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Tangible Assets Threats and Hazards: Risk Assessment and Management in the Port Domain

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Abstract: Port systems are more prone to being risk oriented. Many specific methods have been found to assess risk in a port area or operation. A review is presented in different approaches on human and environmental risks in port area. On the other hand, there is no specific risk management method or framework to cope with threats and hazards regarding on port machines or material accidents and port assets damages or losses. This paper presents a risk management methodology, seeking to investigate a process of assessing the assets hazards and damages into the domain of port container terminal, by taking into account its different factors and their mutual influences. 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 risk level in the critical field of assets damages and losses, in order to facilitate improvement strategies. An empirical study is contacted for the years of 2003~2012, in order to provide evidence for risk assessment and management in an economic effective way, regarding port assets damages and losses, at the Port Container Terminal of Piraeus in Greece.

Key words: Assets, port, risk, assessment, management, Greece.

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 [1].

Risk has been considered as the chance that someone or something that is valuated will be adversely affected by the hazard [2], while "hazard" is any unsafe condition or potential source of an undesirable event with potential for harm or damage [3]. Moreover, risk has been defined as a measure under uncertainty of the severity of a hazard [4], or a measure of the probability and severity of adverse effects [1]. In general, "danger" should be defined as an attribute of substances or processes, which may potentially cause harm [4].

Risk assessment is an essential and systematic process for assessing the impact, occurrence and the consequences of human activities on systems with hazardous characteristics [5] 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 [3, 6].

The main objective of this work is to develop, for a first time, a risk management based methodology suitable for ports through an adaptation of the FSA (formal safety assessment) approach, whilst utilising the knowledge and experience gained through existing RAA (risk analysis and assessment) methods and techniques [7].

Such a methodological framework as FSA, which

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investigates and undertakes shipping related risks as a whole, has been lacked from the port industry. Our research scope, through PRA (port risk assessment) 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

There is significant abundance of literature that is discussing accident prevention, risk management and safety and security in ports. From that reason, it was attempted a literature review of risks that occur at the port industry and a different approach to a new risk classification was established, such as below [8]:

- risks due to human factor;
- hazards for mechanical equipment and port infrastructure;
- environmental hazards;
- risks relating to the security and integrity of the port;
- risks from natural disasters.

The proposed methodology of PRA is an initial attempt to create an essential holistic tool for the ports, assessing risks and accidents. The implementationof PRA could increase the safety of the container terminal by minimizing the risks. In the following case study, it is explored the assessment of a whole port's and terminal's risk level in the critical field of assets damages and losses. 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. Tangible Assets Threats and Hazards, Port Container Terminal of Piraeus, Greece

The following categories of risk, regarding infrastructure and equipment accidents and damages are investigated [9]:

- accident: container;
- accident: container content;
- accident: containership;
- accident: car/truck;
- accident: electrical;
- accident: wharf/pier/cleats;
- accident: security;
- accident: tank;
- accident: crane;
- accident: others.

Table 1 presents the infrastructure and equipment accidents and damages of the Port Container Terminal of Piraeus, per year from the year of 2003 to 2012.

From both Table 2 and Fig. 1, which are grouping the port assets accidents per accident category, it is apparent that the highest percentage respect to damage and accidents is by far accidents in containers.

According to Fig. 2, there was an increasing trend in the first five years of the period examined and a decreasing trend in accidents, regarding the last four years of the period examined.

Table 1 Port assets accidents and losses, Port Container Terminal of Piraeus (2003~2012).

Category	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Accident: container	49	73	136	171	215	31	165	158	56	43	
Accident: Container content	13	30	33	45	55	11	44	6	19	20	
Accident: containership	35	34	43	66	64	21	39	42	27	44	
Accident: car/truck	27	32	33	66	52	40	17	31	21	19	
Accident: electrical	7	1	4	0	0	1	2	2	2	3	
Accident: quay/pier	3	5	4	5	10	6	11	3	7	5	
Accident: security	1	2	2	6	2	3	3	4	9	6	
Accident: tank	4	0	1	1	2	1	1	0	2	0	
Accident: crane	0	4	1	3	4	0	1	5	0	1	
Accident: others	1	1	14	3	8	7	12	3	3	5	
Totals	140	182	271	366	412	121	295	254	146	146	2,333

Source: Ref. [9].

Table 2 Port assets accidents per damage/accident category, Port Container Terminal of Piraeus (2003~2012).

Accident: container	1,097	47.02%
Accident: container content	276	11.83%
Accident: containership	415	17.79%
Accident: car/truck	338	14.49%
Accident: electrical	22	0.94%
Accident: quay/pier	59	2.53%
Accident: security	38	1.63%
Accident: tank	12	0.51%
Accident: crane	19	0.81%
Accident: others	57	2.44%
Total	2,333	

Source: Ref. [9].

