly,

some heritages could be well preserved but not used because of this functional deficiency. The functional adaptation ($I_{1,5}$) aims to upgrade the functional and technological characteristics, which are necessary for the reuse, respecting the historical vocation.
The last level of intervention on a punctual scale is represented by restoration ($I_{1,7}$) of heritage, with a very low state of conservation (materials deterioration and structural damage) and with functional and technological obsolescence. This is the higher vulnerability level for the heritage. The restoration project aims to preserve all the historical values layered over the centuries in the heritage, and, then, can provide structural and functional adaptation. The conservation of traditional structures has to be performed respecting the characteristics of materials and constructive elements, as defined by the Krakow Charter of Restoration. The modern materials (e.g. iron, cast iron, reinforced concrete) mixed to the traditional ones (e.g. stone, bricks and wood) also have to be rigorously restored and preserved. In effect, the new materials used for intervention need to be compatible to the originals. Particular attention has to be focused on the coexistence of different materials and techniques of construction, preserving the historical authenticity. The protection of surfaces from the chemical aggression is a priority in the restoration project, especially for artistic and cultural elements, such as columns or sculptures. All the innovative techniques for the preservation of historical, architectural and material properties of port heritage are encouraged to be used, respecting the original structure, in terms of chemical, structural and visual compatibility.
Particularly the main goal of the restoration project should be the tangible and intangible values preservation, in relation to the heritage category. For industrial archaeology, the restoration project have to enhance the productive vocation of those buildings and sheds. The logistic and military buildings were built in XIX-XX centuries and express a specific maritime and naval morphology. Their restoration has to preserve and enhance this significant characteristic and value for the port identity. Mercantile and commercial facilities of ports have an urban dimension and vocation, representing a centrality in the socio-economic identity of the port-city. For ancient port spaces, as piers and docks, the accessibility and usability, in addition to the materials preservation, have to be guarantee. Conservation actions on archaeological sites have to be executed by specialists

with the principle of the minimum intervention, limiting the excavations and documenting all data. Furthermore, submerged remains of ancient ports, ceramics, shipwrecks have to be preserved on site or, when not possible, in museums.
The interventions for the preservation of port heritage – considered as wide areas – are represented by urban and territorial plans. Waterfronts, historical centres, gardens and maritime districts are some examples of those landscaping elements. In effect, they are complex typologies of heritage, including built heritage, open spaces, viability, etc.
The national regulations on urban and territorial scale provide several typology of plans in relation to the goals to achieve: urban integrated regeneration plans ($I_{2,1}$), urban recovery plans ($I_{2,2}$), historical centres regeneration plans ($I_{2,3}$) and suburb areas redevelopment plans ($I_{2,4}$).
The urban integrated plans of regeneration principally aim to promote the redevelopment of significant parts of cities and urban systems through public interventions. The main goals are the enhancement of environmental and historical values, of the social identity and the satisfaction of the citizens' needs. They can include: regeneration of built environment, through the interventions previously described, applied to wide architectural complexes (e.g. historical curtains); improvement of the quality of open spaces and viability (maritime promenade, port docks, etc); social inclusion and occupation; promotion of ecologic strategies, maritime, pedestrian and bike paths, parks, etc. The urban recovery plans, instead, are those public or private initiatives for the promotion of the restoration, refurbishment and maintenance of large built areas, such as districts, or architectural complexes. Particular plans of regeneration have been also identified for specific urban areas: historical centres and suburb areas. In the first case, several historical districts in Mediterranean contexts have gone through the partial or total abandonment in the last decades for the lack of hygiene requirements, for decay and collapse risk, among the others. The regeneration plan aims to redevelop built heritage, from a material, technological and functional point of view, and promotes socio-economic grow of the area. Occupation, cultural and commercial activities are some initiatives included in the planning process. Despite suburban areas have no the same values than the historical centres, they are other sensible contexts that could be located

near port-city boundaries. These are areas with a high percentage of buildings and spaces damaged and in a very low state of conservation, resulting in social decay.
Relating to historical and natural landscape of port areas, it is certainly necessary to define a safeguard program. They are policies, which aim to protect, monitor and preserve heritages, through indirect intervention on historical assets, such as programs and regulation of protection ($I_{3,1}$). Specifically, from a national, regional and urban point of view, the preservation and safeguard of maritime and of port identity and authenticity have to be introduced as a significant territorial goal. In the view of the heritage conservation, another strategy of safeguard could be the redaction of a list of historical sites of ports that should be protected ($I_{3,2}$), in order to have the possibility to monitor heritage state of conservation, and a periodical list (e.g. every 5 years) of historical sites at risk in the port context ($I_{3,3}$). The listing operations should be carried out on a regional and municipal level, at least. Then, once compiled the lists, stakeholders could have the possibility to know the elements of their port-city system to preserve, protect and enhance, reporting periodically the state of restoration of them through a monitoring activity and periodically non-destructive diagnostic tests ($I_{3,4}$), and providing a supervision and surveillance program ($I_{3,5}$) on site.

Finally, the last category of intervention concerns all those initiatives, which aim to enhance heritages in port contexts, as well as to spread their values, both tangible and intangible. The main goal is the preservation of authenticity and identity of heritage with the inclusion in the social, cultural and economic development of the territory. This category concerns programs, events and other initiatives for the redevelopment of the heritage. Firstly, the dissemination of historical and cultural values of port heritage ($I_{4,1}$) can be promoted with the use of signals, reports and descriptions on site ($I_{4,2}$), which identify and describe heritage in terms of history, characteristics and curiosities. The same goal is achieved through innovative tools, such as websites, 3D reconstructions and augmented reality ($I_{4,3}$), among the others. In this way, the interaction between the users and the heritage increases, because they can see the past configurations and uses of buildings and spaces of ancient ports.

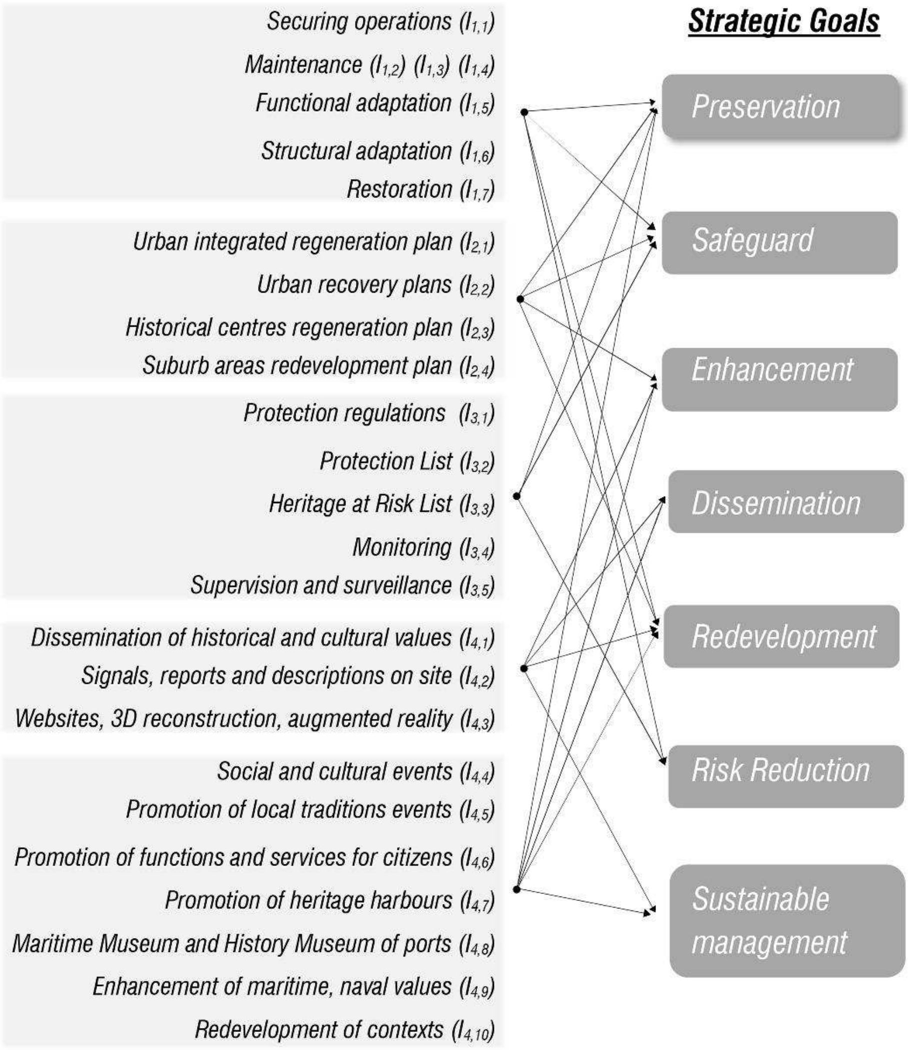


Figure 6. 2 Relationship between strategies on heritage and the main goals of historical ports preservation and development

Categories of intervention			Strategies
Heritage ($I_{n,n}$)	Intervention for conservation ($I_{1,n}$)	Intervention on port heritages, starting from the securing operation to the maintenance and complete restoration. The main goals is the preservation of all the values: tangible and intangible. Material, technological, functional and cultural properties need to be protected, conserved and adapted in order to maintain the continuity of life of these historical sites.	*Securing operations ($I_{1,1}$)*
			Preventive and programmed maintenance ($I_{1,2}$)
			Curative maintenance ($I_{1,3}$)
			Ameliorative maintenance ($I_{1,4}$)
			Functional adaptation ($I_{1,5}$)
			Structural adaptation ($I_{1,6}$)
			Restoration ($I_{1,7}$)
			Other ($I_{1,8}$)
	Plans for conservation ($I_{2,n}$)	Plans and programs for wide historical areas of ports, for the surrounding context of the heritage and for open spaces and paths, in the view of an integrated conservation and enhancement.	*Urban integrated regeneration plan ($I_{2,1}$)*
			Urban recovery plans ($I_{2,2}$)
			Historical centres regeneration plan ($I_{2,3}$)
			Suburb areas redevelopment plan ($I_{2,4}$)
			Other ($I_{2,5}$)
	Safeguard ($I_{3,n}$)	The safeguard policies are all those initiatives, which aim to protect, monitor and preserve heritages. Particularly, they are not direct intervention on historical assets, but they concern programs and regulation of protection, for instance.	*Protection laws and regulations ($I_{3,1}$)*
			Inclusion in lists of historical sites of ports to be safeguarded ($I_{3,2}$)
			Inclusion in a periodical (every 5 years) list of heritages at risk in ports ($I_{3,3}$)
			Monitoring of the state of conservation of historical sites through non-destructive diagnostic tests ($I_{3,4}$)
			Supervision and surveillance ($I_{3,5}$)
			Other($I_{3,6}$)
	Enhancement, promotion and dissemination of cultural values ($I_{4,n}$)	They are all those initiatives, which aim to enhance heritages in port contexts, as well as to spread their values, both tangible and intangible. The main goal is the preservation of authenticity and identity of heritage with the inclusion in the social, cultural and economic development of the territory. This category concerns programs, events and other initiatives for the redevelopment of the heritage.	*Dissemination of historical and cultural values of heritage ($I_{4,1}$)*
			Signals, reports and descriptions on site ($I_{4,2}$)
			Websites, 3D reconstruction, augmented reality ($I_{4,3}$)
			Social and cultural events ($I_{4,4}$)
			Promotion of local traditions events ($I_{4,5}$)
			Promotion of functions and services for citizens ($I_{4,6}$)
			Promotion of heritage harbours ($I_{4,7}$)
			Maritime Museum and History Museum of ports ($I_{4,8}$)
			Enhancement of maritime, naval and productive values ($I_{4,9}$)
			Redevelopment of contexts surrounding the heritage ($I_{4,10}$)
			Other ($I_{4,11}$)

Table 6.2 Strategies and conservation policies for historical sites in ports

The reconversion of waterfront areas can be carried out through different approaches, but the most efficient strategies should promote new cultural and social events and functions ($I_{4,4}$), respecting the local traditions ($I_{4,5}$), as well as the urban citizens' necessities ($I_{4,6}$). Nevertheless, the enhancement of port areas starts with the conservation of maritime vocation: specifically, port cities should have a museum of maritime history ($I_{4,8}$) and they should promote historical shipping harbours ($I_{4,7}$) as well as the redevelopment projects (Gordon, 1999) should preserve and enhance naval and maritime architectures, equipment and spaces ($I_{4,9}$). There are same best-practise examples, such as the waterfront of Santander, Barcelona, Genoa and Saint-Nazaire. The enhancement of the heritage includes intervention of redevelopment of the context ($I_{4,10}$) in which it is located. For instance, a historical building placed in a polluted or abandoned area is affected by a visual damage, at least.

6.4 Strategies for port areas enhancement and redevelopment

In addition to the above-described interventions on heritages, the preservation of historical and cultural values of ports depends on their management and governance, as complex territorial systems (Pinder & Smith, 1999) (Hoyle, et al., 1994) (Hagerman, 2007) (Daamen & Vries, 2013) (Daamen, 2007). Particularly, three typologies of intervention ($P_{n,n}$) have been identified referring to port-city systems or subsystems: strategies for port areas redevelopment ($P_{1,n}$), risk reduction ($P_{2,n}$), and territorial governance and management ($P_{3,n}$).

Firstly, according to the environmental criticalities potentially produced by shipping, storage and processing activities, e.g. production of waste, landfills and pollutants, large coastal areas in ports actually need redevelopment projects able to reduce the contamination and the abandonment ($P_{1,1}$), as well as they need to be reconverted in useful functions for citizens. Furthermore, port systems are frequently characterized by fragmentation and disintegration, generating separated clusters and areas.

In these case, it should be necessary an intervention for increasing the waterfront permeability and accessibility ($P_{1,2}$). In this view, the realization of pedestrian, bicycle and

maritime promenades and paths ($P_{1,3}$) are some examples of good-practise for reconnecting port areas, making them accessible and usable.
In order to enhance port-city landscape, it should be proposed the realization of green and soft viability and transport ($P_{1,4}$). In effect, one of the weaknesses and, at the same time, threads for historical ports has been the construction of intense, large and impactful communication ways, highways and railroads included. Thus, soft mobility should always be preferred in historical landscapes. The waterfront areas, whatever their use, should be completely accessible.
In order to redevelop abandoned and polluted areas, some sustainable strategies are the preferable ones. First of all, the realization of cultural and natural paths and parks ($P_{1,5}$) should be proposed for enhance and regenerate port sub-systems and port-city interfaces. The reconversion of those decommissioned areas, as previously enounced, should be based on an adaptive reuse.
Particularly, for an integrated development of territorial contexts, urban functions should be located in port areas, such as public services and spaces able to attract citizens and, generally, users ($P_{1,6}$). Then, proposing a mixture of functions in the port-city area, it is possible that the overall system will grow sustainably reconnecting the separated clusters.
Another strategy that can be carried out for the redevelopment of port-city contexts is certainly the realization of new sustainable and green residential areas in decommissioned zone ($P_{1,7}$). The new built environment could produce a better integration of fragmented areas, an improvement of environmental quality and a balanced relationship between port and city.

Secondly, considering ports as potential risk areas for population, environment and landscape, the assessment and, consequently, the mitigation of those risks have to be a priority goal for stakeholders and institutions.
The risks, as described in chapters 2, 4 and 5, potentially affecting the landscapes of ports, can produce the losses of social, historical and cultural values, both tangibles that intangibles. Thus, it is necessary carried out protocols and programs for identifying the risk sources in the port area ($P_{2,1}$), in terms of accidental and stationary impact.

In the first case, the industrial and mercantile activities actually located in ports could lead to the occurrence of explosions and fires with serious effect on buildings, environment and populations. These disasters can be mostly caused by ships collisions or can be associated to the loading/unloading or the storage of certain hazardous materials (such as, for example, hydrocarbons).
In order to avoid accidents it is necessary the redaction of emergency, disasters and resilience plans ($P_{2,2}$), with the collaboration of all the stakeholders involved, research centres included. The frequency of the potential accidents and their effects on the surroundings need to be estimated in those plans.
Another policy able to mitigate major accidents risk can be the review of the activities' displacement in the port layout. The relocation of dangerous activities and plants at a security distance from historical, natural and cultural assets ($P_{2,3}$) could certainly reduce the possibility of damaging them.
Stationary impacts, instead, mainly concern the environmental ones. The monitoring of environmental conditions in the port is a first essential operation to be carried out, through sensors linked to network platform able to report data from different areas of the port, principally near urban and cultural zone. Particularly, the concentration of pollutants in air, water and land has to be monitored and controlled.
Once revealed that in specific contexts, if the impacts exceed the limits, some mitigation strategies are necessary: the reduction of the concentration of pollutants, waste and contaminants ($P_{2,4}$), of noise, odours, insanity and discomfort ($P_{2,5}$) and of the visual impact of port activities on landscape ($P_{2,6}$).

Finally, the feasibility of an "integrated" port-city development depends on the territorial governance, and the strategic planning and management (Daamen & Vries, 2013). Ports and cities need to be managed and developed as integrated territorial systems, in order to achieve the social, economic and environmental sustainability.
Thus, the main challenge for institutions should be the re-definition of the regulations concerning the responsibilities and competence of State, Region, Municipality, Port Authority and others. The main aims should be the promotion of an integrated port-city

system of planning and management ($P_{3,1}$), where the different stakeholders could confront and collaborate to define the structural lines of sustainable development of port territory. The participatory planning process has a key role for the definition of the future of our cities. Stakeholders, together with citizens, universities and research centres should discuss about sustainable solutions for social, economic and environmental grow ($P_{3,2}$).

In addition to this, the reconversion of decommissioned and abandoned areas need to be encouraged with mix public-private projects with the supervision of the competent authorities ($P_{3,3}$), following the example of Genoa port restoration of 1992. The complexity in the management and planning of port areas is represented by the interference of different territorial components: landscape, logistic and transportation, urban and industrial area. These components are actually managed by different authorities through different planning and regulations, resulting in a very low homogeneity in the territorial development and generating fragmentation or abandonment.

The previous strategies of intervention aim to preserve the historical values of port cities and they can be included in a single innovative management strategy: the definition of a network of Historical Parks of Port Areas ($P_{3,3}$).

A Historical Port Park can be defined as "a *territorial area characterized by historical sites with maritime and naval properties, fishing, commercial and mercantile vocation, related to port logistic and military activities, or industrial archaeology, with cultural significance, historical identity and authenticity, representing the history of a specific coastal city or culture, which are well preserved, enhanced, safeguarded and accessible for citizenships and visitors*".

Thus, a historical port park can include in its area different typologies of historical heritages and sites: from the archaeological, to architectural and cultural ones, both tangible that intangible. From a morphological point of view, a port park can be included in a unitary perimeter and, then, characterized by a single circumscribed area. It is the case of small port cities, for instance. Furthermore, it can be structured as a "park system": the historical areas are not contiguous and they are conceptually connected and consistent to a territorial cultural project.

