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Port Risk Management in Container Terminals

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Abstract

World trade increasingly relies on longer, larger and more complex port systems, where maritime transportation is a vital backbone of such operations. Port systems are more prone to being risk oriented. Many specific methods have been found to assess risk and safety in a port area or operation. A review is presented of different approaches to quantify the risk in port area. On the other hand, there is no specific risk management method or framework to cope with threats and hazards as a whole.

This conceptual paper presents a Port Risk Management (PRM) methodology, seeking to transfer the safety-oriented Formal Safety Assessment (FSA) framework into the domain of port container terminal. The PRM methodology, has been developed to model all the probable port risks, by taking into account its different factors and their mutual influences.

This paper presents a risk management methodology into the domain of port container terminals. This methodology constitutes a decision support framework that will be used to conduct port to port risk evaluations or to assess a whole port's and terminal's overall risk level in order to facilitate continues improvement strategies.

An empirical study is contacted in order to provide evidence for risk management at the port container terminals in Greece.

There is a need for methodologies and tools for assessing and managing the overall risk in maritime and port operations, which are increasingly complex and are dependable by systematic and nonsystematic risks. The critical impact on a number of port stakeholders has established a new methodology and a port risk index a considerable task.

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Keywords: Risk; Management; Port; Greece

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1. Introduction

Public interest in the field of risk analysis has expanded in leaps and bounds during the last three decades, while risk management has emerged as an effective and comprehensive procedure that supplements and complements the overall management of almost all aspects of our life. Managers of health care, the environment, and physical infrastructure systems all incorporate risk management in their decision-making process. Moreover the omnipresent adaptations of risk management by many disciplines, along with its deployment by industry and government agencies in decision-making, have led to an unprecedented development of theory, methodology, and practical tools (Haimes, 2009).

Moreover, in recent years, we have seen a substantial increase in cooperation between public and private sector for the development and operation of infrastructure for a wide range of economic activities (Chlomoudis and Pallis, 1998), driven by limitations in public funds to cover investments needs, by efforts to increase the quality and efficiency of public services, and by efforts to mitigate the potential risk (Chlomoudis, 2006). There is a comprehensive literature regarding the risk that is associated with investments in seaport projects under public private partnerships (Chlomoudis and Pallis, 2008).

Risk has been considered as the chance that someone or something that is valuated will be adversely affected by the hazard (Woodruff, 2005), while "hazard" is any unsafe condition or potential source of an undesirable event with potential for harm or damage (Reniers et al., 2005). Moreover, risk has been defined as a measure under uncertainty of the severity of a hazard (Høj and Kröger, 2002), or a measure of the probability and severity of adverse effects (Haimes, 2009). In general, "danger" should be defined as an attribute of substances or processes, which may potentially cause harm (Høj and Kröger, 2002).

Risk assessment is an essential and systematic process for assessing the impact, occurrence and the consequences of human activities on systems with hazardous characteristics (van Duijne et al., 2008) and constitutes a needful tool for a safety policy. The diversity in risk management procedures is such that there are many appropriate techniques for any circumstance and the choice has become more a matter of taste (Reniers et al., 2005; Rouvroye and van den Bliek, 2002).

The main objective of this work is to develop a risk management based methodology suitable for ports through an adaptation of the FSA approach, whilst utilising the knowledge and experience gained through existing risk analysis and assessment (RAA) methods and techniques (Marhavilas et al., 2011).

On the other hand, as there is no specific risk management method or framework to cope with safety risks in general and ports in particular, this paper proposes an approach for risk assessment in container terminals which constitutes an adaptation of the IMO Formal Safety Assessment (FSA) (Trucco et al., 2007).

Similar to the structure of the FSA as applied to the safety risks of ships, the proposed Port Risk Assessment (PRA) methodology is based on the evaluation of risks relevant to ports and the analysis of their effective control through combining the economic and risk reducing influence of alternative Risk Control Options (RCO). By virtue of its significance, the two main container terminals of Greece (Piraeus & Thessalonica) present suitable references for demonstrating the applicability of the proposed risk management methodology, through contacting an empirical study on encountered accidents during 2008-2011. The results indicate that the PRA offers a workable methodology for the application of safety risk assessment and management in ports, whilst the conclusions drawn provide a firm basis for further research on this issue.

