Risk Analysis and Assessment by Multicriteria Approach Based in RO-RO Port Terminal. Case Study

Charif MABROUKI [1], Adil BELLABDAOUI [2], Ahmed MOUSRIJ [3]

1, 3 Laboratoire d'Ingénierie Mécanique, Management Industriel et Innovation (LIMMII),

Faculté des Sciences et Techniques – Settat, Maroc Fst BP 577 route de Casablanca, Settat

2 Technologie de l'information et management des entreprises, ENSIAS, université Mohammed V Souissi, B.P. 713 Agdal - Rabat

Abstract :

This work deals with the problem of operational risk management within the port terminals at the RO-RO activity. After mapping the import and export process and an analysis of the historical evolution of risks, the paper proposes a specific methodology for the identification, analysis and evaluation of operational risks at the RO-RO activity in terms of nature of gravity and level of mastery based on AHP multicriteria approach. Critical risks are identified in order to establish preventive measures.

Keywords: Port terminal, AHP method, decision making, risk engineering, risk assessment

1. Introduction

Risk management is "the adoption of financial, technological and organizational changes to the relationship between environmental turbulence and variability in the results ..." (Aubert and Bernard, 2004, p. 8). It may be defined as "a coordinated set of activities that are performed by an organization to identify, measure, evaluate and modify both the probability of occurrence of certain events that may have an impact on one or more entities, and the impact of these events on the entity.»(Aubert and Bernard, 2004).
The port management is exposed to several types of risks e.g. damage when unloading a vehicle, theft of cargo etc..

Risk management is based primarily on the analysis and assessment of all relevant and available information (Hallikas et al. 2004). This process is usually structured around five phases (Dorofee et al., 1996):

(1) Identification of risks. This step is to identify the risk factors, the triggering events, their causes and their potential consequences.

(2) Risk Analysis, is to determine the nature and level of risk. In addition, risk analysis provides a picture of the causes and consequences and aims to describe the risk either qualitatively (in terms of type of risk) or quantitatively (in terms of criticality) (Aven, 2008).

(3) Planning and scheduling preventive and corrective actions.

(4) Monitoring and implementation of action plans.

(5) Effectiveness monitoring of measures taken via mechanisms of prevention and protection.

It is important to note that communication is essential throughout the process of risk management (Figure 1).

Fig. 1. Risk management Process

In the industrial environment, port activity is one of the more complex components of the supply chain where risk management is present on financial, technological, organizational and operational aspects. With over 80% of world trade carried out by sea, port terminals are vital to the development of international trade [Siim Kallas, Vice President of the European Commission 2012]. The safety of maritime transport has thus become an essential condition for the proper functioning of economies. Faced with this situation, a number of international standards have emerged, including: ISPS, C-TPAT, CSI (Barnes et al., 2005; OECD, 2003). Standard ISPS (International Ship and Port Security) corresponds to the security of ships and facilities. All ships and terminals were subjected to ISPS security officers and the ship or the port facility assessments and security plans. C-TPAT, probably an extension of the partial CSI, works a little differently because it covers not only the maritime sector; but it actually covers the entire chain (Fig. 2).

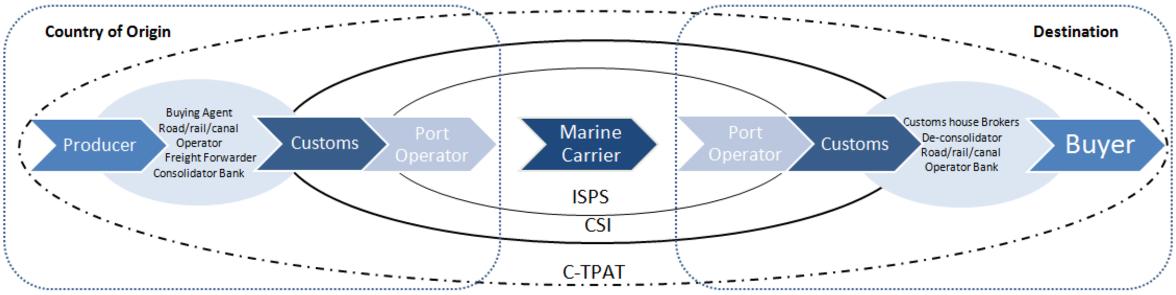

Fig. 2. Scope of IMO and US maritime Security initiatives across a supply chain (OECD, 2003)

The operational level of port terminals is characterized by huge infrastructure and critical resources as limited and rapidly changing traffic. Such an environment so complex, has led many points of failure at several levels, such as administrative activities, operations management, incident management, facilities management, infrastructure management ... Such problems require a particular methodology to identify and assess operational risks in order to establish preventive measures in port terminals.