The main goals of a historical port park should be the safeguard and enhancement of historical port sites, including the redevelopment of the natural landscape and of the territory in their layered historical values. This should lead to increase their public use as new poles of socio-cultural aggregation, as well as to disseminate values, promoting of research and knowledge and encouraging sustainable development and integration of ports and cities.
The project and management of a Historical Port Park provides several tasks: firstly, it must be a cultural and scientific project, in order to identify and analyse the historical, cultural, architectural and landscaping values of the heritages located in the port.
This first step provides the research of historical documentation, cartography, bibliographic sources, diagnostic tests and other investigation and reporting operation.
Subsequently, in the view of the identification of the main risks for heritages, the vulnerability and the port hazard need to be estimated, in order to define specific strategies for the preservation and enhancement of heritage, as well as a cultural project for integrating them to the urban area.
Secondly, specific safeguard policies and programs need to be developed and applied for port heritages, for the protection of all the potential historical assets of the port. Starting from the scientific project, these policies aim to regulate the use of the historical areas, defining the allowed activities as well as the lists of heritages to be safeguarded and the lists of heritage at risk in the port. The policies have to be compatible to the current regulation and laws, eventually updated.
The third step deals with the project of enhancement of heritage, which aim to guarantee principally the preservation, integration and accessibility of port sites, with interventions, plans, strategies as previously described ($I_{n,n}$).
Finally, a management plan defined by several associated partners is necessary also for the economic sustainability. In effect, the involved stakeholders have to collaborate, for example founding new companies with limited participation, in order to conduct the project: port authorities, municipalities, state, regions, privates and others.

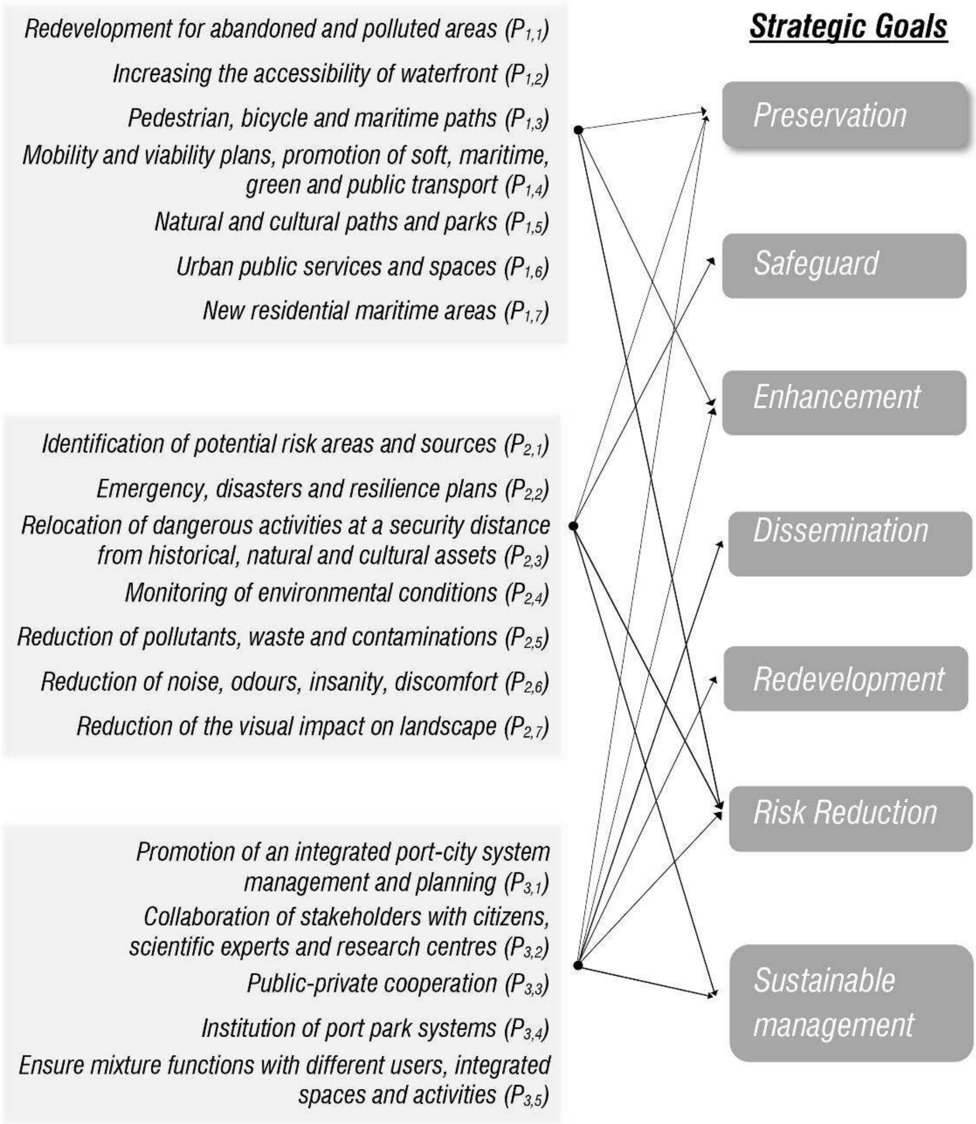


Figure 6. 3 Relationship between strategies on port systems and subsystems and the main goals of historical heritage preservation

<table>
<tr><th colspan="3">Categories of intervention</th><th>Strategies</th></tr>
<tr><td rowspan="24">Port-city systems and sub-systems ($P_{n,n}$)</td><td rowspan="8">Strategies for port areas redevelopment ($P_{1,n}$)</td><td rowspan="8">Port areas often need redevelopment intervention, in order to reduce abandonment and pollution, as well as fragmentation and disintegration of the port-city system. Particularly, another aim is to reconnect port areas, to make them accessible and usable also for citizens.</td><td>Redevelopment plans for abandoned and polluted areas ($P_{1,1}$)</td></tr>
<tr><td>Increasing the accessibility and permeability of waterfront ($P_{1,2}$)</td></tr>
<tr><td>Pedestrian, bicycle and maritime paths ($P_{1,3}$)</td></tr>
<tr><td>Mobility and viability plans, promotion of soft, maritime, green and public transport ($P_{1,4}$)</td></tr>
<tr><td>Natural and cultural paths and parks ($P_{1,5}$)</td></tr>
<tr><td>Urban public services and spaces ($P_{1,6}$)</td></tr>
<tr><td>New residential maritime areas of expansion of the city ($P_{1,7}$)</td></tr>
<tr><td>Other ($P_{1,8}$)</td></tr>
<tr><td rowspan="8">Risk reduction ($P_{2,n}$)</td><td rowspan="8">The preservation of natural and cultural landscape of ports is possible through the identification, assessment and reduction of all the risks induced by port activities and facilities.</td><td>Identification of potential risk areas and sources ($P_{2,1}$)</td></tr>
<tr><td>Emergency, disasters and resilience plans ($P_{2,2}$)</td></tr>
<tr><td>Relocation of dangerous activities at a security distance from historical, natural and cultural assets ($P_{2,3}$)</td></tr>
<tr><td>Monitoring of environmental conditions ($P_{2,4}$)</td></tr>
<tr><td>Reduction of pollutants, waste and contaminations ($P_{2,5}$)</td></tr>
<tr><td>Reduction of noise, odours, insanity, discomfort ($P_{2,6}$)</td></tr>
<tr><td>Reduction of the visual impact on landscape ($P_{2,7}$)</td></tr>
<tr><td>Other ($P_{2,8}$)</td></tr>
<tr><td rowspan="6">Territorial governance and management ($P_{3,n}$)</td><td rowspan="6">Ports and cities need to be managed and developed as integrated territorial systems, in order to achieve the social, economic and environmental sustainability. In this view, authorities, stakeholders, citizens and scientific community have to collaborate.</td><td>Promotion of an integrated port-city system management and planning ($P_{3,1}$)</td></tr>
<tr><td>Collaboration of stakeholders with citizens, scientific experts and research centres ($P_{3,2}$)</td></tr>
<tr><td>Public-private cooperation under public supervision ($P_{3,3}$)</td></tr>
<tr><td>Institution of port park systems ($P_{3,4}$)</td></tr>
<tr><td>Ensure mixture functions with different users, integrated spaces and activities ($P_{3,5}$)</td></tr>
<tr><td>Other ($P_{3,6}$)</td></tr>
</table>

Table 6.3 Strategies and conservation policies for port systems and sub-systems

Chapter 7
Case of study: the port of Brindisi

7.1 Description of the port

7.1.1 Historical background

Since ancient times, the history of Brindisi has been related to the port, as reported by Ennio, Plinio and Tacito [1]. Even the name of the town, according to some scholars, derives from the shape of the harbour and means "deer head", probably in Messapian language (Cazzato, 1992) (Pedio, 1996). Moreover, the certain presence of a prehistoric settlement, located on *Punta delle Terrare*, confirms the ancient origins of the port. During the Roman domination, Brindisi was a strategic pole of the Empire, with the port at the end of the Appian and Trajan Ways[2], linking Rome with the East world (Musca,

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[1]Ennio: *"Brundisium pulchro praecintum praepete portu";* Plinio: *"Brundisium in primis Italiae portu nobile"; Tacito: "Brundisium quod navigandi celerrimum fidissimunque appulsam erat"*;

[2] The censor Appius Claudius built the Appian Way or *Regina Viarum* between 312-190 BC, to connect Rome with Brindisi through *Capua, Beneventum, Venusia, Silvium* and *Tarentum*. Emperor Trajan built the Trajan Way between

1987). Several records prove that role: a framework of the Trajan's Column in Rome showing the Roman fleet in the port of Brindisi; the portrait of the siege by Julius Caesar against Pompeius in the harbour made by Andrea Palladio in 1575 (Figure 7. 1); the presence of Brindisi in the *Tabula Peutingeriana*[3]; numerous references in writings of Latin poets. Symbols of the glorious past of Brindisi and its port are also two Roman columns (Figure 7. 2) representing the end of the so-called *Regina Viarum* in the inner port, as well as several remains of amphorae that would confirm the commercial role of the harbour in ancient times.

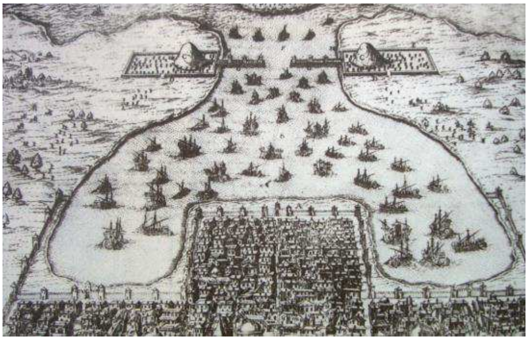

Figure 7. 1 Portrait of the siege by Julius Caesar against Pompeius in the harbour made by Andrea Palladio in 1575 (Atlante Storico della Puglia – Provincia di Brindisi).

Figure 7. 2 View of the remains of the Roman Columns, today in the historical waterfront of Brindisi.

After the fall of the Roman Empire, the role of Brindisi in commercial trades declined in favour of new towns on the Adriatic Sea, including Bari, Trani and Barletta. Only in the XII century, under the Norman domain, the rebirth of the town took place, as ships sailed from the port with crusaders and pilgrims directed to the Holy Land and many merchants headed East (Babudri, 1957) (Petrosillo, 1993). Between the XIII and the XVI centuries, under the Swabia, Aragon and Spanish domains, walls, bastions and castles fortified the city. Particularly, Frederick II built the Swabia Castle in 1233, while Alfonso of Aragon built the Sea Castle in 1481. Then, Philip II was responsible for the

108-110 AC as coastal route from Benevento to Brindisi, passing through the Roman centres of *Herdonia, Canusium, Barium, Neapolis* and *Gnàthia*.

[3] The *Tabula Peutingeriana* is a copy of an ancient Roman map of the XII-XIII century; it shows the military ways of the Empire and it is named after the humanist K. Peutinger who inherited it.

construction of the horn-work, completed in 1583, in St. Andrew Island. Since the late XV century, the progressive occlusion of the inlet canal caused the decline of the inner port and made the city a swampy and noxious area (Simoncini, 1993). Thus, the mercantile activities were concentrated in the outer port, using St. Andrew Island as leper hospital, as witnessed by the Spanish Map in 1739 (Figure 7. 3), as well as by Orlandi in a map in 1773 and other historical maps.

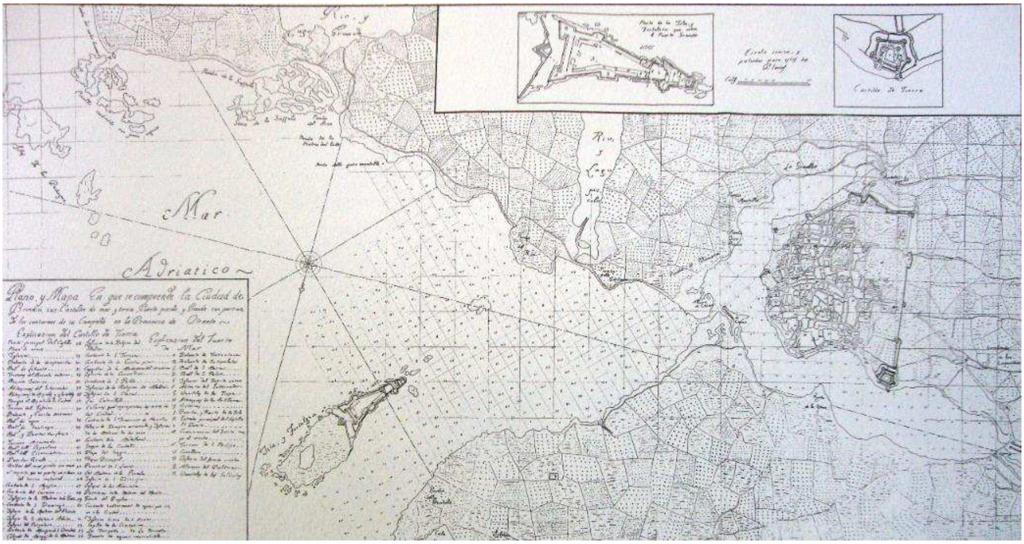

Figure 7. 3 The Spanish Map of Brindisi, representing the port configuration in 1739 (Atlante Storico della Puglia – Provincia di Brindisi)

The reclamation of the inner port and the reopening of its inlet canal at the end of the XVIII century triggered the rebirth of Brindisi (Figure 7. 4) (Figure 7. 5). The interventions were promoted by Bourbon Kingdom Ferdinand IV, carried out by Engineer Andrea Pigonati between 1778 and 1781, with the construction of two docks and completed by Engineer Pollio and then by Captain Cervati, who gave to the canal its final configuration (Donno, 1979) (Cervati, 1843) (Pigonati, 1781).
After the Unification of Italy in 1861, the government allocated a significant amount to recover the port, ranked as commercial port of international interest. As a result, the port of Brindisi was a node of the Indian Mail, a trade link from UK to India. After opening

the Suez Canal in 1869 and the Frejus tunnel in 1871, steamers and railways[4] (Simoncini, 1993) connected Italy and Europe.

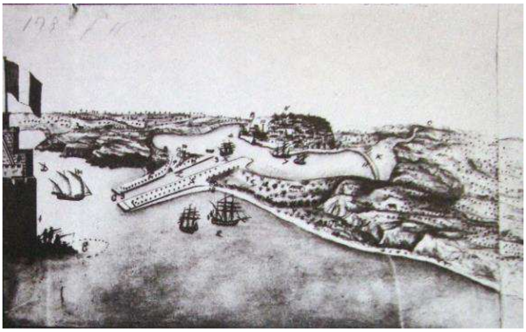

Figure 7. 4 Plan and view of the port of Brindisi after the reopening of the channel, 1781 (Atlante Storico della Puglia – Provincia di Brindisi).

Figure 7. 5 The Pigonati Channel, in an actual view in the inner port of Brindisi.

Those events positively affected the city, with several urban and maritime works: the railway toward the docks in 1870, the first maritime station, the dam and the lighthouse of *Bocche di Puglia* between 1864 and 1890, the lighthouse of *Pedagne* Island in 1861, the first docks in the inner port and the Great International Hotel in 1869. The population increased from 8,000 in 1861 up to 28,000 inhabitants in 1914.

In the XX century, the urban development of Brindisi flourished, including two Port Plans in 1905 and 1907. Furthermore, due to war events, several military, naval and industrial structures were built: *Costa Morena* dam in 1917; Arsenal in the West Bay between 1913 and 1918; some docks in the inner port between 1925 and 1928; *Montecatini* warehouse in 1931, Maritime Academy and Sailor's Monument in 1933, new Maritime Station between 1936 and 1940. The importance of Brindisi for the Italian military defence was also acknowledged on 10th September 1943 by King Vittorio Emanuele, who visited the town and there established the Italian capital until February 1944. After the war, the Consortium of Brindisi in 1949 was founded in order to settle an industrial

[4] The construction of the railway and the urban expansion led to the demolition of a part of the historic defensive system, which today remain a portion of the curtain wall, the Hell Tower, Mesagne Gate, Lecce Gate and the bastion of S. Giacomo.

zone. In fact, in the ‘50s, Brindisi was the third largest port in Italy, in terms of passengers, behind Naples and Genoa, even though commercial trades were quite limited. Particularly, after the war, the construction of *Capo Bianco* and *Punta Riso* dams, respectively in 1949 and between 1984 and 1990, shaped a new area, namely the outer basin. From 1958, an industrial centre was built nearby the outer port, operating chemical and petrochemical activities. It influenced the development of the city that grew up around the West Bay. Meanwhile, the Navy League, born in the 30’s, built the headquarters in 1962.

Finally, the Plan of the Port in 1975 led to the realization of the shipyards in the 90’s and the touristic port in *Bocche di Puglia* bay in 2003. Because of the large number of passengers throughout the last years [5], the port needed an enlargement, with a new ferry terminal built on the dock of *Costa Morena* in the middle port.

7.1.2 Port morphology and characteristics

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. Today the port houses several functions and activities: industrial, productive, energetic, mercantile, passengers and touristic ones.

Nowadays, the port, which has about 5 million square meters, is characterized by three basins (Port Authority of Brindisi Informer, 2010): the outer, the middle and the inner port (Figure 7. 6). 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.

[5]Source: *Port Authority of Brindisi.* The historical data of passenger movements in the port of Brindisi show a significant increase in traffic between 1960 (185.318) and 1997 (1.047.106), while this trend is reversed from 1997 to 2011 (527,000).