2. Port Risk Management

2.1. General

While it is generally accepted that the overall level of maritime safety has improved in recent years, further and ongoing improvements are still desirable. The safety culture of anticipating hazards rather than waiting for accidents to reveal them has been widely used in many industries. The international shipping industry has begun to move from a reactive to a proactive approach to safety through what is known as Formal Safety Assessment (FSA). Formal Safety Assessment was introduced by the IMO as "a rational and systematic process for assessing the risk related to maritime safety and the protection of the marine environment and for evaluating the costs and benefits of IMO's options for reducing these risks". (Chlomoudis et al., 2012)

Since the first trial applications, IMO members realized that FSA is a prerequisite to any significant change to shipping safety regulations. Furthermore, FSA adopts the latest techniques of risk assessment. As a result, FSA is currently the state-of-the-art method to assess shipping risk and formulate safety policy.

Such a methodological framework, which investigates and undertakes shipping related risks as a whole, has been lacked from the port industry. Our research scope, through Port Risk Assessment (PRA) is to adapt from shipping industry to port industry a well-established and effective methodological framework in order to develop proactive safety processes and regulations into the port context.

2.2. Structure of PRA

Although the Port Risk Assessment (PRA) maintains the basic number of steps involved in the structure of the Formal Safety Assessment (FSA), their content is modified to address the port- specific (as opposed to the FSA ship-specific) issues of risk commencing with the preliminary step of "System Identification" and following all subsequent steps as presented in Table 1.

Table 1 - Structure of PRA: Steps & Processes

Step	Step Feature	Step Content
0	System Identification	Port; Container Terminal
1	Risk Identification	What may go wrong and which port functions/capabilities should be protected
2	Risk Assessment	Investigation/quantification of most important port risks
3	Risk Control Options	Measures to mitigate most important port risks and measures to restore port functions/capabilities
4	Cost/Benefit Assessment	Cost/benefit assessment of port risk control measures
5	Decision Making	Recommendation and feedback to assessment - Port Risk Index

Source: Authors

2.3. Risk Identification

With the port being identified as the system of interest, risk identification is the first and in many ways the most important step in risk assessment. An overlooked risk is likely to introduce more error into the overall risk estimate than an inaccurate consequence model or frequency estimate. Therefore, the aim of risk identification is to produce a comprehensive list of all risks (Trbojevic and Carr, 2000).

The usual approach to risk identification which is found in the FSA and supply chain risk literature, and is also described by industry stakeholders, is to try to list all conceivable risks, sometimes helped by a source categorization. Investigating historical data on previous incidents is typically the first step, in addition to structured brainstorming sections with practitioners for conceivable risks. Taking into account the limitation of resources, a typical approach involves the screening of risks in order to identify those which should be targeted on the basis of the combined influence of their frequency of occurrence and their consequences (Berle et al., 2011). Rear incidents of negligible impact are to be disregarded.

Our risk identification technique is a mixture of HAZOP and SWIFT methodology utilizing existing literature and practitioners' experience in order to focus on the risks associated with the specialized system of ports and container terminals. The taxonomy of risks in port container terminals is shown in Table 2, according to which five main risk categories are subdivided into numerous sub-categories.

Table 2 - Taxonomy of Risks in Port Container Terminals

RISK CATEGORIES	RISK SUB-CATEGORIES
Human	Ship collisions Grounding Sinking Navigation error Pilotage error Poor maintenance Falling of a crane Falling of a Container
Machinery	Error in Cargo handling and storage Damage to equipment Fire/explosion Machinery failure System failure
Environment	Ships emissions Dredging Oil spills Chemical contaminants Ballast waters Ship breaking /salvage activities Air toxics Noise pollution Alien species
Security	War / Political instability Terrorist Theft Smuggling Illegal trade Vandalism Illegal immigration Blockade
Natural	Earthquakes Volcanic eruptions Hurricane Strong winds Heavy swell and sea Floods High Temperature during working hours Heavy rain

Source: Chlomoudis et al., 2012.