At the studied port, vehicle traffic activity roll-on/roll-off (RO-RO) represents more than 70% of the port traffic (Port of Casablanca, Morocco 2012). It is quite natural to master the port offer to the evolution which becomes more and more interesting and more complex to manage. However, a good traffic management, improved service quality and especially the satisfaction and loyalty of customers are the keys to success and have good governance. This is why the activity RORO (roll-on/roll-off cargo) is engaged in a dynamic sustainable implementation of Risk Management devices to guarantee better control of operational risk. Moreover, the analysis of the historical evolution of risks has led to the identification of a gap between the reality of operational risk at the field level and risk management policies currently adopted. Hence the need for reassessment of risk in operational activity RO-RO in terms of nature of gravity and level of mastery.

This paper is organized as follows: a literature review of the proposed approaches to risk management is set out in section 2. The issue of port terminals in the port of Casablanca is presented in section 3. A specific method adapted to the problem based on a multi-criteria approach is described in section 4. Finally and before concluding the results are presented and analyzed in section 5.

2. Literature review

The issue of risk management has been studied for a long time in the supply chain (Tang, 2006), but it has been an important development in the field of transport. In the literature, several researchers have addressed this notion in road transport (Bubbicoa et al., 1998; Forta et al., 2010; Scenna and Santa Cruz, 2005; Van Raemdonck et al., 2013), rail transportation (Gheorghea et al., 2005; Elms, 2001) and air (Roelen et al, 2011; Darbra and Casal, 2004; Kirkland et al., 2004; Attaccalite et al., 2012; Janic, 2000).

In the maritime studies, the risk was a central issue because it is often coupled with the safety, efficiency and reliability of transport (Kristiansen, 2005). While efforts have been devoted to the analysis of the safety performance of ships (Alderton and Winchester, 2002; Yip, 2008), identification of risk ships (Degree, 2003; Balmat et al., 2011) or the safety of passenger ferries (Talley, 2002; Talley et al., 2006), our work is more interested in the traffic management system operating within the port.

Trbojevic and Carr (2000) presented a methodology by two steps to improve the safety of maritime operations in ports. In the first step, the process of risk management for port operations carried out qualitatively, is developed and integrated into the system. In the second stage, high-risk areas are discussed in more detail, and the risk of port activities is evaluated quantitatively. This assessment covers both the probability and consequences of a large number of possible accidents in a balanced way.

BALMAT et al. 2011 presented a new approach to risk assessment for maritime safety at sea, it is based on a risk factor determined by a fuzzy expert system.

In terms of risk analysis methodologies, the author Tixier et al. (2002) identified more than 60 risk analysis methodologies in the industrial environment, which may include three main phases: identification, analysis and evaluation.

The techniques most commonly used in engineering risk are:

Failure modes effects and criticality analysis (FMECA): This is a widely used tool for identifying and evaluating the effects and the potential failure of a product or a process (Teoh and Case, 2004).

In addition, the traditional FMECA is carried out by brainstorming (Teoh and Case, 2005) in which information on the risks are obtained and stored in the form of FMECA. However, this technique has some drawbacks: for example, information collected by the traditional FMECA process, a process or product are difficult to reuse. This problem has recently been solved thanks to its automation proposed by Teoh and Case (2004).

It may be noted that the FMECA merely provides a systematic overview of significant failures in a system or process that should be analyzed quantitatively later. In addition, it requires the risk manager to identify critical components of a system and thus plays an important role in the reliability of the system (Aven, 2008; Chen, 2007).

Fault Tree Analysis: The Tree of faults or fault tree analysis is a deductive technique widely applied to identify and analyze the factors that may contribute to an adverse event called top event (ISO: IEC 31010, 2009). Causal factors are identified by inference, logically arranged and plotted in a graph as a tree using logical connections (Contini and MATUZAS, 2011). The aim is to gradually descend until final causes initiating a top event, that means to the underlying causes.

The components of a fault tree are: adverse events, events and basic logical connectives (as detailed in Table 4-10). In addition, the fault tree can be used for analysis of both qualitative and quantitative risk.

It may be noted that the fault tree is used to measure "overall risk" in a system as well as risk factors. The technique is simple to understand and use. In addition, it requires the risk manager to understand the system and gives an idea of the system studied (Rahmat and Jovanovic, 2009).