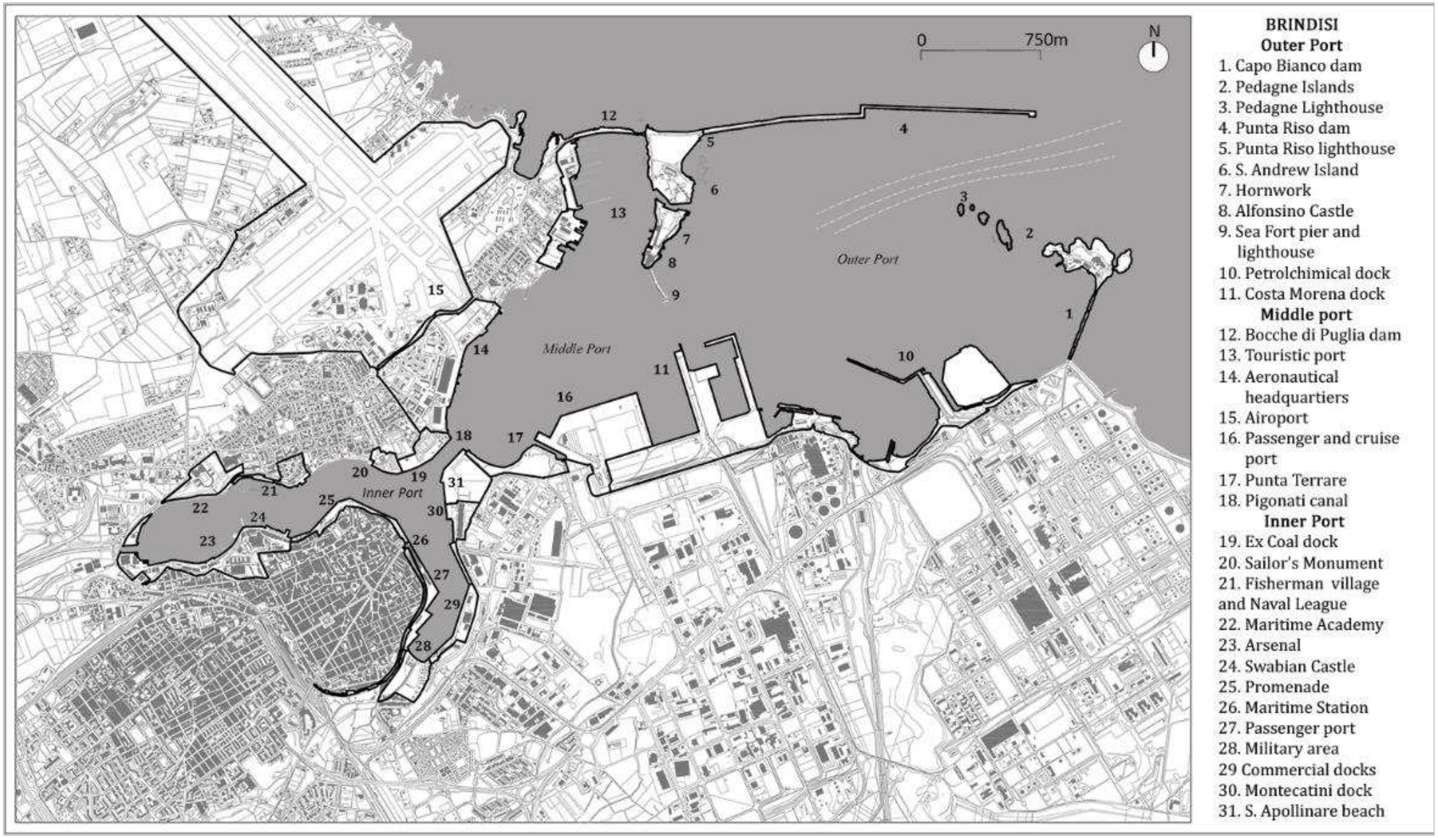

Figure 7. 6 Morphology of the port of Brindisi

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. Andrew 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 harbour of the city, active since the Roman Empire. Its two bays, of East and of West, have represented the centre 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.

7.1.3 Historical sites and architectural heritages of the port

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 (Table 7.1).

Among the historical heritage of the port of Brindisi, it should be mentioned, firstly, in the category B_1, the wooden shed of *Montecatini*, built in 1930 on the docks of East bay of the inner port. The building has housed the production of phosphatic fertilizers until 1999, when it was decommissioned. According to the chemical substances involved, the structure is entirely realized in spruce wood, with bolting and riveting connections: more than forty structural frames of 28 meters of span and 14 meters of height support the pitched roof.

<table>
<tr><th>Classification
of historical heritage of ports</th><th colspan="3">Historical heritage of the port of Brindisi</th></tr>
<tr><td rowspan="10">Historical buildings (B)

B1. Productive and industrial archaeology: warehouses, sheds and stores, shipyards.
B2. Logistic buildings: customhouses, port offices, lighthouses and maritime stations.
B3. Commercial and mercantile buildings: fondaci, caravanserai and similar facilities, palaces for trade and merchants, lodges or markets.
B4. Fortifications and similar buildings: castles, fortresses, bastions, towers and walls.
B5. Sacred architectures: cathedrals, churches, monasteries and convents.</td><th>Heritage</th><th>Category</th><th>Origin</th></tr>
<tr><td>Montecatini shed</td><td>B1</td><td>1930</td></tr>
<tr><td>Maritime Academy</td><td>B2</td><td>1937</td></tr>
<tr><td>Maritime Station</td><td>B2</td><td>1940</td></tr>
<tr><td>Traversa Lighthouse</td><td>B2</td><td>1861</td></tr>
<tr><td>Punta Riso Lighthouse</td><td>B2</td><td>1890</td></tr>
<tr><td>Alfonsino Castle</td><td>B4</td><td>1481</td></tr>
<tr><td>Swabia Castle</td><td>B4</td><td>1233</td></tr>
<tr><td>Pigonati Channel</td><td>S1</td><td>1778-81</td></tr>
<tr><td>Punta delle Terrare</td><td>S2</td><td>Prehistoric</td></tr>
<tr><td rowspan="6">Historical spaces and areas (S)

S1. Historical spaces of ports: docks, piers, quays, wharves, basins and promenade.
S2. Archaeological sites: submerged and on-land remains.
S3. Maritime districts: historical centers, waterfront, curtains, districts.
S4. Military areas: navy, army facilities, districts, bases, arsenals, etc.</td><td>Historical waterfront</td><td>S3</td><td>XII-XIX cent.</td></tr>
<tr><td>Sailor’s Monument</td><td>S3</td><td>1933</td></tr>
<tr><td>Fisherman’s village</td><td>S3</td><td>1960</td></tr>
<tr><td>S. Andrew Island</td><td>S3</td><td>XV-XX cent.</td></tr>
<tr><td>Navy Arsenal</td><td>S4</td><td>1913</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Table 7.1 Assessment of heritage categories in the port of Brindisi

Other buildings in the port context are referred to B_2 category: the lighthouses of the Island of *Pedagne* and of *Punta Riso*, the Maritime Station and the Naval College. The lighthouse of *Punta Riso*, located on the St. Andrew Island was built in 1890, in order to indicate the access in the port. The structure, today decommissioned and compromised, was built with limestone blocks and covered by vaults. The *Traversa* lighthouse, instead, is actually in operation, indicating to ships the route to the port docks. It is dated 1861 and characterized by limestone masonries and vaults. The maritime station of Brindisi represents an exemplary rationalist architecture, designed by the arch. Rapisardi during the Fascist period, exactly in 1938-40. It is structured in a two floors building, with a maritime portico on the inner harbour. The building was erected with reinforced concrete pillars as vertical structure and flats as horizontal one. In the area, a decommissioned railway line, which connected the port to the station, is also located.

Figure 7. 7 The East bay of the inner port of Brindisi: on the left the Montecatini shed and on the right the maritime station.

Figure 7. 8 The West bay: Sailor's Monument, Swabia Castle and the Arsenal

In the first decades of the XX century, a maritime academy was also constructed, witnessing the naval vocation of the port. The architectural complex, articulated in different buildings, housed several sport facilities, surrounded by a large park in the West bay of the inner port. A semi-cylindrical building was erected around a wide central court for sport activities. As the maritime station, the architecture of the academy respects the rationalist principles of the early 19th century, designed by the arch. Minnucci.

Figure 7. 9 The middle port: Bocche di Puglia bay, Aragon Castle and touristic port

Furthermore, some of the most important architectures in Brindisi are represented by the fortifications (B_4), 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. The fortress, also known as *Earth Castle*, was built since the 1233 by Frederick II and subsequently integrated during Aragon and Spanish dominations. The massive structures of this fortification are characterized by limestone blocks masonries and vaults. In order to protect the port, between the outer and the middle basins, another fortress was built in the XV century: the Aragon Castle with the horn-work. It was also called as *sea fortress* or *red castle*, because of the colour of their stone masonries. The caste, today abandoned, is divided in two main architectural complexes: the fortress, characterized by a central dock, located at the east top of the island and linked to it, a second structure houses the parade ground and the horn-work.

Besides the architectural points of relevance, several historical and landscaping areas are found in the port of Brindisi. Specifically, among the historical areas, an archaeological site (S_2) is present near the *Costa Morena* West docks, called *Punta delle Terrare*. The on-land remains dates back around the Bronze Age and, today, they are partially buried: ceramics and ancient glasses are some examples of rests.

The historical port spaces of Brindisi, in terms of docks and piers (S_1), coincide with the Pigonati Channel, completed in 1781 under the supervision of the eng. Andrea Pigonati. The channel represents an important testimony of the port renaissance of the XIX century. In effect before its construction, the city had been in decline for almost 3 centuries and, when re-opened, the inner port became the centre of commercial activities. It is structured in two docks, named St. Ferdinand and St. Carlo in honour of the king and the queen of the Bourbon Reign.

Figure 7. 10 The inner port: historic centre, Roman Columns and promenade R. Margherita

Figure 7. 11 The West bay of the inner port

The other heritage concerns the historical waterfront, the monumental park of the Sailor's Monument, the fishing district and the island of St. Andrea (S_3).

The waterfront of Brindisi includes a curtain of historical buildings 800 meters long, the monumental promenade *Regina Margherita* and several monuments, such as the Roman columns and the fascist fountain of *Tancredi*. Furthermore, the promenade originally housed the commercial docks of the port and it has been recently redeveloped. Located in the West bay of the inner port, the fisherman's district is characterized by a built area and fishing docks actually in a very poor state of conservation. The area was built in 1959-60 to house the fishing activities previously placed on the historical waterfront. The Sailor's monument is another historical monument of the port. It was built since 1932 in order to celebrate the maritime and naval history of Brindisi and inaugurated by Mussolini in 1933. The high sculpture represents a hem and takes place in a garden facing on the West bay. Finally, another historical and natural site of the port of Brindisi is the Saint Andrew Island, facing both in the middle and outer basins. The

island, today connected to the mainland through the *Bocche di Puglia* dam, was used as lazaret of the port and subsequently as military defensive area.
The military area of the Brindisi Navy Arsenal is another historical area (S_4), built since the early XX century. The area, which includes into its boundaries the Swabia Castle, is located in the West bay of the inner port of Brindisi and it counts several structures, used such as warehouses and offices, displaced on a dock more than 500 meters long.

Figure 7. 12 The Navy Arsenal of Brindisi in the West bay of the inner port

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.

7.2 The heritage vulnerability assessment

The assessment of the vulnerability of historical heritage has been carried out through 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. The qualification of heritage conditions has been carried out through direct surveys on sites and from data reported in the Ten-Ecoport Research Project (De Fino , et al., 2015), while the historical information has been obtained from the Brindisi State Archive and bibliographic research.

The estimation of the heritage vulnerability has been effectuated through the reporting of specific forms of 14 historical sites of the port of Brindisi, as described in Chapter 3. The investigation was structured in two level of analysis: the L0 forms have led to gather all the general data about the heritage, such as name, location, dimension, category, use, property, etc.; the L1 forms, instead, have led to estimate an index of vulnerability for each heritage analysed, calculated through several specific 17 indicators, for which a score has been assigned in relation to the state of conservation and management. The assessment has allowed us to identity three partial indexes (material, functional and cultural vulnerability) and a global value of vulnerability, summarizing the actual criticalities and threats affecting the port heritages of Brindisi. The vulnerability is considered as high for values more than 66%, medium for range of 33-66% and, then, low for scores less than 33%, shown in the following tables in grayscale.

In the Table 7. 2, the material vulnerability and, then, the related indicators have been estimated for each one of the historical sites located in the port of Brindisi. Firstly, the port buildings and facilities (B_n) have been analysed considering the characteristics of materials, structures, architectural components and, when present, cultural-artistic-decorative elements. In addition to this, the vulnerability to fires and chemicals has been considered. Analysing the scores assigned to the indicators, it points out that the 30% of the built heritages is characterized by a high material vulnerability, while the 15% by a medium index and the 60% by low values. The Maritime Academy and the *Punta Riso* lighthouse are the most damaged heritages, followed by the Aragon Castle. The main

cause of these pathological criticalities is represented by the material deterioration of the architectural and structural elements, which affects all the buildings in the port of Brindisi. These phenomena concern erosion, corrosion, blackening, loss of materials, and other physical and chemical attacks. Moreover, the 30% of the port buildings actually have structural damage: in the case of the *Punta Riso* lighthouse they are serious, while for the Maritime Academy and for the Aragon Castle there is a minor damage. Regarding the susceptibility to fires, the main vulnerable heritage is represented by the wooden *Montecatini* shed, while a low value is assigned for the maritime station, built with reinforced concrete structures. The other buildings have a very low propensity to be damaged by fires, such as the stone made ones. Regarding the building category, another indicator describes the behaviour of materials when attacked by chemicals, which are commonly present in ports in the atmosphere, in water and soil. Particularly, it comes out that all the heritages have a medium-low susceptibility to the aggression by chemicals, except the wooden *Montecatini* shed. In relation to this indicator, the reinforced concrete structures of the Academy and maritime station are the most vulnerable historical sites.
Among the spaces, the assessment has led to figure out that the 28% of them is actually in a very low state of conservation and, then, with a high material vulnerability. It is the case of the Fisherman's District (S_3) and of the St. Andrew Island (S_3), where more than the 75% of the built environment and the majority of the open spaces and the viability have a low state of conservation. A medium vulnerability characterized another percentage of spaces (42%): the *Pigonati* Channel (S_1) and *Punta delle Terrare* (S_2). The access way to the inner port, built in 1778-81, actually has two docks with structural criticalities and widespread decay. In addition to this, the two warning lights are susceptibility to the chemical aggression and to fires. The archaeological site, instead, is partially buried, but it is completely exposed to atmospheric agents, pollutants, waste and other external impact, resulting as threats especially for movable heritage. The other 42% of spaces has a good state of conservation, principally because they have been recently restored and because they are located in urban areas. the Sailor's Monument and the historical waterfront *Regina Margherita* have a very low material vulnerability.

Heritage Data			Material Vulnerability Assessment					
Brindisi Port Heritage		Components	Structural Damage (0:9)	Material Decay (0:9)	Vulnerability to fire (0:3)	Vulnerability to chemicals (0:3)	State of con-servation (0:3)	Material V. Index (0:1)
B_1	Montecatini shed	STR	0	3	3	0		**0.25**
B_2	Maritime Academy	STR	6	9	1	2		**0.75**
B_2	Maritime Station	STR	0	2	1	2		**0.20**
B_2	Traversa Lighthouse	STR	0	2	0	1		**0.12**
B_2	Punta Riso Lighthouse	STR	9	9	0	1		**0.79**
B_4	Aragon Castle	STR	4	6	0	1		**0.48**
		CULT		5				
B_4	Swabia Caste	STR	0	3	0	1		**0.18**
		CULT		2				
S_1	Pigonati Channel	STR	4	6	0	1		**0.46**
		EQU		3	1	3		
S_2	Punta delle Terrare	IMMO	0	0	0	1		**0.40**
		MOV		5				
S_3	Sailor's Monument	BUILT					0	**0.22**
		SPACE					1	
		VIAB					1	
S_3	Fisherman's dis-trict	BUILT					2	**0.67**
		SPACE					2	
		VIAB					2	
S_3	St. Andrew Island	BUILT					3	**0.89**
		SPA					2	
		VIAB					3	
S_3	Historical waterfront	BUILT					1	**0.11**
		SPACE					0	
		VIAB					0	
S_4	*Navy Arsenal*	BUILT					1	**0.33**
		SPACE					1	
		VIAB					1	

Table 7. 2 Schematic results of the material vulnerability assessment of the historical sites of the port of Brindisi

Concerning to the functional vulnerability, the indicators are listed in the Table 7. 3. It shows that the 57% of the sites are actually inaccessible to citizens, visitors and tourists. The 28% of them, instead, are completely accessible: in some cases, they are urban areas recently redeveloped and integrated, such as the waterfront *Regina Margherita* and the Sailor's Monument; other sites are accessible because they are completely abandoned and not enclosed as in the St. Andrew Island and *Punta delle Terrare*. The other 15% of sites are accessible only for employees.
Another relevant aspect is represented by the actual use of the heritages. In fact, it points out that the 30% of port sites are completely abandoned and unused since almost 10 years. This is a key factor in the preservation of the historical heritages and it influences significantly the global vulnerability. It is the case of the *Montecatini* shed, the Maritime Academy, the Aragon Castle and the St. Andrew Island. The 23% of them, instead, is partially used. Concerning the compatibility of the actual use with the original one, the table shows that only the 15% of sites have an acceptable situation, such as the maritime station. The 46% is characterized by an actual compatible use, which does not threaten the historical values of sites: the Swabia Castle is used as navy base; the *Traversa* Lighthouse continue to perform its function, as well as the Fisherman's District; the Sailor's Monument is actually a monumental garden; finally, the historical waterfront, for centuries used as commercial docks of the port, is today a monumental and touristic promenade.
A specific indicator for archaeological sites is the level of protection, which has been estimated as very low for *Punta delle Terrare* site.
In the 33% of cases, the different property and management represent a real impediment for the redevelopment of the heritage: the Maritime Academy, the Aragon Castle and the St. Andrew Island. Finally, state of restoration has been estimated for each port heritage of Brindisi. Specifically, only the waterfront *Regina Margherita* has been recently redeveloped in the last 5 years. In the last 15 years, intervention of maintenance and restoration characterized the 42% of heritage, such as the Aragon Castle and the *Montecatini* shed. Another 42% of buildings and spaces no interventions have been executed or programmed.

Heritage Data		Functional Vulnerability Assessment						
Brindisi Port Heritage		Accessibility (0:3)	Protection (0:3)	Use Compatibility (0:3)	Level of Use (0:3)	Property and management (0:3)	Interventions, plans, etc. (0:3)	Functional Vuln. Index (0:1)
B_1	Montecatini shed	3		3	2	0	1	**0.60**
B_2	Maritime Academy	3		3	3	3	3	**1.00**
B_2	Maritime Station	1		1	1	0	1	**0.27**
B_2	Traversa Lighthouse	2		0	0	0	3	**0.33**
B_2	Punta Riso Lighthouse	3		3	3	0	3	**0.80**
B_4	Aragon Castle	3		3	3	3	1	**0.87**
B_4	Swabia Caste	1		0	0	0	1	**0.13**
S_1	Pigonati Channel	3		1	1	0	3	**0.53**
S_2	Punta delle Terrare	0	3			3	3	**0.75**
S_3	Sailor's Monument	0		0	0		1	**0.08**
S_3	Fisherman's district	0		0	0		2	**0.17**
S_3	St. Andrew Island	3		3	3		3	**1.00**
S_3	Historical waterfront	0		0	0		0	**0.00**
S_4	Navy Arsenal	3		0	1		1	**0.40**

Table 7. 3 Schematic results of the functional vulnerability assessment of the historical sites of the port of Brindisi

Thirdly, the estimation of the cultural vulnerability (Table 7. 4), as degree of loss of the identity and authenticity and as a level of safeguard, protection and relationship with the context, has been analysed and estimated. The investigation has revealed that the 57% of the port heritage in Brindisi are actually subject to safeguard policies, as shown in the regional landscape plan of Apulia (Piano Paesaggistico Territoriale Regionale P.P.T.R. , 2015) and the Urban Plan (P.R.G.) of the city. The 43% of historical sites of the port are, instead, neither protected nor recognized as cultural assets to safeguard by institutions, resulting in a somewhat vulnerable state: for instance, the Maritime Academy, the *Pigonati* Channel and the lighthouses are not listed, as well as the St. Andrew Island. The assessment has led to investigate about the level of preservation of the socio-cultural identity of heritages. The local community, in fact, recognizes as landmarks only the 35% of port heritages, while the 65% is partially or poorly acknowledged, such as in the case of *Pigonati* Channel: part of the citizens proposed to enlarge it and transform it for a higher accessibility to cruises, for instance. This intervention could compromise the natural and historical landscape morphology with potential losses and environmental impacts. The cultural losses are also measurable in terms of level of conservation of the historical authenticity, as defined by the Krakow Charter. An example can be certainly the Maritime Academy or the lighthouse of *Punta Riso*, which have lost several historical properties due to their very advanced deterioration process. It affects the 57% of port sites, from a low to a high level. The cultural vulnerability deals with the capacity of institutions to disseminate and diffuse the heritage values and history. In effect, today this represents a weakness for Brindisi landscape: the 71% of heritages is not adequately sponsored and it is known only a local scale, as well as it is not reported and described on site. The lack of descriptions, signals and reports contributes to decrease the cultural loss of values. Finally, it points out that the 38% of historical areas is actually poorly connected with the urban and infrastructural nodes of Brindisi, resulting isolated for context deficiency or restricted permission access, as in the case of *Montecatini* shed or Aragon Castle. Regarding the context characteristics, it comes out that in the 66% of cases, the historical sites are located in very deteriorate areas which affect their cultural and landscaping value.