2.4. *Risk Assessment*

In FSA, the risk assessment is often divided into a qualitative and a quantitative part. Qualitative methods for exploring risks could be influence diagrams, e.g. showing interrelations between regulatory, operational and organizational influences, etc. Quantitative methods include fault and event trees and Bayesian Belief Networks, where barriers that prevent incidents from occurring or mitigate consequences are normally included (Berle et al., 2011).

Risk can be quantitatively and qualitatively assessed by the use of a risk matrix (Table 3) in which the rows represent the increasing severity of consequences of a released risk and the columns represent the increasing likelihood or frequency of these consequences.

Table 3 - Risk Matrix

Frequency (FI)	Severity (SI)			
	1	2	3	4

		Minor	Significant	Severe	Catastrophic
7	Frequent	8	9	10	11
6		7	8	9	10
5	Reasonable Possible	6	7	8	9
4		5	6	7	8
3	Remote	4	5	6	7
2		3	4	5	6
1	Extremely remote	2	3	4	5

Source: Authors

The quantification of the risk is performed through the summation of frequency (FI) and severity (SI) indices which express various levels of corresponding significance, as shown in Tables 4 and 5 respectively.

Table 4 - Frequency Index (FI)

FI	Frequency	Definition	F (per Year)
7	Frequent	Likely to occur once per day	10
5	Reasonable Possible	Likely to occur once per month	1
3	Remote	Likely to occur once per year	0.1
1	Extremely remote	Likely to occur once in a life time	0.01

Source: Adapted by IMO FSA

Table 5 - Severity Index (SI)

SI	Severity	Effects on Human Safety	Effects on Equipment or Infrastructure	Effects on Environment	S (Equivalent Fatalities)
1	Minor	Single or minor injuries	Local equipment damage	Local environmental damage	0.01
2	Significant	Multiple or severe injuries	Non severe equipment or infrastructure damage	Non severe Local environmental damage	0.1
3	Severe	Single fatality or multiple severe injuries	severe equipment or infrastructure damage	Severe Local environmental damage	1
4	Catastrophic	Multiple fatalities	Total loss	Catastrophic extended environmental damage	10

Source: Adapted by IMO FSA

The matrix indicates the combinations of likelihood and consequence and there are typically three distinct regions:

Manage for continuous improvement – Acceptable Risk
Incorporate risk reduction measures – ALARP
Intolerable – Unacceptable Risk

Unacceptable risk (intolerable) should either be forbidden or reduced at any cost. Between this region and the Acceptable Risk region the ALARP (As Low As Reasonable Practicable) region is defined. Risk that is falling in that region should be reduced until it is no longer reasonable (economically effective) to reduce the risk. Acceptance of an activity whose risk falls in the ALARP region depends on cost – benefit analysis (Kontovas and Psaraftis, 2009).

For each risk one or several 'barriers' can be specified to prevent or minimize the likelihood of risk release. For any barrier there may be internal or external factors which affect its effectiveness. These factors or barrier failure modes can be modelled as 'escalation factors' each of which can be controlled by 'escalation factor control'. These escalation factor controls can be envisaged as secondary barriers. Any risk should have a sufficient number of barriers and escalation factor controls to ensure the integrity of the risk assessment.

If a risk is released, the accidental event can escalate to one of the several possible consequences. To prevent escalation, the mitigation measures, emergency preparedness and escalation control measures need to be in place to stop chain of events propagation and or to minimize the consequences of escalation. Each recovery measure can be associated with one or several failure modes, or escalation factors. Control measures can be specified to prevent or minimize these failures.

In a qualitative approach, it is possible to set targets for acceptance of sufficient controls being in place to meet objectives. For example, for risks in the ALARP region the minimum requirement may be to have two independent barriers for each threat, and two independent recovery measures for each consequence, one of which must be to detect the incident, and the other to prevent further escalation (Trbojevic and Carr, 2000).

In an effort to demonstrate the validity of the proposed Port Risk Assessment (PRA) through a workable example, we obtained the historical data (2008-2011) of "incidents" involving human and environmental damages in the two main container terminals of Greece (Piraeus & Thessalonica), as shown in Tables 6 and 7.