However, the fault tree is rather difficult to use in the study of a system with several events, levels and logical connectors (Amornsawadwatana, 2003). In addition, it provides a snapshot of the risk, this technique is not necessary for a system with dynamic characteristics.

Tree Analysis of Events: tree analysis of events is a graphical technique for representing sequences of events in a mutually exclusive event initiator according to the system functioning. This technique can be used qualitatively and quantitatively. In the first case, it determines the consequences of an initiating event possible and thus gives the image a possible scenario. In the quantitative case, it considers the probability of an output event (Mokhtari et al., 2011).

Monte Carlo simulation: Monte Carlo is a statistical technique to estimate uncertainty in a process or system, it can be applied in a particularly complex configuration where analytical techniques are not available (Mun, 2006; Vose, 2008).

The Monte Carlo simulation model is able to handle the temporal aspect with ease compared to other analytical techniques where the aspect of time is rarely addressed. In addition, this model requires a number of input data but the output of this model is rich in information.

The main drawback of this simulation is the computation time and effort required to develop and run the simulation. In addition, it is difficult to verify whether the result produced by the algorithm is reliable (Wang and Roush, 2000).

FMEA is a well documented method to quantify and analyze the security issues for a product or process (MIL-STD-1629A [24]). As a contribution, we need plans and diagrams, probabilities and frequencies on the basis of historical knowledge. Output, FMEA provides a list of most of the major risks and mitigation targets (Tixier et al. 2002).

Among all the available solutions, it is possible to classify them on the basis of alternative criteria finite or infinite, certainty or uncertainty. Among these approaches, the most common and widely used are the Simple Multi-Attribute Rating Techniques called SMART (Von Winterfeldt and Edwards, 1994; 2007), AHP (Analytical Hierarchy Process) of Saaty (2004), MACBETH (Bana e Costa et al., 2003; Bana e Costa and Vansnick, 1994) and the decision framework of Choquet integral (Grabisch and Labreuche, 2009).

3. Process description

The business process management of roll-on/roll-off (RO-RO) within the port terminal consists of three main steps: (1) planning and making available the human and material resources; (two) operational management import and / or export (3) billing and collection (see Fig. 3).