Heritage Data		Cultural Vulnerability Assessment						
Brindisi Port Heritage		Level of Safe-guard (0:3)	Socio-cultural identity (0:3)	Historical au-thenticity (0:3)	Dissemination of values (0:3)	Level of con-nection (0:3)	Context decay (0:3)	Cultural Vuln. Index (0:1)
B_1	Montecatini shed	0	1	0	2	3	3	**0.50**
B_2	Maritime Academy	3	1	2	2	1	0	**0.50**
B_2	Maritime Station	0	1	2	2	0	0	**0.28**
B_2	Traversa Lighthouse	3	1	0	2	0	3	**0.50**
B_2	Punta Riso Lighthouse	3	1	2	2	1	3	**0.66**
B_4	Aragon Castle	0	0	1	0	2	3	**0.33**
B_4	Swabia Caste	0	0	0	1	1	1	**0.16**
S_1	Pigonati Channel	3	2	2	2	3	3	**0.83**
S_2	Punta delle Terrare	0	2	1	2	2	3	**0.55**
S_3	Sailor's Monument	0	0	0	1	0		**0.07**
S_3	Fisherman's district	0	1	1	3	1		**0.60**
S_3	St. Andrew Island	3	2	3	3	3		**0.93**
S_3	Historical waterfront	0	0	0	0	0		**0.00**
S_4	Navy Arsenal	3	0	0	0	1		**0.25**

Table 7. 4 Schematic results of the cultural vulnerability assessment of the historical sites of Brindisi

The calculation of the 17 indicators, defined specifically for each heritage category, has led to estimate the indexes of vulnerability of the 14 historical sites of the port of Brindisi. The following overall consideration can be pointed out by analysing the Table 7. 5 and the Figure 7. 13, in order to identify the adequate conservation policies.

Firstly, it has been reported that the 56% of the historical sites are today somewhat vulnerable elements in the port landscape, in terms of material, structural and architectural state of conservation, as well as highly susceptible to fires and chemicals, which are potential hazards in the port. In effect, in the 28% of cases the heritage has serious structural damage and deterioration processes, which are probably undergoing a progressive development. It is the case of the Maritime Academy and of the *Punta Riso* lighthouse, affected by both structural damage and materials decay, such as erosion and loss of stone materials, and corrosion of metals. Furthermore, a high physical decay characterizes also open spaces and wide areas, such as in the St. Andrew Island. For the 28% of port assets, instead, a medium material vulnerability comes out: these heritages are characterized by a widespread decay of materials and surfaces, and sometimes by minor structural damage.

Secondly, it is also evident that all the most vulnerable heritages have a high level of functional deficiency. The 44% of historical port spaces and buildings is abandoned or decommissioned, contributing to generate also pathological decay of materials. Furthermore, most of the sites under assessment show low accessibility and usability, except from some open spaces (*Regina Margherita* waterfront, Sailor's Monument, Fishermen's District). That condition comes from disuse (Aragon Castle and hornwork, *Montecatini* warehouse, ex Maritime Academy) and abandon (*Punta delle Terrare*, St. Andrew Island) or from restrictions of public access for the functional destination (Maritime Station, Swabia Castle and Arsenal).

Nevertheless, in most sites, the state of conservation is quite good – for instance, the Aragon Castle was recently restored as museum, but it is currently not accessible. The assessment also reveals that a variety of authorities is in charge of managing and controlling buildings and areas. Therefore, restoration and retrofitting processes are slow and fragmented even to outline and schedule - for instance, within St. Andrew Island, which is under state property along with the horn-work, the Architectural Superintendence manages the Aragon Castle.

Thirdly, it is worth saying that, despite the high levels of decay and criticalities, the historical sites of Brindisi maintain a quite level of cultural significance for the local community and for the institution involved. Only three assets (21%), in fact, have a high cultural vulnerability: *Punta Riso* lighthouse, *Pigonati* Channel and St. Andrew Island, which are the most affected areas. However, the 44% of sites has a medium level of cultural losses, which are principally caused by the lack of dissemination of values and of restoration programs, as well as by context deficiency and decay. In effect, the low level of connections between contexts in the port contributes to isolate cultural assets, increasing their vulnerability. This overall fragmentation of the port coast results in the low accessibility to the sea front, where only 4 out of 18 kilometres of waterfront is actually accessible.

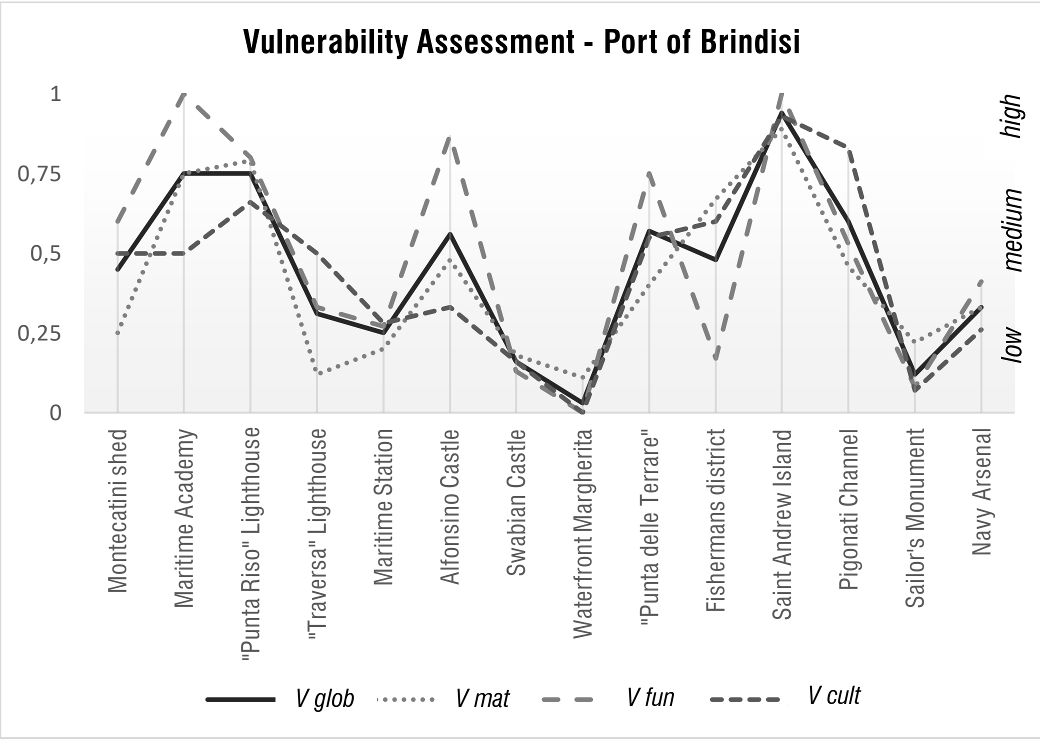

Figure 7. 13 Schematic representation of the partial and global indexes of vulnerability for the historical sites of the port of Brindisi

Heritage Data		Vulnerability Assessment			
Brindisi Port Heritage		Material Vulnerability Index (0:1)	Functional Vulnerability Index (0:1)	Cultural Vulnerability Index (0:1)	Global Vulnerability Index (0:1)
B_1	Montecatini shed	**0.25**	**0.60**	**0.50**	**0.45**
B_2	Maritime Academy	**0.75**	**1.00**	**0.50**	**0.75**
B_2	Maritime Station	**0.20**	**0.27**	**0.28**	**0.25**
B_2	Traversa Lighthouse	**0.12**	**0.33**	**0.50**	**0.31**
B_2	Punta Riso Lighthouse	**0.79**	**0.80**	**0.66**	**0.75**
B_4	Aragon Castle	**0.48**	**0.87**	**0.33**	**0.56**
B_4	Swabia Caste	**0.18**	**0.13**	**0.16**	**0.16**
S_1	Pigonati Channel	**0.46**	**0.53**	**0.83**	**0.60**
S_2	Punta delle Terrare	**0.40**	**0.75**	**0.55**	**0.57**
S_3	Sailor's Monument	**0.22**	**0.08**	**0.07**	**0.12**
S_3	Fisherman's district	**0.67**	**0.17**	**0.60**	**0.48**
S_3	St. Andrew Island	**0.89**	**1.00**	**0.93**	**0.94**
S_3	Historical waterfront	**0.11**	**0**	**0**	**0.03**
S_4	Navy Arsenal	**0.33**	**0.40**	**0.25**	**0.32**

Table 7. 5 The partial and global indexes of vulnerability estimated for the historical sites of the port of Brindisi

Finally, the vulnerability assessment reveals that, in the case of Brindisi, the 21% of ancient facilities and historical areas actually need interventions and strategies aimed to protect, restore, reuse and safeguard them. These sites are today highly threaten and certainly compromised, because of their high global vulnerability, in terms of material decay, functional obsolescence and cultural losses. For several others (36%), instead, the medium level of vulnerability means that they could represent a potential compromised heritage, if specific preservation and enhancement policies will not be carried out. In order to estimate the heritages with a high level of risk of losses of historical, cultural, material values, the vulnerability must be compared to the impacts of the port activities and facilities on the historical elements.

7.3 The stationary impact of port activities

The evaluation of the stationary impacts in the port of Brindisi is carried out through the assessment of the activities producing environmental effects on historical sites. As explained in the Chapter 4, it is structured is different tasks. In the first step, the general information about the port is collected.

The Table 7. 6 summarizes the main data of the port of Brindisi. First of all, it was founded in the VII century as natural harbour, today represented by the inner port with the West and East bay. Since the 19th century, it was enlarged designing the actual port morphology. In effect, the middle and other basins were realized, with the construction of the *Bocche di Puglia* and *Punta Riso* dams. Thus, it can be considered partially as natural harbour and artificial one.

The three basins have a gross surface of about 5 million s.m., bordering urban areas, natural landscapes and industrial plants. It is worth underlining that the level of interference between territorial components is very high.

The main stakeholders involved in the administration of port activities and areas are the Port Authority, Municipality, State, Navy and different employees, ships companies, Marinas, other privates, etc. Regarding the port functions, Brindisi can be considered an industrial port, with also mercantile, passengers and commercial, touristic and energetic activities.

General Data – PORT OF BRINDISI					
Morphology	Artificial port				
	Natural harbour				
Location	City	Brindisi		Province	Brindisi
	Region	Apulia		State	Italy
Dimenson	Area	4.927.000 s.m.			
History	Origin		VII secolo a.c.		
	Transformations		XII-XV and XVIII-XX centuries		
Confini	Urban area				
	Urban area with historical and cultural values				
	Protected natural area				
	Not protected natural area				
	Industrial area				
	Other				
Stakeholders	Port Authority		Municipality		State
	Navy		Private		others
Functions	Commercial		Industrial		Touristic
	Passengers		Energetic		Other
Survey	Direct	Total	Partial	data	2013

Table 7. 6 Hazard Form: the general information about the port of Brindisi

7.3.1 Assessment of the port activities in Brindisi

The second step deals with the identification of the activities carried out in the port, with specific attention to their evaluation in terms of territorial extension and frequency.
The port of Brindisi houses several typologies of activities, from the industrial plants to the mercantile facilities, as listed in the Table 7. 7: shipping, bunkering, passenger and cargoes transportation, process plants, among the others.

The assessment of port activities points out that the 76% has a high territorial extension and impact, with more than 10 ha of gross surface. Concerning the frequency, the 57% of activities takes place continuously while the 33% almost once a day. Combining the high extension and frequency, is possible to estimate the potential overall effect of all the activities in terms of environmental impacts. The main activities in Brindisi are described below.

The shipping activity regards all the port waters, from the inner port to the outer. In effect, different typologies of ships get it and out the port, transporting people, cars, trucks, and cargoes, which can be hazardous substances. In relation to the stationary impacts, all ships represents a source of pollution and hazards, because they can release substances into the atmosphere, water and soil. Thus, it is considered as high impact for Brindisi, also because of the large extension and high frequency of operations. Subsequently, other activities related to shipping are estimated: bunkering, pilotage and mooring are the most frequent.

A potential impact on environment is certainly produced by the land transportation by cars and trucks with containers, and several other cargoes, as well as the urban traffic represents another important source of air pollution.

Furthermore, a Marina, e.g. the touristic yacht port, is also located in a wide area of the *Bocche di Puglia* bay, near the Aragon Castle and the St. Andrew Island. It has a high territorial extension and frequency, with the movement of hundreds of boats and yachts, responsible principally of water discharges and spills.

Nevertheless, the largest activities of the port coincide with the industrial pole, which include both transportation, loading/unloading operations, storage and processing of materials, substances with a high level of risk for population, environment and landscape. In effect, a very wide industrial area is located in the closeness of the urban zone and of natural and cultural assets. This is area placed principally in the middle and outer port, with petrochemical, food plants, refineries and power stations. In the inner port is also present an aggregate plant, which processes fine particles and powder. Each one of these industries have a gross surface more than 10 ha and, then, have a territorial impact very high, as well as the operations frequency, which is continuous.

Assessment of Port Activities - PORT OF BRINDISI			
Activity	Extension	Frequency	Score
Shipping	3	3	6
Bunkering	2	3	5
Land Transport	3	3	6
Passenger Transport	3	3	6
Dredging and Deposal			0
Fishing and Aquaculture	1	3	4
Maintenance of install./infrastr.	2	1	3
Ship building/repair	2	1	3
Marinas and Yatch	3	3	6
Waste Management	3	2	5
Mooring, Pilotage, Towing	3	3	6
Containers Handling	3	2	5
Dry Bulk Handling	3	2	5
Oil Gas Handling	3	2	5
Hazmat (non-oil) Handling			0
Liquid Bulk Handling	3	2	5
Perishable Goods Handling			0
Vehicles Handling	2	2	4
Ro-Ro	3	2	5
Aggregate Ind.	3	3	6
Petrolchemical Ind.	3	3	6
Agro-Food Ind.	3	3	6
Metallurgic Ind.			0
Oil Refineries	3	3	6
Power Station	3	3	6
Port and Coastal Engineering			0

Table 7. 7 Hazard Form: the estimation of the activities in the port of Brindisi

7.3.2 Identification of the Significant Environmental Impacts for Heritage

The assessment of the port activities leads to the identification of the main Significant Environmental Aspects for Heritage (SEAH). The SEAH are listed in Table 7. 9 and include: air emission (AIR), water discharge (WAT), contamination of soil (SOIL) and of sediments (SED), noise, odour, waste production (WAST) and port development both on sea (PDS) and on land (PDL). Estimating port activities with a value between 1 and 6, in relation to the extension and frequency, the identification of the scores for each SEAH is carried out. In effect, every activity can have specific impact on environment and, then, concern different aspects in relation of the typologies of operation. The correlation between each one of the activities potentially present in port areas was described in the previous Chapter 4. Thus, it is possible estimate that air emission is the most frequent environmental aspect in the port of Brindisi, principally because it is produced by all port activities, with different contributes.

Port area	Data	Pollutant	Concentration ($\mu g/m^3$)
Costa Morena	2014	SO_2	3,5
		NO_2	22
		O_3	60
		PM_{10}	18
East Bay	2014	SO_2	2,6
		NO_2	20
		O_3	29
		PM_{10}	23
West Bay	2014	SO_2	2
		NO_2	17
		PM_{10}	18

Table 7.8 Pollutants concentration in the port of Brindisi (ARPA, 2014)

The main causes of air pollution are the processing plants, as the industrial ones, as well as the transport system. To confirm this, the data monitored in three different meteorological station in the port show that the concentrations of pollutants are higher in port areas with industrial plants, such as in the East bay or in the middle port, that in the West bay, as in Table 7.8.

Significant Environmental Aspects for Heritage (SEAH)								
AIR	**WAT**	**SOIL**	**SED**	**NOISE**	**ODOUR**	**WAST**	**PDS**	**PDL**
6	6			6		6		
5	5			5				
6		6		6		6		
6	6			6		6		
	0	0	0	0		0		
	4	4	4	4	4	4		
3	3	3	3	3		3		
3	3			3	3	3		
6	6			6		6		
5						5		
6	6							
5	5			5			5	5
5				5		5		
5	5	5	5		5			
0	0	0	0			0		
5	5	5	5					
0	0				0	0		
4				4			4	4
5	5			5		5		
6	6			6			6	6
6	6	6				6	6	6
6	6			6	6	6	6	6
0	0			0		0	0	0
6	6	6	6			6	6	6
6							6	6
0				0		0	0	0
105	**83**	**35**	**23**	**70**	**18**	**67**	**39**	**39**

Table 7. 9 Hazard Form: calculation of the SEAH for the port of Brindisi

Besides the atmospheric pollution, other aspects with a high impact are represented by noise, water discharges and waste production. These ones can principally generate effects on the usability and comfort of historical sites located in the closeness. Despite port development has not a high score in the overall estimation of the aspect (Table 7.9), it is worth saying that it should be continuously monitored and mitigated the impact of the soil exploitation and of the coast transformation, because the effects could be serious.

7.3.3 Estimation of the effects on historical heritage

In the following step, the level of territorial aggression to the historical and cultural assets is identified calculating the impacts of the SEAH, in terms of physical and materials deterioration of heritages, of production of discomfort, insanity and abandonment of port areas, and of degeneration of the landscaping features. The Table 7. 11 shows that the most frequent impact is represented by the potential chemical aggression of construction materials of historical buildings, areas and spaces. The 26% of the materials decay is produced by air emission, which is the major cause, followed by discharge to water (20) and waste (17). In effect, mainly air pollution is likely to produce erosion and blackening of stone surfaces, as well as corrosion of metal or iron-concrete structures, with the potential risk of loss of cultural and historical properties.