Table 6 - Human Damage (2008 – 2011)

Month	Injury Severity	2008	2009	2010	2011	Total
January	Minor	1	1	3		5
	Significant			1		1
	Single Fatality					0
	Total	1	1	4	0	6
February	Minor	1	1	1		3
	Significant			1		1
	Single Fatality					0
	Total	1	1	2	0	4
March	Minor	1		1	1	3
	Significant	1	1		1	3
	Single Fatality					0
	Total	2	1	1	2	6
April	Minor	3	2	1	2	8
	Significant			1		1
	Single Fatality				1	1
	Total	3	2	2	3	10
May	Minor	1	1		2	4
	Significant					0
	Single Fatality					0
	Total	1	1	0	2	4
June	Minor	2		2	1	5
	Significant			1		1
	Single Fatality					0
	Total	2	0	3	1	6
July	Minor	2	2	3		7
	Significant				2	2
	Single Fatality					0
	Total	2	2	3	2	9
August	Minor			2		2
	Significant	3			1	4
	Single Fatality			1		1
	Total	3	0	3	1	7
September	Minor	1	1		1	3

	Significant	2		2		4
	Single Fatality	2				2
	Total	5	1	2	1	9
October	Minor	1	1		1	3
	Significant	1				1
	Single Fatality					0
	Total	2	1	0	1	4
November	Minor		1			1
	Significant				2	2
	Single Fatality			1		1
	Total	0	1	1	2	4
December	Minor				1	1
	Significant					0
	Single Fatality	1		1		2
	Total	1	0	1	1	3
	Severity	2008	2009	2010	2011	Total
Overall	Minor	14	10	13	9	59
	Significant	7	1	6	6	24
	Single Fatality	3	0	3	1	9
	Overall Total	24	11	22	16	92

Source: Authors

By scaling all human injuries to single fatalities according to the severity equivalence (S) shown in Table 5, the fatality rate at two main container terminals of Greece (Piraeus & Thessalonica) over the period 2008-2011 is found to be equal to 1.498 fatalities per port-year. (Equivalent Single Fatalities = 59x0.01+24x0.1+9x1 = 11.99)

Table 7 - Environmental Damage (2008 – 2011)

	Severity	2008	2009	2010	2011	Total
Overall	Local environmental damage	2	4	21	13	40
	Non severe Local environmental damage	1	0	3	1	5
	Severe Local environmental damage	0	0	0	0	0
	Catastrophic extended environmental damage	0	0	0	0	0
	Overall Total	3	4	24	14	45

Source: Authors

In terms of the environmental damage at the two main container terminals of Greece (Piraeus & Thessalonica) over the period 2008-2011, there were **forty five incidents**, regarding oil spills, which were assumed to equate to a total of 3.5 ton. of oil spilled, thus presenting an oil spillage rate of 0.43 ton. per port-year. (Equivalent Single Fatalities = 40x0.01+5x0.1+0x1+0x0= 0.9)

2.5. *Risk Control Options (RCO)*

The purpose of this step is to propose economically effective Risk Control Options (RCOs) which comprises the following four principal stages:

- Focusing on risk areas in need of control
- Identifying potential risk control measures

- Evaluating the risk reduction potential of control measures
- Grouping risk control measures into RCOs and practical regulatory options

The basic task is to group risk control measures into possible RCOs. Useful tools in the identification of possible risk reduction measures are the development of causal chains or the development of risk contribution diagrams, using fault trees or event trees diagrams. The areas, that have to be focused, are those related to high frequencies or high consequences, where the risk is intolerable.

Risk control measures, through expert meetings and decisions, are combined into potential RCOs. The criteria of grouping can vary, can be just the decision of the experts or can be the fact that risk control measures prevent the system from the same failure or type of accident. The grouping of risk control measures is very important and more important is the grouping of RCOs. The outcome of this step is a list of RCOs that will be analyzed in the next step for their cost and benefit effectiveness.

Moreover, the risk reduction (ΔR) of an RCO is a very important parameter, because it provides a measure of the risk control obtained by each RCO, which can either reduce the risk to the acceptable level or can provide an even higher reduction rate.

Port expert judgment is employed in order to determine the proposed RCOs and estimate their risk reduction rate (%), with the aim of mutually targeting towards the control of both types of risks, i.e. of human and environmental consequences.