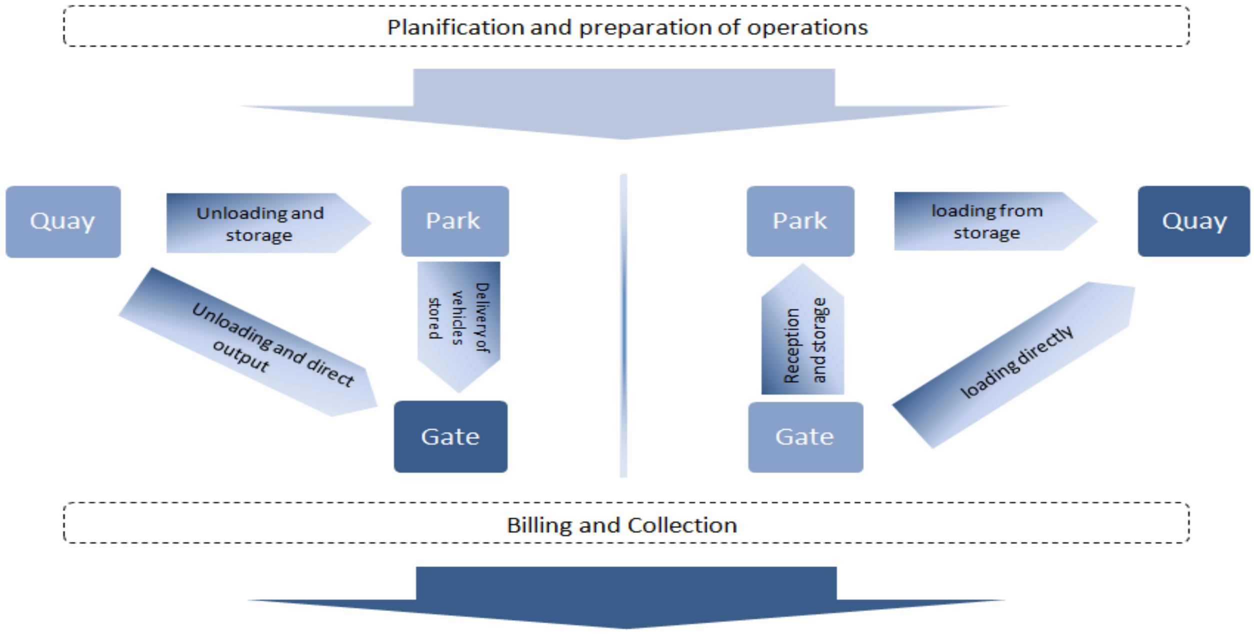

Fig. 3. Mapping of major RO-RO activity

After receipt of the manifest, the agent of the park looking at the number of vehicles and brands to discharge. It specifies the number of conductors required for the routing of vehicles for loading or unloading. On the other hand, the agents specify the park and reserve the exact area for the storage of vehicles. After docking the vessel wharf agent balancing ensures the ramp of the vessel (mobile) with the ramp (fixed) or dock. Drivers at the dock landing vehicles (depending on the discharge plan developed by the board). Pointer company has landed the number of vehicles and simultaneously satisfies the slip condition score by checking the internal and external vehicles. Drivers carry vehicles at the place of storage or directly to customers doors on trucks cars. Finally, the customer pays his bills either in cash or credit.

The approach is based on three steps. Paragraphs 4, 5 and 6 propose the identification, analysis and the assessment of operational risks at the activity RO-RO.

4. Identification

After examining the process in the field with the collaboration of the various stakeholders of the RO-RO activity, we chose to categorize risk or on the basis of their nature, or on the basis of their activity (ie, internal or external to the business). Our approach in this step is based on experience and brainstorming (Royer, 2000). Subsequently, we identified thirty risks to operations. Fig. 4. presents a classification of operational risks identified in five major activities: unloading and storage, unloading and direct output, delivery vehicles stored boarding direct planning and preparing of the charging and discharging operations.

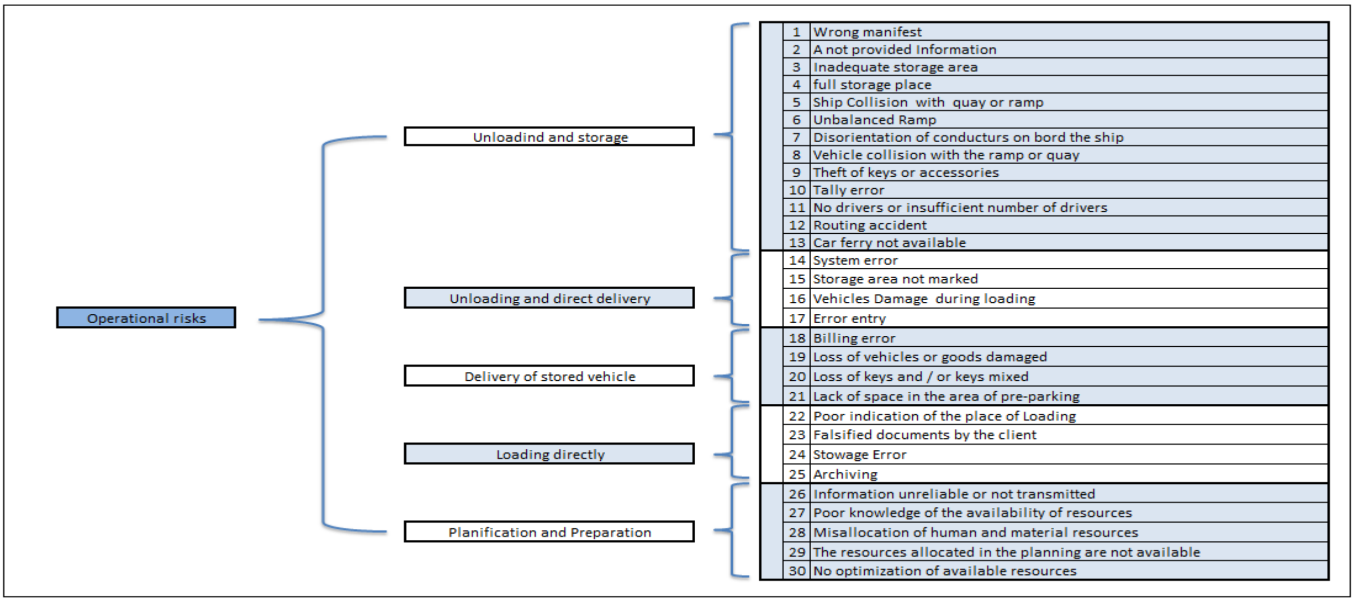

Fig. 4. Integral problems list given by the survey

These risks are determined qualitatively from the description of the probability (sure, probable and improbable). We chose to extract very meaningful risk estimates (or some very probable) in terms of impact and probability of occurrence. Table 1 list's the selected operational risks.