Material	5 years between maintenance	10 years between maintenance	15 years between maintenance	20 years between maintenance
Painted steel *White plastic* *Limestone*	40 μg/m^3 45 μg/m^3 36 μg/m^3	20 μg/m^3 22 μg/m^3 18 μg/m^3	13 μg/m^3 15 μg/m^3 12 μg/m^3	10 μg/m^3 11 μg/m^3 9 μg/m^3
Average values	40 μg/m^3	20 μg/m^3	13 μg/m^3	10 μg/m^3

Table 7. 10 Acceptable values of particular matter (Community Research and Development Information System - European Commission, 2010)

Referring to the potential blackening phenomena, which can affect the heritage in the port of Brindisi, it is worth underlining that the levels of PM_{10} overcome the limit values, as shown in Table 7. 10 (Community Research and Development Information System - European Commission, 2010). The minimum value of PM_{10} concentration in Brindisi is 18 $\mu g/m^3$, which is higher than the acceptable ones in Table 7. 10, if a distance of 10-15 years from the last maintenance or restoration is considered.

The port activities in Brindisi also generate impacts on the usability of historical spaces and buildings. In effect, the presence of noise, bad odours, visible spills and waste in the areas nearby historical areas contributes to deteriorate the level of comfort and of health for citizens, visitors and, generally, users. These effects could lead to abandon those cultural sites. The excessive exploitation of the coastline and waterfront for port heavy activities and plants is another negative consequence, which can produce an irreversible modification of natural and cultural areas, generating boundaries, fragmentation and inaccessibility of specific port contexts. It is the case of Brindisi, where several port activities or spaces have been decommissioned and actually represents empty spaces characterized by decay, waste and pollution. An example is certainly the St. Andrew Island, which is the only way to get to the Aragon Castle, but today it is a restricted and abandoned area.

Finally, another aspect relevant in terms of stationary impact regards the deterioration and loss of landscaping values and properties. This aspect is commonly not considered in the management and planning of ports, as shown in the ESPO priorities (ESPO-European Sea Port Organization, 1994) in last decades. Recently, the acknowledgment of the effects of port transformations on natural and cultural environment has led to focus on the preservation on landscape. In Brindisi, the interventions on the port since the '60 have produced significant changes, in terms of morphological impact, and visual and symbolic one. Particularly, the main effects is the modification of the image of the historical heritages, due to the deterioration of materials (56%). Other two key contributes are the waste production (21%) and the port development (23%). In effects, the industrialization of both the three basins of Brindisi has led to modify irreversibly the original landscape: the impact is morphological because the new port facilities have different materials and dimensions; other changes regards the loss of historical and natural visual and perspective, as well as the loss of symbolic values for some port areas.

Effect and consequences on historical heritage of BRINDISI			
Significant Environmental Aspects for Heritage	**MATERIAL impact**	**Impact on USE**	**Impact on LANDSCAPE**
Emission to Air	105		105
Discharge to Water	83		83
Discharge to Soil	35		
Sediments Contamination	23		
Noise		70	
Odour		18	
Waste	67	67	67
Port Development on Sea	39	39	39
Port Development on Land	39	39	39
Total	**391**	**233**	**333**

Table 7. 11 Identification of the effects of port activities on historical sites of Brindisi

The estimation of port activities and, then, of their consequences on the historic landscape aims to identify a global hazard index of the port of Brindisi. The main goal is the identification of the level of hazard affecting the historical assets in order to define some strategies for the heritage preservation and risk mitigation.
Specifically, combining the three partial indexes of hazard, in the port of Brindisi, an overall high level of hazard is estimated, which results in a percentage of territorial aggression of about 70%. This should suggest that the monitoring and mitigation of

environmental impact in Brindisi is necessary in order to protect the cultural and natural landscape, particularly in the East bay of the inner port, in the middle and outer basins.

Indexes of PORT HAZARD	
Material impact: **Hmat**	**0,67**
Impact on use and function: **Huse**	**0,66**
Impact on landscape: **Hlan**	**0,69**
Index of Global Hazard: **Hglob**	**0,68**

Table 7. 12 Port Hazards Indexes for Brindisi case of study

7.4 The accidental impact of port activities

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 by 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 6000 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 to 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 identified, two main scenarios have been analyzed, 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.

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

According to a historical survey of major accidents occurred in ports (Darbra, et al., 2004) (Darbra & Casal, 2004), 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 risk associated to 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)$^{-1}$.

Scenarios	Frequency
Gas tankers: 1. Continuous release of 180 m^3 in 1800 s 2. Continuous release of 90 m^3 in 1800 s	$0.00012 \times f_0$ $0.025 \times f_0$
Semi-Gas tankers (refrigerated) 1. Continuous release of 126 m^3 in 1800 s 2. Continuous release of 32 m^3 in 1800 s	$0.00012 \times f_0$ $0.025 \times f_0$

Table 7. 13 Scenarios for loss of containment due to impact of ships in ports (National Institute of Public Health and the Environment - RIVM, 2009)

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 7. 13. 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 (F) has been estimated as:

(7.1) $$f_0 = 6.7 \times 10^{-11} \times T \times t \times N = 6.7 \times 10^{-11} \times 4500 \times 15 \times 160 = 7.2 \times 10^{-4} visit^{-1}$$

(7.2) $$F = 0.00012 \times f_0 = 8.64 \times 10^{-8} visit^{-1} = 1.30 \times 10^{-5} year^{-1}$$

Where:

T = 4.500 ships, the total number of ships per annum in the port (Assoporti , 2009-2014)

t = 6.000 tons/400 tons h^{-1} = 15 h, the average time of loading operation per ship (Port Authority of Brindisi Informer, 2010)

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

The frequency of an explosion occurring in a ship impact in the port could be estimated with an event-tree analysis. The event-tree analysis is a methodology that provides the frequencies of the diverse accidental 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.); the probabilities are known from expert knowledge and research projects (De Haag & Ale, 1999) (National Institute of Public Health and the Environment - RIVM, 2009).

Particularly, according to previous studies (Ronza, et al., 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 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, shown in the Figure 5.17 are the followings ones:

(7.3) $$P_{(UVCE)} = \underline{P_1} \times P_4 \times P_5 \times P_6 = 0{,}5 \times 0.935 \times 0.5 \times 0.4 = 0.094$$

(7.4) $$F_{(UVCE)} = 0.094 \times 1.30 \times 10^{-5}\, year^{-1} = 1.22 \times 10^{-8}\, year^{-1}$$

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.

Data	
Ship typology and tanks capacity	LPG carrier (6,000 tons average capacity) with 3 tanks with average of 2000 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}

Table 7. 14 Generic data of the ship and substance transported in the port of Brindisi

In the case of Brindisi, the LPG carriers have an average capacity of 6000 tons (with a maximum value of 20000 tons) and are characterized by 2, 3 or 4 tanks per ship, depending on the ship size. Table 7. 14 gives some data concerning the LPG transportation by ship.

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 7. 13).

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):

(7.5) $$W_{TNT}\,(kg) = \mu \times M \times (\Delta H_C \div \Delta H_{TNT}) = 23300\,kg$$

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:

(7.6) $$D_{SC}\,(m) = R \div (W_{TNT})^{1/3} = R \times 0.035$$

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:

(7.7) $$\Delta P(bar) = 1 \div (d_{SC}) + 1 \div (d_{SC})^2 + 1 \div (d_{SC})^3$$

The results obtained for the overpressure at different distances can be seen in Table 7. 15 and Figure 7. 14.

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

Table 7. 15 Relationship between the distance, the scaled distance and the overpressure

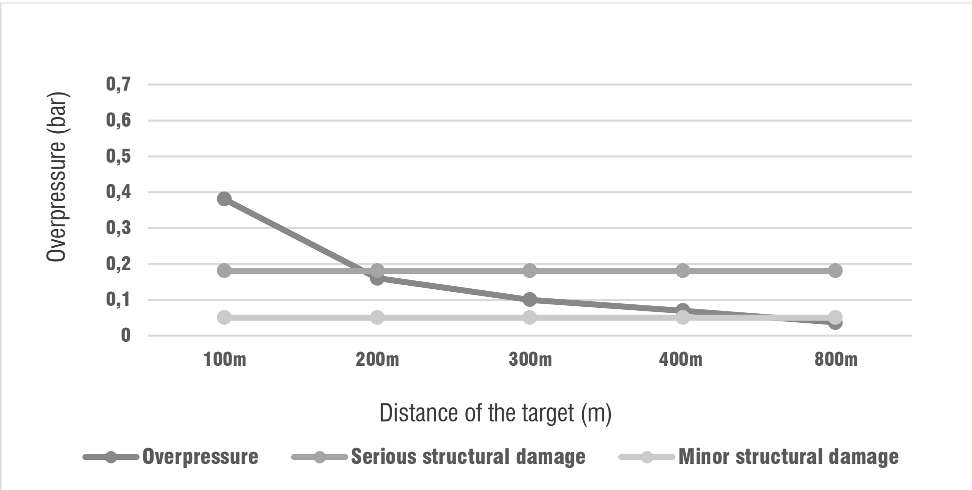

Figure 7. 14 Relationship between the real distance and overpressure in the UVCE

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).

7.4.2 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 50000 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 , 2009-2014).

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}

Table 7. 16 Expected frequencies of grain explosions (Demontis et al., 2012)

The explosions of silos, which can have very severe effects and consequences, have occurred from time to time, as shown by statistical surveys (Abbasi & Abbasi, 2007) (Demontis & 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

7. 16). In the case of Brindisi, the average frequency is 1 x 10^{-3} $year^{-1}$ or 1 x 10^{-6}(operative $hours)^{-1}$.
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 & 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.

7.4.3 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. 15. 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 the vulnerability assessment, is in poor state of conservation and, then, is a somewhat vulnerable element.

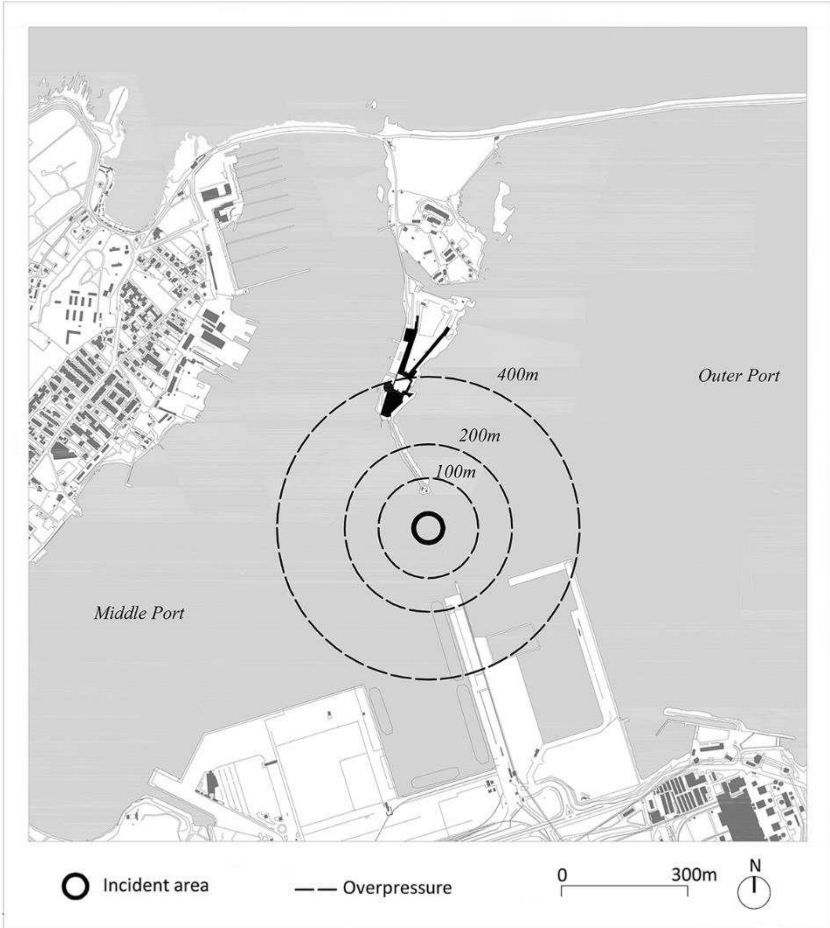

Figure 7. 15 Dangerous area for scenario no.1

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 (Figure 7. 16). Furthermore, they are not in good state of conservation, because they are unused, 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.

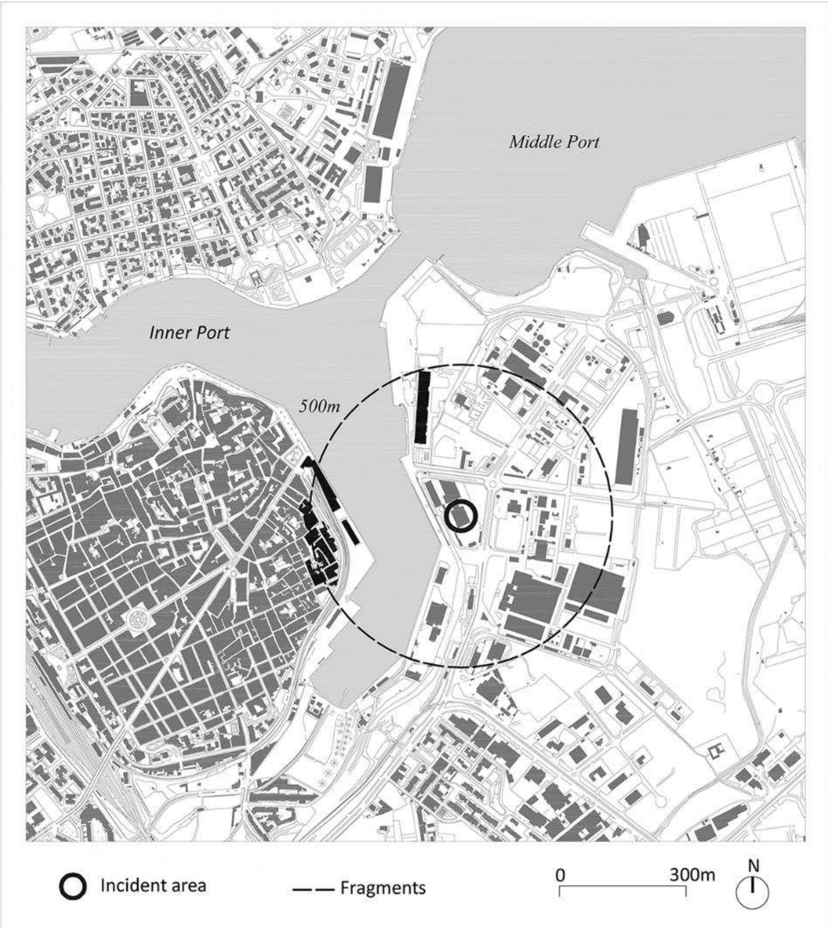

Figure 7. 16 Dangerous area for scenario no.2

The assessment of exceptional impacts on landscaping elements and historical heritage in port context was 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 reveales that there are some potential accident scenarios with effects on landscaping components. Two main scenarios are 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 are 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 Aragon 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 aims to underline 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.

7.5 Towards the definition of a historical port park of Brindisi

The sustainable preservation, enhancement and development of the historical port of Brindisi need to be the main goal to achieve for Municipality, Region, State (Cultural and Tourism Ministry), port authority, research centres and other stakeholders involved in the port management and planning. The definition of a “Historical Park of the Port of Brindisi” is proposed as main innovative strategy for the cultural, social and economic development of the Apulian port, in order to preserve the maritime vocation of the city.

The main goal of the establishment of a port park is Brindisi is the preservation of the maritime, mercantile, productive and naval vocation, enhancing and disseminating the historical tangible and intangible values of the port, giving them public accessibility and redeveloping the overall landscape of the city. The historical sites and their surrounding should represent centrality and landmarks for citizens and population.

The realization of the port park is a complex project, which needs several activities and partners, and it is carried out in different work packages (Figure 7. 17): the scientific and cultural project (WP1), the safeguard plan (WP2), the enhancement project (WP3) and, then, the management plan (WP4).

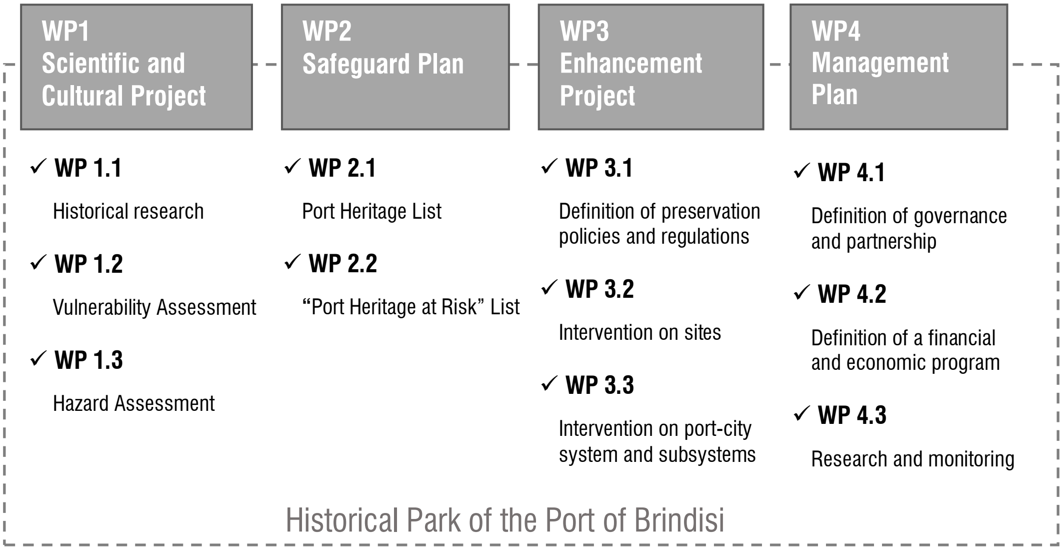

Figure 7. 17 Conceptual scheme of the Historical Park of the Port of Brindisi

The scientific and cultural project (WP1) is a key phase, because it concerns the identification and assessment of the historical sites of the port, aiming to the construction of the knowledge framework. The heritages have to be analysed in terms of historical properties and evolutions (WP1.1), reporting all the documentation, data, events and values layered over the centuries. In addition to this, the scientific project aims to assess the materials, construction, functional, technological and cultural characteristics of the historical buildings, spaces and areas located in the port, in order to preserve those significant features and to qualify their actual state of conservation (WP1.2). For the present case of study, the historical research and documentation is summarized in the section 7.1, while the scientific assessment of the Brindisi port heritage is described and explained in the 7.2 paragraph. The scientific work package aims to report in detail the main property of the sites representing the basis on which the enhancement project develops. It also include the analysis of the port territory, identifying the main risk factors (WP1.3), which can potentially affect the heritages. Exactly they are described in paragraphs 7.3 and 7.4.

The scientific assessment of the port of Brindisi leads to the definition of a safeguard plan of the historical port (WP2). In effect, from the WP1.1 phase it is possible to define a list of buildings, spaces and areas with a potential historical and cultural interest. Particularly, Brindisi has a very heterogeneous amount of assets with these potentialities, starting from logistic buildings, such as lighthouses, maritime station and academy, which are commonly not protected and listed by State (Codice dei Beni Culturali e del Paesaggio, 2004) and Regions (Piano Paesaggistico Territoriale Regionale P.P.T.R. , 2015). In addition to this, some spaces represent historical landmarks for the city: it is the case of the *Pigonati* Channel or the *Regina Margherita* Waterfront. Thus, it is possible to draw up a new "Port Heritage List of Brindisi" (WP2.1), reporting the sites to protect and enhance, as in Table 7.1.