Table 8 - RCOs

RCO PARAMETER	RCO 1	RCO 2	RCO 3
Identification / Description	Training / Education Program	Quality Assurance System	24-7 Monitoring System
Risk Reduction Rate (%)	20	30	40
ΔC ($/port)	50,000	100,000	200,000
Expected Lifetime (years)		5	

Source: Authors

In an exercise which could be split into two separate tasks, port expert judgment firstly proceeded with the identification of RCO and secondly with the estimation of the risk reduction rate. In the first task, experts have to collect data from previous steps and to identify the potential measures and which of them are suitable to produce a number of possible and practical RCOs. An appropriate way to produce them is not to aggregate the opinions of all experts – using a mathematical approach – but through discussions, or using a suitable technique (e.g. Delphi), to let experts conclude on common measures (behavioural approach). A mathematical approach can provide an estimation of risk matrices and a statistical method an aggregate a common value. The concordance coefficient can be also used to in ranking of RCOs according to their risk reduction effect.

According to the aforementioned expert judgment, three distinct RCOs are proposed of increasing risk reduction rate and cost, involving a training/educational program (RCO1), a quality assurance system (RCO2) and a 24-7 monitoring system (RCO3). These RCOs are to be examined for a period of five years during which their quoted risk reduction rates can be reached and maintained through routine RCO updating and without the need to introduce major modifications. Furthermore, on this basis, the NPV cost of each RCO has been determined through an extensive market research and includes the initial investment as well as the operational expenditure involving the RCO running costs (e.g. safety personnel, training seminars etc) over the four-year period.

2.6. *RCO Economic Effectiveness*

The economic effectiveness of each Risk Control Option (RCO) is evaluated based upon: a) the Net Present Value (NPV) cost of its implementation and operation (incl. maintenance) through its lifetime (ΔC) and b) its risk reduction (ΔR) over the same period.

Depending on the nature of risks addressed, the RCO acceptance and prioritization is weighed against the Implied Cost of Averting a Fatality (ICAF) or the Cost of Averting a Tonne of oil Spilled (CATS). Although many proposals exist for appropriate optimum values of ICAF no universally accepted values are currently established. However, the value of $ 3 million as suggested for use by IMO continues to be a valid proposal (Skjong et al., 2005). Furthermore, Skjong et al. (2005), Vanem et al. (2007a;b) and Psarros et al. (2009) presented an environmental criterion equivalent to ICAF which assesses the RCO's economic effectiveness towards the prevention of accidental releases of oil to the marine environment. This criterion was named CATS and its suggested threshold value was $ 60,000 per ton. A specific RCO for reducing environmental risk should be recommended for adoption provided its ΔC/ΔR value is below that of CATS, otherwise that particular RCO should not be recommended (Kontovas et al., 2010; Yamada, 2009).

Therefore for RCO acceptance and prioritization the expression ICAF ≤ ΔC/ΔR and CATS ≤ ΔC/ΔR applies with regard to risks of human and environmental consequences respectively.

Although the above mentioned criteria refer to the averting of negative externalities expressed in terms of human and environmental costs, it is important to note that the assessment of the economic effectiveness of an RCO would be improved by considering its beneficial influence in averting private costs associated with the restoration and repair of damaged equipment or infrastructure, as well as with the loss of revenues. In such case, the net effect of private costs (ΔC) and benefits (ΔB) should be also be taken into account for RCO acceptance and prioritization.

The risk reduction (ΔR) and the economic effectiveness (ΔC/ΔR) of the three proposed Risk Control Options (RCOs) for the control of human and environmental risks associated with the two main container terminals of Greece (Piraeus & Thessalonica) are presented in Table 9, as follows:

Table 9 - ΔR & ΔC/ΔR for human and environmental damages

RISK PARAMETER		RCO 1	RCO 2	RCO 3
RCO Identification / Description		Training / Education Program	Quality Assurance System	24 X 7 Monitoring System
Risk Reduction Rate (%)		20	30	40
a) Human Damage (fat./port-year)			1.498	
b) Environ. Damage (ton./port-year)			0.43	
Expected Lifetime		5 years	5 years	5 years
ΔR	a) fat./port	a) 1.498	a) 2.247	a) 2.996
	b) ton./port	b) 0.43	b) 0.64	b) 0.86
ΔC ($/port)		50,000	100,000	200,000
ΔC/ΔR vs ICAF ($/fat.)		33,378 < 3,000,000	44,504 < 3,000,000	66,756 < 3,000,000
ΔC/ΔR vs CATS ($/ton.)		116,279 > 60,000	156,250 > 60,000	232,558 > 60,000