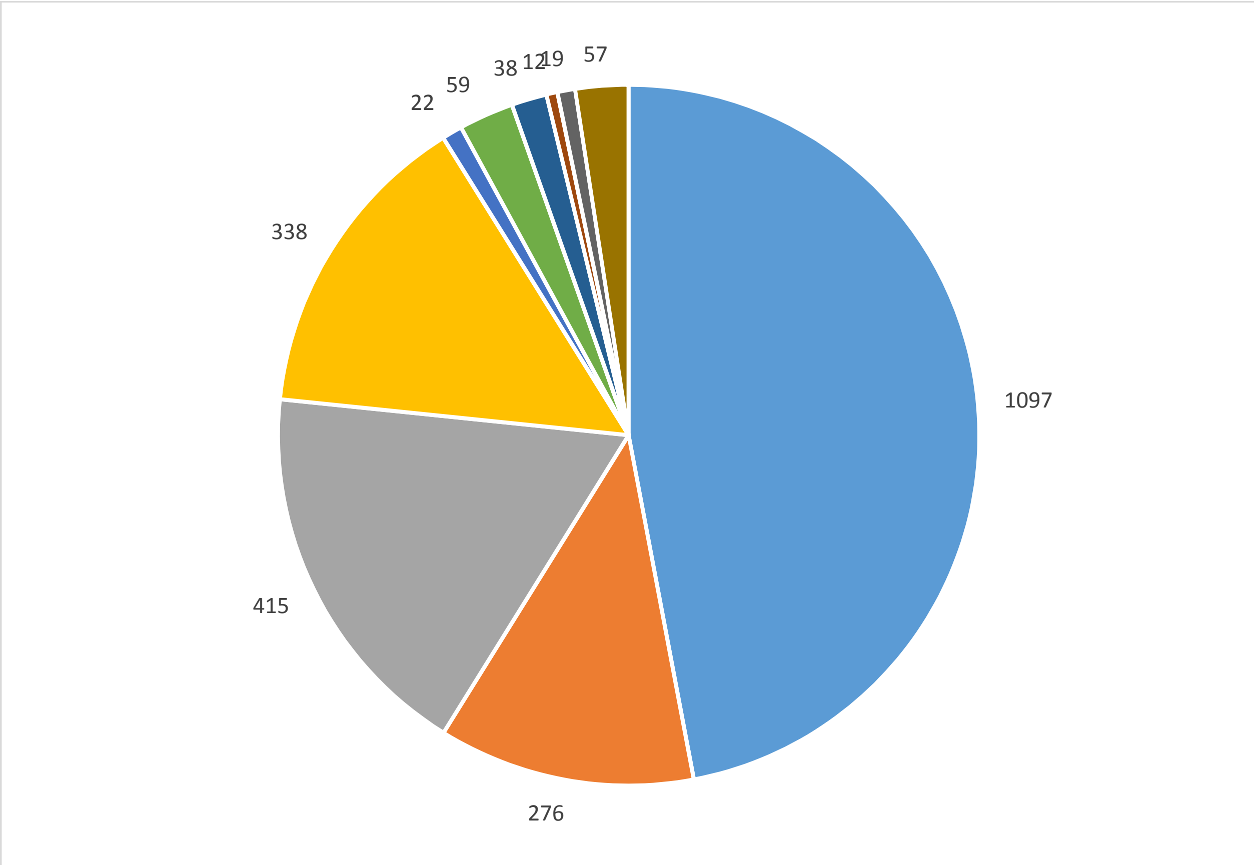

Fig. 1 Port assets accidents per damage/accident category, Port Container Terminal of Piraeus (2003~2012).
Source: Ref. [9].

3. The Implementation of Port Risk Assessment Methodology on Port Container Terminal of Piraeus

3.1 Risk Assessment

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 [10].

Fig. 2 Port assets accidents, Port Container Terminal of Piraeus (2003~2012).
Source: Ref. [9].

Table 3 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 (International Maritime Organization) FSA.

Table 4 Severity index (SI).

SI	Severity	Effects on equipment or infrastructure	S (equivalent fatalities)
1	Minor	Local equipment damage	0.01
2	Significant	Non severe equipment or infrastructure damage	0.1
3	Severe	severe equipment or infrastructure damage	1
4	Catastrophic	Total loss	10

Source: Adapted by IMO FSA.

Table 5 Port assets accidents, Port Container Terminal of Piraeus (2003~2012).

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Accident of local infrastructure/equipment	120	134	188	202	261	88	156	140	99	93	1,481
No severe accident of infrastructure/equipment	10	33	48	110	102	31	76	57	37	38	542
Severe accident of infrastructure/equipment	10	15	35	54	49	2	63	57	10	15	310
Total loss	0	0	0	0	0	0	0	0	0	0	0
Total	140	182	271	366	412	121	295	254	146	146	2,333
Equivalent accident of port asset						$1,481 \times 0.01 + 542 \times 0.1 + 310 \times 1 + 0 \times 10 = 379.01$					

Source: Ref. [9].