Subsequently, combining it with the risk assessment (WP1.2/WP1.3) the heritages most affected by risk in the port can be identified. In effect, the assessment of the vulnerability of historical sites, compared with the level of aggression and hazards of the port activities, leads to the identification of a list of "Port Heritages at Risk" in the port of Brindisi (WP2.2). The definition of this list, updated periodically every 5-10 years, should allow institutions and stakeholders to monitor the state of historical and cultural assets, in order to program interventions for their preservation. Particularly, the main results of the risk estimation are listed in Table 7. 17. Considering the actual state of conservation, the most affected sites potentially at risk are those heritages with a certain level of vulnerability, mixed with a potential territorial aggression.

List of “Port Heritage at Risk” - BRINDISI				
Heritage	**Global Vulnerability**	**Stationary Impact**	**Accidental Impact**	**At Risk**
Montecatini shed	Medium	X	X	X
Maritime Academy	High			X
Maritime Station	Low	X	X	X
Traversa Lighthouse	Low	X		
Punta Riso Lighthouse	High	X		X
Aragon Castle	Medium	X	X	X
Swabia Castle	Low			
Pigonati Channel	Medium	X	X	X
Punta delle Terrare	Medium	X		X
Historical waterfront	Low			
Sailor’s Monument	Low			
Fisherman’s village	Medium			
S. Andrew Island	High	X		X
Navy Arsenal	Low			

Table 7. 17 The List of "Port Heritage at Risk in Brindisi"

Firstly, in the case of the Aragon Castle, *Montecatini* shed and maritime station, the material and functional vulnerability, added to the potential risk of disaster with disruptive effect, represents a high threat, which can lead to loss important cultural and historical values. In addition to this, a tangible risk for these buildings is represented by the stationary effects produced by air pollution mainly, as it can cause pathological deterioration processes of construction and decorative materials.

Secondly, there are some historical sites for which the accidental risk is not considered because the distance from accidental impact sources is great enough. Nevertheless, the estimation of a somewhat potential risk is justified by the high vulnerability, such as for the *Punta Riso* lighthouse or for St. Andrew Island, and by the high level of environmental aggression induced by the port activities, such as for *Punta delle Terrare*. Suddenly, it points out that the heritages affected by a high level of risk with the necessity of specific strategies and intervention for preservation and protection are the following: *Montecatini* shed, maritime station, *Punta Riso* lighthouse, Aragon Castle, among the buildings; the *Pigonati* Channel, *Punta delle Terrare*, and St. Andrew Island are, instead, the most affected spaces.

The WP3 phase aims to identify the strategies for the project and realization of the historical park. In detail, starting from the previous tasks, the enhancement project concerns all those interventions for the rehabilitation and enhancement of historical heritages in the port of Brindisi. As shown in Figure 7. 17, the WP3 has three main goals: the identification of the preservation policies and regulation for historical sites (WP3.1); identification of the interventions in order to enhance each port heritage (WP3.2); the definition of strategies for port systems and subsystems (WP3.3).

The general preservation and safeguard policies (WP3.1) of the park, which have been summarized in Chapter 6, are those initiatives that should directly and indirectly protect historical sites of Brindisi. Firstly, the restoration and maintenance of heritage need to ensure the application of the guidelines introduced firstly by Venice Charter and, then, by the Krakow one, respecting the Italian Cultural Heritage Code 42/2004. Secondly, each single intervention on the port heritage has to respect the general regulation of the park. Regarding the safeguard of heritage ($I_{3,n}$), a continuous monitoring of the state of conservation of heritage through non-destructive diagnostic tests is necessary for the preservation of cultural values, as well as the surveillance and supervision of the sites.

As a general guideline, the project of the park provides that all the port sites have to be signalled and described on site, including the use of innovative tools such as 3D reconstruction and augmented reality ($I_{4,1}$), ($I_{4,2}$) and ($I_{4,3}$).

The intervention of enhancement ($I_{4,n}$) of heritages aims to preserve the naval, maritime, productive, cultural values, which are a unique testimony of the port history of Brindisi.

In effect, the first theme of the park regards the archaeological sites, which are a witness of the glorious past of the port in Roman Empire: Punta delle Terrare and the two columns of the Appian Way represent a challenge for the enhancing of the ancient history of Brindisi. Secondly, the maritime fortifications of the city, e.g. the Aragon Castle, are another important historical value, as well as the intervention made on the port in XIX century: the Pigonati Channel is the most important one, which has given back to Brindisi its inner port contributing to make the city one of the ports of the Oriental Indian Company. Furthermore, some of the main properties of the port are represented by the Fascist architectures and spaces, which gave to Brindisi a monumental aspect and an international value in the early 20th: the Maritime Academy area, the Sailor's Monument gardens, and the maritime station with the east docks are some significant examples. An industrial archaeology example, the Montecatini shed, also gives to Brindisi a productive vocation that has to be enhanced. Thus, the intervention and plans on historical sites have as the main goal the enhancement of all these thematic historical paths.

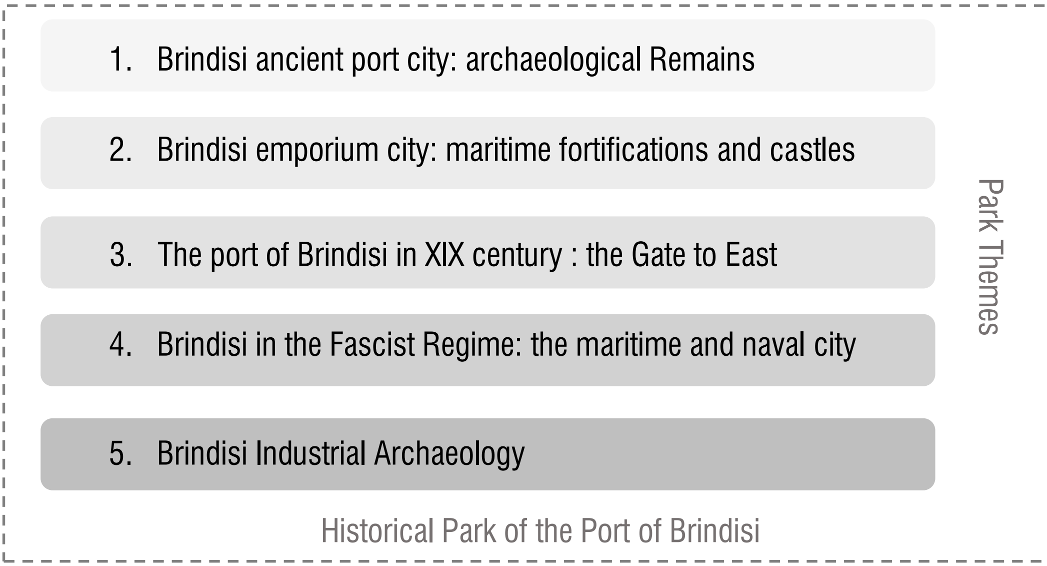

Figure 7. 18 The suggested themes for the historical park of the port of Brindisi

In order to regenerate the port areas of Brindisi, it is worth saying that, together with the restoration and maintenance of cultural sites, the promotion of social and cultural

events at a local, regional and national scale at least could be an opportunity for the city. In addition to this, another strategy could be the location of public services and functions in some port sites, compatibly to their characteristics, for a better integration with the urban areas life.
In the WP3.2, starting from the results of the risk assessment, the main interventions and strategies for heritages redevelopment and reuse are identified. Particularly, some guidelines are subsequently listed for the regeneration of the port areas of Brindisi:

- **Montecatini shed**: the warehouse built in 1930 by *Montecatini* industrial company has been decommissioned and, then, abandoned. In order to reuse the building, which actually has a fair state of conservation and functional obsolescence, it should be carried out an intervention of curative maintenance ($I_{1,3}$), together with a functional adaptation ($I_{1,5}$). The present heritage reconversion represents a very significant challenge for Brindisi, because it is an exemplar industrial archaeology heritage with extraordinary wooden structures. According to the morphology and typology of building, it is proposed to house a maritime and historical museum of Apulia and Brindisi ($I_{4,8}$), giving importance and centrality to the entire area, which actually need a regeneration project ($I_{4,10}$) in order to connect it to the urban areas and to increase the quality of spaces.
- **Maritime Academy**: the also called Naval College ONB, built in 1937, is actually abandoned and it has a very high vulnerability level, needing immediate secure operation for avoiding the risk of collapse. Suddenly, for its redevelopment and reuse, it should be carried out a restoration project ($I_{1,7}$) including both the materials and construction rehabilitation, both the functional adaptation in the view of a new use. Specifically, particular attention should be given to the intervention on reinforced-concrete structures, vulnerable to the chemical aggression, with protection and consolidation intervention. The restoration project aims to the enhancement of the maritime and naval values of the Fascist period, e.g. the rationalist architectural properties ($I_{4,9}$). Thus, since the complex is located at the centre of a landscaping urban area of Brindisi, it is worth suggesting that

it should have a public and urban function, able to attract population, citizens and users, respecting the historical vocation ($I_{4,6}$) ($I_{4,9}$). It could be a new centrality for the district *Casale*, which is actually threaten by social and physical decay.

- **Maritime Station**: as the maritime academy, this is another important historical testimony of the large intervention made by the Fascist Regime during the two World Wars. It is a rationalist architecture built in 1936-40. Today, the building is partially destined to port offices and has lost the historical vocation of housing passengers and travellers. The building has a quite good state of conservation, but has lost some historical properties: an example is the colour of the facades, which have been changed by recent interventions. In addition to this, the docks and railroads are abandoned. Interventions of curative maintenance ($I_{1,3}$) and functional adaptation ($I_{1,5}$) are necessary to give back this centrality to the historical centres. The new destination proposed should have the capacity to attract and entertain population, tourists and visitors, respecting the original vocation of the building ($I_{4,6}$) ($I_{4,9}$). In effect, since when the Oriental Company steamers have moored in Brindisi, this area of the inner port has represented the centre of travels, routes and commercial traffics.

- **St. Andrew Island and *Punta Riso* Lighthouse**: the lighthouse represents the essence and the symbol of ports, since ancient times. Brindisi has two of them, both built in XIX century. While *Traversa* lighthouse is actually in operation and in a quite good state of conservation, the *Punta Riso* one is surely compromised. Since the construction of the homonymous dam, it has not worked. Today, the building has a high material vulnerability, with the risk of collapse. Thus, firstly some securing operation ($I_{1,1}$) are necessary, in the view of a complete restoration project ($I_{1,7}$), able to give a new function to the heritage.
  The island is either abandoned in a very low state of conservation, with abandoned and deteriorate military facilities, waste and it is a restricted area.
  The rehabilitation of both the historical assets depends on the conversion of the entire area from a military function to a public and urban one. In effect, since it

is a territory with potential landscaping values, it should be proposed the realization of a maritime and natural green park, to make accessible to population, where the lighthouse could be a centrality, housing touristic and receptive structure ($I_{2,1}$) ($I_{4,6}$) ($P_{1,1}$). The island clearly needs a regeneration plan in order to redevelop both the natural and built environment, mitigating the pollution and waste impact.

- **Fortifications, the Sea and Land Castles:** the port of Brindisi certainly represents an excellence also because it houses two large fortifications. The Land or Swabia Castle, built since 1233, respects the traditional characteristics of the castle in Apulia Region: it is realized next to the historical centre boundaries, linked to the ancient walls. Today it is well-preserved, also because it has been used with a compatible function: a navy base. In effect, it cannot be considered as a heritage at risk.

  The Sea fortification, named also Red Castle, dates back 1481, when Brindisi needed a new defensive element for the protection of the port. It is one of the most landscaping architectures of Brindisi, visible from almost all the port areas. Today, it represents a great challenge and opportunity for the city, but it is abandoned and not protected. The high functional vulnerability is a consequence of the abandonment process, as well as the material decay. In effect, the building is located in a very hazardous area of the port, where the effects of air pollution are the highest and with the risk of potential major accidents at a short distance. The redevelopment of the middle port and the *Bocche di Puglia* bay depends on the rehabilitation of this massive heritage.

  The actual state needs a restoration project ($I_{1,7}$) for the preservation of materials and constructive elements and, principally, for giving to the castle and to the horn-work a new compatible use. The geographical location can be considered both as an opportunity for the closeness to the St. Island, both a weakness, for the low accessibility, possible only by maritime way and through the dam. The new function should have the strength to attract visitors and people in this suburb area of the port-city system ($I_{4,4}$) ($I_{4,5}$) ($I_{4,6}$) ($I_{4,10}$). A natural and cultural destination, jointly the regeneration of the St. Andrew Island is proposed for the Sea Fortress.

- **Pigonati Channel:** built in 1778-81 under the engineer Pigonati, the access channel of the inner port represents a significant historical testimony for Brindisi, since the fact that after its opening the city had a renaissance period. Actually, the two docks, named as the King and Queen of Bourbon, are completely abandoned, inaccessible and deteriorate with structural stability criticalities. Their complete redevelopment and enhancement ($I_{1,7}$) ($I_{2,4}$) ($I_{4,9}$) ($P_{1,1}$). is strongly suggested, realizing a cultural area accessible for visitors and citizens, with the restoration of the two docks, and of the facilities located on them. Descriptions, 3D reconstruction and augmented reality should show to visitors the past port configuration, before and after this intervention.
- **Sailor's Monument Garden and the Historical Waterfront:** the monument represents a symbol of the maritime and naval importance of Brindisi in the national history. It was built in 1933 during the Fascist Regime in the West bay of the inner port. Nowadays, it has a good state of conservation and preserve its socio-cultural identity as well as historical authenticity.
  The waterfront of Brindisi is probably the most landscaping value of the city, with their historical curtains, the Regina Margherita promenade, and the Roman columns symbol of the Appian Way. It has been recently restored and redeveloped. Both the two sites have a very low vulnerability, representing the best-conserved heritages in Brindisi. For this area it is highly suggested the promotion of a heritage harbour, with traditional and historical ships ($I_{4,7}$).
- **Fishermen District:** the area, located in *Casale* district, dates back 1959-60 when the fishermen docks were moved from the "*Sciabiche*", an area next to the Swabia Castle, to the opposite shore of the bay. The district today show an overall low state of conservation, both for docks, open spaces and residential buildings. Social decay and losses are also present, contributing to deteriorate the historical and cultural significance of the places. It is highly suggested a

regeneration and integrated plan ($I_{2,1}$) ($I_{2,2}$), in order to increase the level of habitability, of quality of spaces and of connection with the other urban areas. The buildings mainly need curative maintenance, including functional adaptation. Open spaces, docks and paths, instead, should be redeveloped in terms of materials, surfaces and structures. The enhancement of the area should go through the introduction of mixed public-private functions and services for revitalize the district ($I_{4,6}$) ($I_{4,9}$), with a particular attention to the preservation of the fishing ships, docks, structures and, then, to the maritime properties.

The following task concerns the definition of strategies for port systems and subsystems (WP3.3). Regarding the redevelopment of port areas, the main criticalities are represented by the very low accessibility and level of connection of the waterfront, as well as the presence of several abandoned, restricted and polluted areas, which represents both a threat for the immediate close historical heritage.
Firstly, it is worth mentioning the actual state of abandonment of the St. Andrew Island, which is restricted and inaccessible, compromising the Aragon Castle usability. Secondly, in the East bay of the inner port, the presence of some decommissioned and unused areas leads to fragment and isolate some potential cultural sites: the St. Apollinaire and ex-coal docks compromises the accessibility of the *Pigonati* Channel and also of the *Montecatini* shed. The interventions in these areas aims to increase public accessibility and the quality of open spaces, reconnecting a large part of the inner basin ($P_{1,2}$). In effect, today only four of the 18 km of the port are connected and accessible to citizens and visitors. Thus, it represents an important challenge for the port-city regeneration and for the park success. The usability of port areas should be improved by a new mobility plan, promoting public soft transports such as maritime shuttles or the realization of green, pedestrian and bicycle paths to reconnect port sites respecting historical vocation and natural environment ($P_{1,3}$) ($P_{1,4}$) ($P_{1,5}$). The maritime transports should connect at least the three different basins of the port, allowing visitors to move from the historical waterfront *Regina Margherita* to the *Bocche di Puglia* bay, as well as to *Montecatini* shed.

Furthermore, the risk assessment reveals the presence of stationary and accidental impacts on historical assets. The main hazardous areas are the East bay of the inner port and the middle and outer basins, with a potential risk of explosion and the environmental effects of industrial plants, in terms of waste, air pollution and landscaping impact. Thus, emergency and resilience plans have to be carried out considering both the risk on people, nature and cultural sites, defining strategies for the mitigation of those impacts and reducing the risk of loss ($P_{2,1}$) ($P_{2,2}$). When possible the most dangerous activities need to be relocated in spaces with a great distance from assets ($P_{2,4}$). Regarding the environmental management of port activities, a continuous monitoring of emissions, waste, noise and odours has to be performed by authorities, defining strategies for their reduction as soon as possible ($P_{2,4}$) ($P_{2,5}$) ($P_{2,6}$) ($P_{2,7}$). The visual impact of port transformation need to be mitigated in future interventions, particularly in sensible areas.

Finally, a management plan should be necessary (WP4), in order to identify the partners and collaborators of the project (WP4.1), to define an economic plan of financial sustainability (WP4.2) and for define a monitoring and research program (WP4.3). In effect, Brindisi port areas involved different institutions and stakeholders, such as Brindisi Port Authority, Brindisi Municipality, Apulian Region, Italian Navy and State, shipping companies, privates, etc. Thus, it is suggested as management strategy the foundation of a limited participation company, in which all these partners (clearly with different percentage) give a contribution to define the main goals of the project and to develop it. The collaboration of scientists, experts, universities and research centres is necessary for the project and, then, management of the port park. In effect, the preservation of historical and cultural sites need an intense research in order to improve the actual technical strategies and to find innovative systems of sustainable interventions and management.

Discussion and conclusion

The current research work was aimed to carry out a methodology for the identification of the risks - in terms of losses of material, artistic, cultural values- affecting the historical heritage of ports, in order to identify guidelines and strategies for its preservation and enhancement, as well as for the integration of the port-city system.
Firstly, the assessment of the architectural heritages of the most significant Mediterranean port cities led to build a knowledge framework for the classification and qualification of maritime and port heritage, and for the understanding of the dynamics of the port transformation over the centuries. Particularly, the morphological and historical evolution of ports, described in Chapter 1, allowed reconstructing the relationship between port and city in different historical periods and geographical areas, from the Oriental ports, as Acre, Tripoli and Alexandria, to the West European ones, mainly repre-

sented by Genoa, Venice, Marseille and Barcelona. The main models of ports are identified: the port-city and the city with a port. In the first case, the relationship between ports and urban areas is synergic. The other cases, instead, concern cities with port infrastructures, which are separated clusters. From the assessment of those ports, a classification of historical heritages was carried out, identifying five categories of buildings and four of port areas. Among the buildings, productive and industrial archaeology, mercantile facilities, logistic buildings, fortifications and sacred architectures are the most frequent examples. The spaces concern docks and piers, archaeological sites, waterfronts and military areas. Furthermore, the construction techniques of piers and docks were described and discussed in the first chapter.

Secondly, a methodology for the identification and estimation of risks, which can affect historical heritages in ports, was structured. Starting from the assessment of the state of art of the risk concept relating both cultural heritage and ports, it pointed out that the proposed method should be aimed to evaluate risk through the assessment of the vulnerability of heritages of ports and of the main hazards produced by port activities.