Source: Authors

2.7. *Decision Making*

The recommendations for decision making should be a synthesis of the previous steps, selecting which measures to include and the identification of those Risk Control Options (RCOs) which keep risks as low as reasonable practicable. We suggest that both individual and societal types of risk should be considered for all port stakeholders, in the direction of creating a Port Risk Indicator, with objective acceptable or non-acceptable regions. In that way, all ports could be ranked, benchmarking themselves based on quantification of their risk level. Subsequently, port managers and marketers would invest in their port's ALARP reputation, in order to attract potential customers.

All the proposed RCOs are found to be economically effective towards the control of human-related risks, whilst with regard to their prioritization RCO1 is the most effective and RCO3 the least effective. On the contrary, none of the RCOs are found to be economically effective for the control of the environmental risk, although RCO1 is closest in satisfying the CATS criterion and RCO3 the most distant.

It should be noted at this point that the risk reduction rate for each of the proposed RCOs is considered to be equally applicable to human and environmental risks. However, in a more realistic approach, it should be considered that RCOs are bound to have a different risk control influence with regard to the perspective risks. Therefore it is found that by adopting a differentiated approach to the risk reduction rate of RCO1 (as being the most effective RCO), the CATS criterion would be satisfied at a risk reduction rate of 39%.

Alternatively an RCO may prove to be more effective over an extended period application provided the increase of RCO costs (ΔC) due to the accumulation of extra operational costs is low. For example, RCO1 would become economically effective with regard to controlling the environmental risk (i.e. it would satisfy the CATS criterion) if it were to applied for a period of at least 9.7 years, provided its cost (of $ 50,000) and risk reduction rate (of 20%) remain unchanged.

As shown in Table 10, the application of an RCO will not only lower the risk level from "6" to "3" depending on the RCO influence upon the frequency and/or the severity of the risk, but it will do so in the most economically effective manner. In this manner, port safety risk levels expressed through an industry agreed and standardized Port Risk Index (PRI) will facilitate the ranking of the safety-cost function amongst various ports of similar specialization (e.g. container terminals) and will also provide a benchmark for self- improvement and eventually a practical risk management tool.

Table 10 - Port Risk Matrix and Index

FREQUENCY / SEVERITY	Minor	Significant	Severe	Catastrophic
Frequent	5	6	7	8 (Highest PRI)
Reasonable Possible	4	5	6	7
Remote	3	4	5	6
Extremely remote	1 (Lowest PRI)	3	4	5

Source: Authors

3. Concluding Remarks – Future Research

As seaports are becoming operationally complex and increasingly vital towards the sustainability of freight and passenger transport, there is an emerging need for the development and application of methodologies and tools which will deliver a systematic assessment and management of safety risks.

The proposed Port Risk Assessment (PRA) methodology builds its structure and functionality in accordance with the Formal Safety Assessment (FSA) and is adapted through the utilization of port expert judgment and existing literature in order to tailor its applicability within the port domain.

The empirical investigation of the two main container terminals of Greece (Piraeus & Thessalonica) provided a workable example through which the reliability of the proposed PRA was demonstrated and the factors affecting the economic effectiveness of proposed Risk Control Options (RCOs) were highlighted. The proposed PRA methodology examined human and environmental risk incidents through a four years period of time. The main objective of our future research is to investigate the influence of other related risks, such as machinery, security and natural risks, into the overall equation of port risks.

Moreover, the PRA methodology, should take into account further environmental risks, regarding chemical contaminants, ships and cars emissions, air toxics and noise pollution. The proposed PRA methodology needs to be tested in other container terminals in Greece, across Europe and other continents, as well as in other port segments, such as passenger, car and cruising terminals in order to detect how their operational particularities may affect their existing risk profile and subsequently its control.

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