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 3 and 4, respectively.

In an attempt to demonstrate the validity of the proposed methodology PRA through a functional case study using historical data of incidentsinvolving property damage and accidents in assets (2003~2012), in the port of Piraeus container terminal, as shown in Tables 1 and 2.

There were 2,333 incidents, regarding equipment and infrastructure damages in the container terminal of Piraeus during the period 2003~2012. These accidents had a significant cost impact for the container terminal. This cost is estimated to be equal to the total of about \$1,400,000 or \$140,000 per year.

3.2 RCO (Risk Control Options)

The purpose of this step is to propose economically effective RCOs (risk control options) 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 experts' judgment, as the CEO (chief executive officer) of the port container terminal and the port security officer, 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 port assets risks.

According to the aforementioned expert judgment, three distinct RCOs are proposed to increase risk reduction rate and cost, which are suitable for the Port Container Terminal of Piraeus, involving:

- A training/educational program (RCO1);
- A quality assurance system (RCO2);
- 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 (net present value) 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 five-year period.

3.3 RCO Economic Effectiveness

The economic effectiveness of each RCO is evaluated based upon:

(1) the NPV cost of its implementation and operation (including maintenance) through its lifetime (ΔC); and

(2) its risk reduction (ΔR) over the same period.

Depending on the nature of risks addressed, the RCO acceptance and prioritization is weighed against the CAAD (cost of averting an asset damage).

This criterion was named CAAD and its suggested threshold value was \$580,000, as this figure regards the port's annual insurance for its assets damage and repair.

A specific RCO for reducing port assets risk should be recommended for adoption provided its $\Delta C/\Delta R$ value is below that of CAAD, otherwise that particular RCO should not be recommended.

Therefore for RCO acceptance and prioritization, the expression $CAAD \leq \Delta C/\Delta R$ applies with regard to risks of assets consequences.

Although the above mentioned criterion refers to the averting of negative externalities expressed in terms of assets damages and losses, 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 taken into account for RCO acceptance and prioritization.

3.4 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 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 (as low as reasonable practicable) reputation, in order to attract potential customers.

All proposed RCOs are found to be cost effective to control the risks associated with infrastructure and equipment (assets), while in terms of hierarchy between them, the proposed RCO1 is the most effective and RCO3 the least effective.

However, a more realistic approach should be considered that the RCOs will certainly have different risk control influence on the perspective of risk. Therefore, it is found that by adopting a differentiated approach to risk reduction rate RCO1 (as the most effective RCO), the CAAD criterion will be satisfied with a higher rate of risk reduction.

Table 6 RCOs, Port Container Terminal of Piraeus (2003~2012).

RCO parameter	RCO1	RCO2	RCO3
Description	Education/training program	Quality assurance system	24-7 monitoring system
Risk redzuction rate (%)	20	30	40
ΔC ($/port)	50,000	100,000	200,000
Expected lifetime (years)	5		

Source: Ref. [9].

Table 7 ΔR&ΔC/ for port assets accidents, Port Container Terminal of Piraeus (2003~2012).

RCO parameter	RCO1	RCO2	RCO3
Description	Education/training program	Quality assurance system	24-7 monitoring system
Risk reduction rate (%)	20%	30%	40%
Accident of port asset (infrastructure/equipment) ($/port-year)		140,000	
Expected lifetime (years)	5 years		
ΔR $/port	0.357	0.047	0.071
ΔC ($/port)	50,000	100,000	200,000
$\Delta C/\Delta R$ vs. $CAAD$ ($/port)	140,000 < 580,000	210,000 < 580,000	280,000 < 580,000

Source: Ref. [9].

Table 8 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: Ref. [9].

Alternatively, an RCO may prove to be more effective if applied for an extended time period though a cost increase (ΔC) is increased decreasing due to the accumulation of the additional operating costs, which is low.

As shown in Table 8, 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 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.

4. Conclusions

On the basis of research concerning the emergence of risks in port container terminals and the valuation methodology—their evaluation, the results of this research, form important conclusions, contribute to scientific knowledge and provide answers to modern practical questions.

The findings of the case study of the Port Container Terminal of Piraeus showed that development and implementation of an approach based on the steps of the PRA could cope and meet the safety requirements and offer an effective solution to address assets risks.

Through the proposed methodology, it is examined, incidents of assets damages through a period of 10 years (2003-2012). Proposed RCOs are identified, which assess the degree of risk reduction (%), for the mutual target to control the risk type, i.e., materials.

All proposed RCOs are found to be cost effective to control the risks associated with infrastructure and equipment (assets), while in terms of hierarchy between them, the proposed RCO1 is the most effective and RCO3 the least effective.

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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