A simplified methodology for assessing the vulnerability of cultural assets in ports was defined and described in chapter 3, considered as sum of three main contributes: material vulnerability, and functional and cultural one. The estimation was provided through specific forms, defined for each specific category of port assets, as shown in the section Annexes of the thesis. The material vulnerability was estimated through indicators referring to the state of conservation, to susceptibility to fire and chemicals, among the others. The functional index was calculated considering the level of accessibility, usability, level of protection, property and management, for instance. The third component dealt with the cultural vulnerability, i.e. a parameter based on the level of safeguard, the socio-cultural identity, the historical authenticity, etc. The weighted average value led to identify a global index representing all the criticalities of the heritages.

Subsequently in Chapters 4 and 5, the concept of hazard, i.e. impacts of port activities on historical heritages, was explained and analyzed proposing methods for its assessment. The hazard was considered in two main typologies: stationary and exceptional

ones. The stationary impact refers to the environmental consequences, which are continuously produced by port activities, such as emission to air, water and soil. The main effects of these impacts on heritage are described in order to provide a method for their estimation. They concern mostly impacts on construction materials, on use and function and on landscaping values. The stationary impacts were estimated through the assessment of the territorial extension and operational frequency of the port activities, which led to calculate the scores for each Significant Environmental Aspect for Heritage (SEAH) and, then, the effects on historical port assets. A hazard index of the port was identified in percentage.
The exceptional impacts, instead, are those ones potentially produced by the occurrence of the so-called major accidents: mainly explosions and fires, produced by hazardous substances in ships collision, storage and loading/unloading operations in ports. A methodology for the estimation of the frequency of those accidents, as well as of the evaluation of the consequences on historical sites, was proposed, mostly focusing on explosions.

The heritage classification and the definition of a methodology for risk assessment aimed to identify specific guidelines for an integrated development of the port-city system, with particular attention to the preservation and enhancement of historical sites, and the mitigation of risks affecting them in ports.
Analyzing the main interventions or ports redevelopment and reconversion since the last century, some strategies for heritage preservation and port-city system sustainable development were identified and explained. Particularly, the chapter 6 described that five approaches of port reconversion have redesigned ports in the last decades, starting from the American one of the 1960-70, followed by the Tertiary and Residential one of North Europe in the '80s. These approaches contribute to deteriorate socio-cultural identity and historical authenticity of port areas. The approaches which can be considered as best-practice are partially the Event one, and certainly the Saint-Nazaire and the Sustainable and Ecologist ones. In effect, in these cases, the port redevelopment gave to the sustainability and to historical landscape a central role, considering them as opportunities rather than constraints.

Thus, two levels of strategy of intervention were defined: strategy on heritage and, and on port system or subsystems. The main goals of the guidelines are the preservation, safeguard and enhancement of historical landscape of ports, the dissemination of their cultural values, the territorial redevelopment, the risk reduction and, finally, the sustainable and integrated governance.

Finally, the research methodology was applied to a given case, the port of Brindisi located in Apulia, South-East of Italy. The case of study was chosen because particularly interesting in terms of level of interference of the industrial, mercantile, commercial and logistic activities with the cultural and historical heritages of the port. Brindisi port area was analyzed in terms of history, morphology, functions and characteristics.

The vulnerability assessment of port assets was carried out revealing that the majority of them are certainly compromised. The 56% of them are somewhat vulnerable elements: the 56% of sites has a medium or high material vulnerability, with material or structural damage and deterioration processes; the 44% of heritage has functional deficiency as abandonment or inaccessibility; despite the low state of conservation and the high level of abandonment, it pointed out that only the 21% of historical buildings and spaces of the port are vulnerable from the cultural point of view.

It is worth saying that the high percentage of medium-high V_{cult} of sites is certainly an indication that without specific measures of protection and enhancement, the risk of cultural losses is very high.

Comparing vulnerabilities with the assessment of stationary and exceptional impacts, it came out that actually there are some historical assets of the Brindisi seriously threatened. In effect, the assessment of port activities with potential stationary impacts on cultural sites led to recognize specific port areas with a high level of aggression.

From the assessment, the material deterioration due to air pollution was the main hazard factor, followed by discharges to water and soil, as well as waste and noise.

The visual and morphological impact of port activities, specifically industrial plants in the outer port, was identified as another important hazard affecting Brindisi landscape. The overall level of hazard estimated with a value of 70%, i.e. high hazard.

The assessment of exceptional impacts on landscaping elements and historical heritage in port context was carried out, focusing on the specific case of the port of Brindisi, in order to identify the heritage at risk.
Firstly, it pointed 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 revealed that there are some potential accident scenarios with effects on landscaping components. Two main were 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 were estimated for the identified scenarios.
The results showed 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 centre 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 vapour 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.

In the view of a risk mitigation and sustainable development of the Apulian port-city, a strategic scenario was proposed: the constitution of a “Historical Park of the Port of Brindisi”. A structured strategy of intervention is defined: first of all, the redevelopment of port areas, as well as the risk reduction, should be a priority for the city in order to preserve historical properties and values; secondly, a port-city governance must be organized for defining the main future sustainable goals of the territorial system, considering cultural and historical landscape preservation and enhancement as challenge and opportunity. Concerning the historical heritage, a list of port assets needing protection and safeguard was defined, as well as a "heritage at risk list" containing all the sites most affected by risks. For those ones, specific strategies for materials and structures conservation, functional rehabilitation and cultural enhancement were identified, with particular attention to the maritime, historical, cultural and port values, both tangible that intangible.

Analysing the research thesis carried out, it is worth saying that the planning and development in the specific context of the port-city system have to be oriented to the protection and safeguard of the cultural, historical and natural landscapes, which are often very sensible and vulnerable components. Specifically, it points out that the main risks, in terms of loss of tangible and intangible cultural values, are related to the vulnerability of the heritage, on the one hand, and the potential impacts of the port activities, on the other. Firstly, the vulnerability should be considered as not only a concept related to the physical state of conservation but also to the management and relationship with the context, which are factor very important in the preservation, even more in ports. Secondly, dangerous port activities have to be located in specific areas where the interference with the historical and natural components is very low, as well as the level of security has to be continuously high. In order to avoid consequences on people and landscape it is also necessary the instantaneous monitoring of the environmental conditions in the port areas.
Furthermore, the research performed shown that, although the frequencies of the 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. Since it was demonstrated that port areas are sensible and vulnerable historical areas, the thesis wants to underline the necessity to develop specific programs and strategies for the mitigation of risks affecting cultural sites in ports, as well as for the preservation and enhancement of their historical vocation. The work aims to promote a scientific debate about the particular criticalities in the preservation and development of historical Mediterranean ports, suggesting as a future goal the definition of a Charter of Conservation of Historical Ports and Waterfronts, in which they

will be considered both stationary and exceptional impacts of port activities, on the one hand, and vulnerability of heritage, on the other one.

Acknowledgments

The current thesis is based on the work and the research activities carried out during the PhD program “Risk and Environmental, Territorial and Building Development“, at Politecnico di Bari.

I started this path three years ago, as architect engineer, with passion, hope and devotion, and after an intense study, the participation in national and international conferences, the collaboration with colleagues and researchers, I think I significantly improved my skills in research, communication, writing and, generally, as man.

Thus, I would like to thank some colleagues and friends, which have supported and helped me to achieve these goals.

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I wish to acknowledge my thanks to my colleague, roommate and friend Alessandro, with which I've spent probably the most of the time of this PhD, sharing several activities, experiences and the everyday life in university.
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Finally, I thank my partner in life Sabrina for being always by my side, for supporting and encouraging my choices and aims. I would not have been at this step of my life without her.
Anyway, I hope that the best for me is yet to come.

Annexes

1. **Vulnerability Form for Historical Buildings (B)**
2. **Vulnerability Form for Historical Docks and Piers (S_1)**
3. **Vulnerability Form for Archaeological Sites (S_2)**
4. **Vulnerability Form for Waterfronts, Historical Centres and Maritime Districts (S_3)**
5. **Vulnerability Form for Military areas (S_4)**
6. **Hazard Form for Historical Ports**

Vulnerability form					n.1
Photographic documents					
Level 0 - General data					
Name					
Historical heritage category	B1. Industrial archaeology - Productive facilities				
	B2. Logistic buildings (lighthouses, maritime station, etc.)				
	B3. Commercial and mercantile buildings				
	B4. Fortification and similar				
	B5. Sacred architectures				
Location	City		Province		
	Region		State		
	Zone		GPS		
Dimension	Area		Volume		
Origin Period					
Property	Public		Private		
Original use					
Actual use					
Documentation/sources	Photographic	Archive	Bibliography		
Report and survey	Direct	Total	Partial	Date	
Vulnerability					0

Annex 1.1 The Level 0 form for Buildings (B)

<table>
<tr><td colspan="2">Vulnerability form</td><td colspan="4"></td><td>n.2</td></tr>
<tr><td colspan="7">MATERIAL VULNERABILITY</td></tr>
<tr><td rowspan="12">Structural components</td><td>Vertical structures
Typology/materials</td><td colspan="5"></td></tr>
<tr><td>Horizontal structures
Typology/materials</td><td colspan="5"></td></tr>
<tr><td>Roofs
Typology/materials</td><td colspan="5"></td></tr>
<tr><td colspan="6">State of Conservation</td></tr>
<tr><td colspan="2" rowspan="2">Damage Class (DC)</td><td colspan="4">Damage Level (DL)</td></tr>
<tr><td>Gravity</td><td>Urgency</td><td>Diffusion</td><td>Score</td></tr>
<tr><td colspan="2">Structural damage</td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="2">Material deterioration</td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="5">Total</td><td>0</td></tr>
<tr><td rowspan="2">List of artistic and cultural elements</td><td colspan="3">Presene of artistic elements</td><td>yes = 1
no=0</td><td>0</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="5">Artistic and cultural components</td><td colspan="2" rowspan="2">Damage Class (DC)</td><td colspan="4">Damage Level (DL)</td></tr>
<tr><td>Gravity</td><td>Urgency</td><td>Diffusion</td><td>Score</td></tr>
<tr><td colspan="2">Material deterioration</td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="5">Total</td><td>0</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="5">Building</td><td colspan="6">Materials vulnerability</td></tr>
<tr><td colspan="5" rowspan="2">Vulnerability to fire</td><td>Score</td></tr>
<tr><td>0</td></tr>
<tr><td colspan="5" rowspan="2">Vulnerability to chemical aggression</td><td>Score</td></tr>
<tr><td>0</td></tr>
<tr><td>Vmat</td><td colspan="5">Vmat (%) = S Pi / Pmax</td><td>0</td></tr>
</table>

Annex 1.2 The material vulnerability form for Buildings (B)

Vulnerability form		n.3
FUNCTIONAL VULNERABILITY		
Accessibility	Public access	0
	Temporary public access	1
	Access only to employers	2
	Inaccessible	3
	Accessibility	
Use	Actual use	
	Original use	
	Compatible	0
	Acceptable	1
	Just acceptable	2
	Incompatible or unused	3
	Use compatibility	
	Total Use	0
	Partial Use	1
	Unused (<10 years)	2
	Abandoned (>10 years)	3
	Level of use	
Property and management	Property	
	Management	
	Compatible or coincident	0
		1
		2
	Incompatible/different	3
	Property/management	
Conservation policies	Intervention (date)	
	Plans (date)	
	Current / realized (< 5 years)	0
	Realized (5-15 years)	1
	Not realized but programmed	2
	Not realized and programmed	3
	Conservation policies	
V_{fun}	V_{fun} (%) = S P_i / P_{max}	0

Annex 1.3 The functional vulnerability form for Buildings (B)

Vulnerability form		n.4
CULTURAL VULNERABILITY		
Safeguard, laws	Yes	0
	No	3
	Safeguard	
Historical and cultural identity	*Acknowldgement of the historical values by local community*	
	Yes	0
	Partial	1
	Poorly	2
	No	3
	Identity	
Authenticity	The heritage maintains all the values	0
	The heritage maintains the majority of values	1
	The heritage maintains a low amount of values	2
	The heritage has lost many values	3
	Authenticity	
Dissemination and knowledge	*Dissemination of the historical values through descriptions and reports available to the public*	
	High (national, regional, local)	0
	Medium (regional, local)	1
	Low (local)	2
	Inadequate or absent	3
	Dissemination	
Context	Adequate	0
	It does not affect heritage	1
	It needs redevelopment	2
	Inadequate	3
	Context	
	Adequate viability, transport and connessions	0
	Good connections	1
	Poorly connected	2
	Isolated	3
	Connection to urban nodes	
Vcult	**Vcult (%) = S Pi / Pmax**	**0**

Annex 1.4 The cultural vulnerability form for Buildings (B)

<table>
<tr><th>Vulnerability form</th><th colspan="5"></th><th>n.1</th></tr>
<tr><td colspan="7">Photographic documents</td></tr>
<tr><th colspan="7">Level 0 - General data</th></tr>
<tr><td>Name</td><td colspan="6"></td></tr>
<tr><td rowspan="5">Historical heritage category</td><td colspan="6">S1. Port spaces: Piers, docks, equipment</td></tr>
<tr><td colspan="6">Pier</td></tr>
<tr><td colspan="6">Dock</td></tr>
<tr><td colspan="6">Equipment</td></tr>
<tr><td colspan="6">Other</td></tr>
<tr><td rowspan="3">Location</td><td>City</td><td colspan="2"></td><td>Province</td><td colspan="2"></td></tr>
<tr><td>Region</td><td colspan="2"></td><td>State</td><td colspan="2"></td></tr>
<tr><td>Zone</td><td colspan="2"></td><td>GPS</td><td colspan="2"></td></tr>
<tr><td>Dimension</td><td>Area</td><td colspan="2"></td><td>Volume</td><td colspan="2"></td></tr>
<tr><td>Origin Period</td><td colspan="6"></td></tr>
<tr><td>Property</td><td colspan="3">Public</td><td colspan="3">Private</td></tr>
<tr><td>Original use</td><td colspan="6"></td></tr>
<tr><td>Actual use</td><td colspan="6"></td></tr>
<tr><td>Documentation/sources</td><td colspan="2">Photographic</td><td colspan="2">Archive</td><td colspan="2">Bibliography</td></tr>
<tr><td>Report and survey</td><td>Direct</td><td>Total</td><td>Partial</td><td>Date</td><td colspan="2"></td></tr>
<tr><td colspan="6">Vulnerability</td><td>0</td></tr>
</table>

Annex 2.1 The Level 0 form for Port Spaces (S_1)

Vulnerability form						n.2
MATERIAL VULNERABILITY						
Spaces and structures	**Structures**					
	Spaces					
	State of Conservation					
	Damage Class (DC)		Damage Level (DL)			
			Gravity	Urgency	Diffusion	Score
	Structural damage					0
	Material deterioration					0
	Total					0
	Material Vulnerability	Vulnerability to fire				Score
		Vulnerability to chemical aggression				Score
Port equipment	**List of port equipment**	Presence of historical equipment			yes = 1 no=0	0
	State of Conservation					
	Damage Class (DC)		Damage Level (DL)			
			Gravity	Urgency	Diffusion	Score
	Material deterioration					0
	Total					0
	Material Vulnerability	Vulnerability to fire				Score
		Vulnerability to chemical aggression				Score
V_{mat}	**V_{mat} (%) = S P_i / Pmax**					**0**

Annex 2.2 The material vulnerability form for Port Spaces (S_1)

Vulnerability form		n.3
FUNCTIONAL VULNERABILITY		
Accessibility	Public access	0
	Temporary public access	1
	Access only to employers	2
	Inaccessible	3
	Accessibility	
Use	Actual use	
	Original use	
	Compatible	0
	Acceptable	1
	Just acceptable	2
	Incompatible or unused	3
	Use compatibility	
	Total Use	0
	Partial Use	1
	Unused (<10 years)	2
	Abandoned (>10 years)	3
	Level of use	
Property and management	Property	
	Management	
	Compatible or coincident	0
		1
		2
	Incompatible/different	3
	Property/management	
Conservation policies	Intervention(date)	
	Plans (date)	
	Current / realized (< 5 years)	0
	Realized (5-15 years)	1
	Not realized but programmed	2
	Not realized and programmed	3
	Conservation policies	
V_{fun}	V_{fun} (%) = S Pi / Pmax	0

Annex 2.3 The functional vulnerability form for Port Spaces (S_1)

Vulnerability form		n.4
CULTURAL VULNERABILITY		
Safeguard, laws	Yes	0
	No	3
	Safeguard	
Historical and cultural identity	*Acknowldgement of the historical values by local community*	
	Yes	0
	Partial	1
	Poorly	2
	No	3
	Identity	
Authenticity	The heritage maintains all the values	0
	The heritage maintains the majority of values	1
	The heritage maintains a low amount of values	2
	The heritage has lost many values	3
	Authenticity	
Dissemination and knowledge	*Dissemination of the historical values through descriptions and reports available to the public*	
	High (national, regional, local)	0
	Medium (regional, local)	1
	Low (local)	2
	Inadequate or absent	3
	Dissemination	
Context	Adequate	0
	It does not affect heritage	1
	It needs redevelopment	2
	Inadequate	3
	Context	
	Adequate viability, transport and connessions	0
	Good connections	1
	Poorly connected	2
	Isolated	3
	Connection to urban nodes	
Vcult	**Vcult (%) = S Pi / Pmax**	**0**

Annex 2.4 The cultural vulnerability form for Port Spaces (S_1)

<table>
<tr><th>Vulnerability form</th><th colspan="4"></th><th>n.1</th></tr>
<tr><td colspan="6">Photographic documents</td></tr>
<tr><th colspan="6">Level 0 - General data</th></tr>
<tr><td>Name</td><td colspan="5"></td></tr>
<tr><td rowspan="5">Historical heritage category</td><td colspan="5">S2. Archaeological sites:</td></tr>
<tr><td colspan="5">On land site</td></tr>
<tr><td colspan="5">Submerged site</td></tr>
<tr><td colspan="5">Other</td></tr>
<tr><td colspan="5">Other</td></tr>
<tr><td rowspan="3">Location</td><td>City</td><td></td><td>Province</td><td colspan="2"></td></tr>
<tr><td>Region</td><td></td><td>State</td><td colspan="2"></td></tr>
<tr><td>Zone</td><td></td><td>GPS</td><td colspan="2"></td></tr>
<tr><td>Dimension</td><td>Area</td><td></td><td>Volume</td><td colspan="2"></td></tr>
<tr><td>Origin Period</td><td colspan="5"></td></tr>
<tr><td>Property</td><td colspan="2">Public</td><td colspan="3">Private</td></tr>
<tr><td>Original use</td><td colspan="5"></td></tr>
<tr><td>Actual use</td><td colspan="5"></td></tr>
<tr><td>Documentation/sources</td><td colspan="2">Photographic</td><td>Archive</td><td colspan="2">Bibliography</td></tr>
<tr><td>Report and survey</td><td>Direct</td><td>Total</td><td>Partial</td><td colspan="2">Date</td></tr>
<tr><td colspan="5">Vulnerability</td><td>0</td></tr>
</table>

Annex 3.1 The Level 0 form for Archaeologic Sites (S_2)

Vulnerability form						n.2
MATERIAL VULNERABILITY						
Immovable heritage	**Structures**	Underground site (>75%)			yes = 0 no= 1	0
		Vertical and horizontal structures				
		Surfaces and floors				
		Columns, capitals				
		Sculpture, inscriptions				
		Paintings, mosaics				
		Other				
	State of Conservation					
	Damage Class (DC)		Damage Level (DL)			
			Gravity	Urgency	Diffusion	Score
	Structural damage					0
	Material deterioration					0
	Total					0
Movable heritage	**Movable remains**	Presence of movable remains			yes = 1 no=0	0
		Epigraphes, sculpture, other				
		Shipwrecks				
		Weapons, objects				
		Numismatic remains				
		Ceramics, ancient glass, etc.				
		Other				
	State of Conservation					
	Damage Class (DC)		Damage Level (DL)			
			Gravity	Urgency	Diffusion	Score
	Material deterioration					0
	Total					0
Site	**Material Vulnerability**	Vulnerability to fire				Score
		Vulnerability to chemical aggression				Score
V_{mat}	Vmat (%) = S P_i / Pmax					0

Annex 3.2 The material vulnerability form for Archaeologic Sites (S_2)

Vulnerability form		n.3
FUNCTIONAL VULNERABILITY		
Accessibility	Public access	0
	Temporary public access	1
	Access only to employers	2
	Inaccessible	3
	Accessibility	
Level of Protection	Protection strategies	
	Absence of protection elements and microclimate control	3
	Presence of horizontal structures of protection (roofs and walkways)	2
	Site characterized by vertical panels and roofs	1
	Site protected by an envelope and with microclimate control / Underground site	0
	Protection strategies	
Property and management	Property	
	Management	
	Compatible or coincident	0
		1
		2
	Incompatible/different	3
	Property/management	
Conservation policies	Intervention(date)	
	Plans (date)	
	Current / realized (< 5 years)	0
	Realized (5-15 years)	1
	Not realized but programmed	2
	Not realized and programmed	3
	Conservation policies	
V_{fun}	**Vfun (%) = S Pi / Pmax**	**0**

Annex 3.3 The functional vulnerability form for Archaeologic Sites (S_2)

Vulnerability form		n.4
CULTURAL VULNERABILITY		
Safeguard, laws	Yes	0
	No	3
	Safeguard	
Historical and cultural identity	*Acknowldgement of the historical values by local community*	
	Yes	0
	Partial	1
	Poorly	2
	No	3
	Identity	
Authenticity	The heritage maintains all the values	0
	The heritage maintains the majority of values	1
	The heritage maintains a low amount of values	2
	The heritage has lost many values	3
	Authenticity	
Dissemination and knowledge	*Dissemination of the historical values through descriptions and reports available to the public*	
	High (national, regional, local)	0
	Medium (regional, local)	1
	Low (local)	2
	Inadequate or absent	3
	Dissemination	
Context	Adequate	0
	It does not affect heritage	1
	It needs redevelopment	2
	Inadequate	3
	Context	
	Adequate viability, transport and connessions	0
	Good connections	1
	Poorly connected	2
	Isolated	3
	Connection to urban nodes	
Vcult	**Vcult (%) = S Pi / Pmax**	**0**

Annex 3.4 The cultural vulnerability form for Archaeologic Sites (S_2)

<table>
<tr><th>Vulnerability form</th><th colspan="5"></th><th>n.1</th></tr>
<tr><td colspan="7">Photographic documents</td></tr>
<tr><th colspan="7">Level 0 - General data</th></tr>
<tr><td>Name</td><td colspan="6"></td></tr>
<tr><td rowspan="5">Historical heritage category</td><td colspan="6">S3. Waterfronts, maritime districts, etc.</td></tr>
<tr><td colspan="6">Waterfront and historical centres</td></tr>
<tr><td colspan="6">Maritime districts</td></tr>
<tr><td colspan="6">Parks, gardens and landscaping areas</td></tr>
<tr><td colspan="6">Other</td></tr>
<tr><td rowspan="3">Location</td><td>City</td><td colspan="2"></td><td>Province</td><td colspan="2"></td></tr>
<tr><td>Region</td><td colspan="2"></td><td>State</td><td colspan="2"></td></tr>
<tr><td>Zone</td><td colspan="2"></td><td>GPS</td><td colspan="2"></td></tr>
<tr><td>Dimension</td><td>Area</td><td colspan="2"></td><td>Volume</td><td colspan="2"></td></tr>
<tr><td>Origin Period</td><td colspan="6"></td></tr>
<tr><td>Property</td><td colspan="3">Public</td><td colspan="3">Private</td></tr>
<tr><td>Original use</td><td colspan="6"></td></tr>
<tr><td>Actual use</td><td colspan="6"></td></tr>
<tr><td>Documentation/sources</td><td colspan="2">Photographic</td><td colspan="2">Archive</td><td colspan="2">Bibliography</td></tr>
<tr><td>Report and survey</td><td>Direct</td><td>Total</td><td>Partial</td><td>Date</td><td colspan="2"></td></tr>
<tr><td colspan="6">Vulnerability</td><td>0</td></tr>
</table>

Annex 4.1 The Level 0 form for Waterfronts (S_3)

<table>
<tr><td colspan="2">Vulnerability form</td><td></td><td>n.2</td></tr>
<tr><td colspan="4">MATERIAL VULNERABILITY</td></tr>
<tr><td rowspan="10">Built Environment</td><td colspan="3">Typologies of architectures</td></tr>
<tr><td>Buildings</td><td colspan="2"></td></tr>
<tr><td>Monuments</td><td colspan="2"></td></tr>
<tr><td>Other architectures</td><td colspan="2"></td></tr>
<tr><td colspan="3">State of Conservation</td></tr>
<tr><td colspan="2">Very few buildings is in good state of conservation (0-25%)</td><td>3</td></tr>
<tr><td colspan="2">Few buildings is in good state of conservationo (25-50%)</td><td>2</td></tr>
<tr><td colspan="2">The majority of building is in good state of conservation (50-75%)</td><td>1</td></tr>
<tr><td colspan="2">The areas is almost totally in good state of conservation (75-100%)</td><td>0</td></tr>
<tr><td colspan="2">State of Conservation</td><td></td></tr>
<tr><td rowspan="10">Public spaces</td><td colspan="3">Typologies of open spaces</td></tr>
<tr><td>Promenade</td><td colspan="2">Squares</td></tr>
<tr><td>Parks</td><td colspan="2">Gardens</td></tr>
<tr><td>Open spaces</td><td colspan="2">Other</td></tr>
<tr><td colspan="3">State of Conservation</td></tr>
<tr><td colspan="2">Very few spaces is in good state of conservation (0-25%)</td><td>3</td></tr>
<tr><td colspan="2">Few spaces is in good state of conservationo (25-50%)</td><td>2</td></tr>
<tr><td colspan="2">The majority of spaces is in good state of conservation (50-75%)</td><td>1</td></tr>
<tr><td colspan="2">The areas is almost totally in good state of conservation (75-100%)</td><td>0</td></tr>
<tr><td colspan="2">State of Conservation</td><td></td></tr>
<tr><td rowspan="10">Viability and streets</td><td colspan="3">Typologies of viability</td></tr>
<tr><td>Streets</td><td colspan="2">Pedestrian paths</td></tr>
<tr><td>Landscaping paths</td><td colspan="2">Cultural paths</td></tr>
<tr><td>Other</td><td colspan="2"></td></tr>
<tr><td colspan="3">State of Conservation</td></tr>
<tr><td colspan="2">Very few paths is in good state of conservation (0-25%)</td><td>3</td></tr>
<tr><td colspan="2">Few paths is in good state of conservationo (25-50%)</td><td>2</td></tr>
<tr><td colspan="2">The majority of paths is in good state of conservation (50-75%)</td><td>1</td></tr>
<tr><td colspan="2">The viability is almost totally in good state of conservation (75-100%</td><td>0</td></tr>
<tr><td colspan="2">State of Conservation</td><td></td></tr>
<tr><td>V_{mat}</td><td colspan="2">Vmat (%) = S P_i / Pmax</td><td>0</td></tr>
</table>

Annex 4.2 The material vulnerability form for Waterfronts (S_3)

Vulnerability form		n.3
FUNCTIONAL VULNERABILITY		
Level of accessibility and usability	Adequate access points, streets, pedestrian and maritime viability, as well as public transport	0
	Adequate access points, streets, pedestrian and maritime viability, but public transport absent	1
	Public transport absent, poor viability	2
	Poorly accessible to public: poor viability, public transport absent, access point inadequate	3
	Accessibility	
Historical vocation	Historical vocation	
	Actual use	
	Compatible	0
	Acceptable	1
	Poorly acceptable	2
	Uncompatible or unused	3
	Compatibility of use	
	Total use / high frequency	0
	Partial use / medium frequency	1
	Unused (<10years) / low frequency	2
	Abandoned (>10years)	3
	Level of use	
Conservation policies	Intervention(date)	
	Plans (date)	
	Current / realized (< 5 years)	0
	Realized (5-15 years)	1
	Not realized but programmed	2
	Not realized and programmed	3
	Conservation policies	
V_{fun}	**V_{fun} (%) = S Pi / Pmax**	**0**

Annex 4.3 The functional vulnerability form for Waterfronts (S_3)

Vulnerability form		n.4
CULTURAL VULNERABILITY		
Safeguard, laws	Yes	0
	No	3
	Safeguard	
Historical, cultural and social identity	*Acknowldgement of the historical values by local community*	
	Yes	0
	Partial	1
	Poorly	2
	No	3
	Identity	
Historical authenticity	The heritage maintains all the values	0
	The heritage maintains the majority of values	1
	The heritage maintains a low amount of values	2
	The heritage has lost many values	3
	Authenticity	
Dissemination	*Dissemination of the historical values through descriptions and reports available to the public*	
	High (national, regional, local)	0
	Medium (regional, local)	1
	Low (local)	2
	Inadequate or absent	3
	Dissemination	
Context	Adequate viability, transport and connessions	0
	Good connections	1
	Poorly connected	2
	Isolated	3
	Connection to urban nodes	
Vcult	**Vcult (%) = S Pi / Pmax**	**0**

Annex 4.4 The cultural vulnerability form for Waterfronts (S_3)

Vulnerability form					n.1
Photographic documents					
Level 0 - General data					
Name					
Historical heritage category	S4. Military Areas				
	Arsenal				
	Military base				
	Other				
Location	City		Province		
	Region		State		
	Zone		GPS		
Dimension	Area		Volume		
Origin Period					
Property	Public		Private		
Original use					
Actual use					
Documentation/sources	Photographic	Archive	Bibliography		
Report and survey	Direct	Total	Partial	Date	
Vulnerability					0

Annex 5. 1 The Level 0 form for Military Areas (S_4)

Vulnerability form		n.2
MATERIAL VULNERABILITY		
Built Environment	**Typologies of architectures**	
	Buildings	
	Monuments	
	Other architectures	
	State of Conservation	
	Very few buildings is in good state of conservation (0-25%)	3
	Few buildings is in good state of conservationo (25-50%)	2
	The majority of building is in good state of conservation (50-75%)	1
	The areas is almost totally in good state of conservation (75-100%)	0
	State of Conservation	
Public spaces	**Typologies of open spaces**	
	Docks / Squares	
	Open spaces / Gardens and parks	
	Equipment (cranes, etc.) / Other	
	State of Conservation	
	Very few spaces is in good state of conservation (0-25%)	3
	Few spaces is in good state of conservationo (25-50%)	2
	The majority of spaces is in good state of conservation (50-75%)	1
	The areas is almost totally in good state of conservation (75-100%)	0
	State of Conservation	
Viability and streets	**Typologies of viability**	
	Streets / Pedestrian paths	
	Landscaping paths / Cultural paths	
	Other	
	State of Conservation	
	Very few paths is in good state of conservation (0-25%)	3
	Few paths is in good state of conservationo (25-50%)	2
	The majority of paths is in good state of conservation (50-75%)	1
	The viability is almost totally in good state of conservation (75-100%	0
	State of Conservation	
V_{mat}	Vmat (%) = S P_i / Pmax	0

Annex 5. 2 The material vulnerability form for Military Areas (S_4)

Vulnerability form		n.3
FUNCTIONAL VULNERABILITY		
Level of accessibility and usability	Open access to specific areas, guide access in the other areas.	0
	Access to employees and officials; rare and temporary access to public, also with guide visit.	1
	Access to employees and officials; rare and temporary access to public	2
	Restricted access; access only for officials and employees	3
	Accessibility	
Historical vocation	Historical vocation	
	Actual use	
	Compatible	0
	Acceptable	1
	Poorly acceptable	2
	Uncompatible or unused	3
	Compatibility of use	
	Total use / high frequency	0
	Partial use / medium frequency	1
	Unused (<10years) / low frequency	2
	Abandoned (>10years)	3
	Level of use	
Conservation policies	Intervention(date)	
	Plans (date)	
	Current / realized (< 5 years)	0
	Realized (5-15 years)	1
	Not realized but programmed	2
	Not realized and programmed	3
	Conservation policies	
V_{fun}	V_{fun} (%) = S Pi / Pmax	0

Annex 5. 3 The functional vulnerability form for Military (S_4)

Vulnerability form		n.4
CULTURAL VULNERABILITY		
Safeguard, laws	Yes	0
	No	3
	Safeguard	
Historical, cultural and social identity	*Acknowldgement of the historical values by local community*	
	Yes	0
	Partial	1
	Poorly	2
	No	3
	Identity	
Historical authenticity	The heritage maintains all the values	0
	The heritage maintains the majority of values	1
	The heritage maintains a low amount of values	2
	The heritage has lost many values	3
	Authenticity	
Dissemination	*Dissemination of the historical values through descriptions and reports available to the public*	
	High (national, regional, local)	0
	Medium (regional, local)	1
	Low (local)	2
	Inadequate or absent	3
	Dissemination	
Context	Adequate viability, transport and connessions	0
	Good connections	1
	Poorly connected	2
	Isolated	3
	Connection to urban nodes	
Vcult	**Vcult (%) = S Pi / Pmax**	**0**

Annex 5. 4 The cultural vulnerability form for Military Areas (S_4)

<table>
<tr><th>Hazard form</th><th colspan="5">Port of ……………………..</th><th>n.1</th></tr>
<tr><td colspan="7">Plan of the Port, with functions and areas</td></tr>
<tr><th colspan="7">General Data</th></tr>
<tr><td rowspan="5">Morphology</td><td colspan="6">Bay</td></tr>
<tr><td colspan="6">River</td></tr>
<tr><td colspan="6">Estuary</td></tr>
<tr><td colspan="6">Artificial Port</td></tr>
<tr><td colspan="6">Natural harbour</td></tr>
<tr><td rowspan="3">Location</td><td>City</td><td colspan="2"></td><td>Province</td><td colspan="2"></td></tr>
<tr><td>Region</td><td colspan="2"></td><td>Stato</td><td colspan="2"></td></tr>
<tr><td>Zone</td><td colspan="2"></td><td>GPS</td><td colspan="2"></td></tr>
<tr><td>Dimension</td><td>Area</td><td colspan="5"></td></tr>
<tr><td rowspan="2">History</td><td colspan="2">Origin</td><td colspan="4"></td></tr>
<tr><td colspan="2">Evolution</td><td colspan="4"></td></tr>
<tr><td rowspan="6">Boundaries</td><td colspan="6">Urban area</td></tr>
<tr><td colspan="6">Urban are with cultural and historical value</td></tr>
<tr><td colspan="6">Protected natural area</td></tr>
<tr><td colspan="6">Unoprotected natural area</td></tr>
<tr><td colspan="6">Industrial area</td></tr>
<tr><td colspan="6">Other</td></tr>
<tr><td rowspan="2">Authority involved</td><td colspan="2">Port Authority</td><td colspan="2">Municipality</td><td colspan="2">State</td></tr>
<tr><td colspan="2">Navy</td><td colspan="2">Private</td><td colspan="2">Other</td></tr>
<tr><td rowspan="2">Functions</td><td colspan="2">Commercial</td><td colspan="2">Industrial</td><td colspan="2">Touristic</td></tr>
<tr><td colspan="2">Passengers</td><td colspan="2">Energetic</td><td colspan="2">Other</td></tr>
<tr><td>Report Information</td><td>Direct</td><td>Total</td><td>Partial</td><td colspan="3">data</td></tr>
<tr><td colspan="6">Global Hazard Index</td><td>0</td></tr>
</table>

Annex 6.1 The Hazard Form: general information of the port

Hazard form	Port of			n.2
PORT ACTIVITIES				
Activity		Gross surface	Frequency	Points
Shipping				0
Bunkering				0
Land Transport				0
Passenger Transport				0
Dredging and Deposal				0
Fishing and Aquaculture				0
Maintenance of install./infrastr.				0
Ship building/repair				0
Marinas and Yatch				0
Waste Management				0
Mooring, Pilotage, Towing				0
Containers Handling				0
Dry Bulk Handling				0
Oil Gas Handling				0
Hazmat (non oil) Handling				0
Liquid Bulk Handling				0
Perishable Goods Handling				0
Vehicles Handling				0
Ro-Ro				0
Aggregate Ind.				0
Petrolchemical Ind.				0
Agro-Food Ind.				0
Metallurgic Ind.				0
Oil Refineries				0
Power Station				0
Port and Coastal Engineering				0

Annex 6.2 The Hazard Form: estimation of port activities

Hazard form			Port of					n.3
SIGNIFICANT ENVIRONMENTAL ASPECTS (SEA)								
AIR	**WAT**	**SOIL**	**SED**	**NOISE**	**ODOR**	**WAST**	**PDS**	**PDL**
0	0			0		0		
0	0			0				
0		0		0		0		
0	0			0		0		
	0	0	0	0		0		
	0	0	0	0	0	0		
0	0	0	0	0		0		
0	0			0	0	0		
0	0			0		0		
0						0		
0	0							
0	0			0			0	0
0				0		0		
0	0	0	0		0			
0	0	0	0			0		
0	0	0	0					
0	0				0	0		
0				0			0	0
0	0			0		0		
0	0			0			0	0
0	0	0				0	0	0
0	0			0	0	0	0	0
0	0			0		0	0	0
0	0	0	0			0	0	0
0							0	0
0				0		0	0	0
0	0	0	0	0	0	0	0	0

Annex 6.3 The Hazard Form: calculation of partial scores of the SEAH

Hazard Form	Port of		n.4
EFFECTS ON HISTORICAL AND CULTURAL HERITAGE			
Significant Environmental Aspects (SEA)	**Material damages**	**Impact on use**	**Landscaping impact**
Emission to Air	0		0
Discharge to Water	0		0
Discharge to Soil	0		
Sediments Contamination	0		
Noise		0	
Odor		0	
Waste	0	0	0
Port Development on Sea	0	0	0
Port Development on Land	0	0	0
Total	**0**	**0**	**0**

HAZARD INDEXES	
Material impact: Hmat	0
Impact on use and function: Huse	0
Impact on landscape: Hlan	0
Global impact: Hglob	0

Annex 6.4 The Hazard Form: calculation of the hazard indexes

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Curriculum

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PUBLICATION LIST

[8] **MARTINO A.,** (2017) "*La conservazione del paesaggio portuale: dalla definizione della vulnerabilità del patrimonio storico all'individuazione degli impatti delle attività portuali*" contributo in atti di convegno Artec - Colloquiate 2016, Matera.

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