R1	Infrastructure sizing and capacity siaing, optimization of process management storage zone
R2	Theft of keys or accessories
R3	Tally error
R4	Information System failure
R5	Error entry
R6	Billing error or not complet
R7	Bad keys management system
R8	Routing Plan
R9	Archiving
R10	A not provided Information or not exact information
R11	bad forcasting of material and human means availibility
R12	Bad allocation of material and human means
R13	Available means are not used in an optimased way

Table. 1. List of the major risks

5. Risk analysis

The analysis of the risks statistical evolution has led to the identification of a gap between the reality of operational risk at the field level and risk management policies currently adopted by authorities. Hence the need for reassessment of risk in operational activity RO-RO, using a survey presented to persons affected by the selected risk. To this end, a questionnaire provides a grid cause / result focusing on two criteria selected, the severity or impact of the risk (critical, major, low) and its level of mastery (excellent, good, poor) each risk identified as shown in Fig. 4.

It should be noted that gravity does not take into account at this stage, corrective actions or the probability of occurrence. The scale does not refer to an event but the overall perception of the scope of the risk. But, in terms of risk control, the participant expresses his perception of risk, taking into account the actions and controls currently in place. Its scale relates well to the present situation.

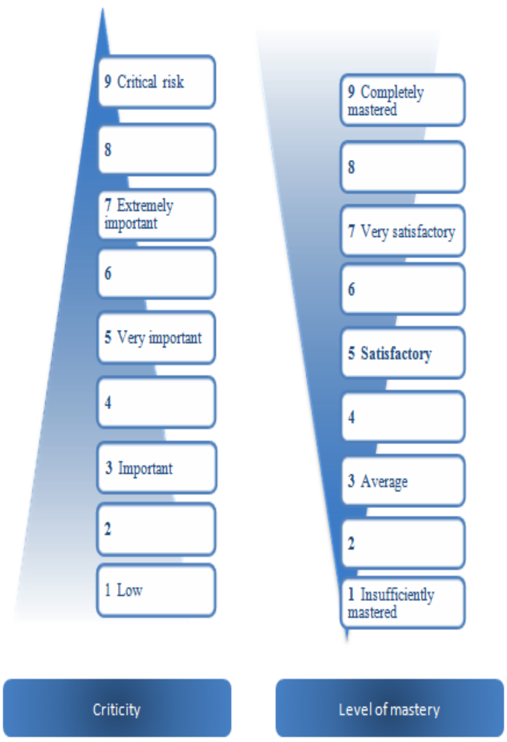

Fig 5: cotation scale by criterion

Following a comparison of risk analysis between the different actors, a consensus evaluation score of each major risk is proposed with respect to each criterion. Grid mapping of risks is presented in Fig. 5.

The Committee considered urgent risks that exceed the level 7 gravity and those that limit the level of mastery to 7. Subsequently, to address critical risks are limited to the risks named 1, 2, 3 and 8.

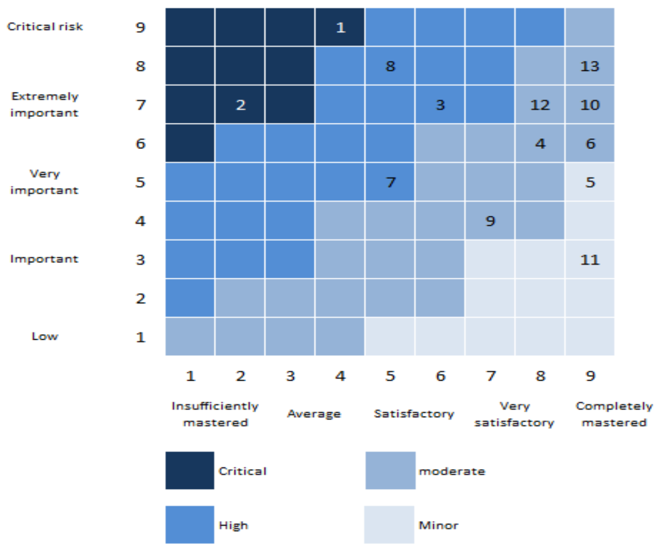

Fig. 6. Risks Classification Matrix

6. Risk assessment with the AHP method

After identification and assessment of the risks, the next step is to develop strategies and measures to manage these risks. However, risk measurements refer to many different methods, approaches and techniques. Our methodology in this step can be divided into three main phases: selection criteria, compare the risks and classifying risks, while based on the AHP method to assess the major risks in the activity RO-RO. Figure 1 shows the tree to characterize and prioritize our various criteria. The top of the hierarchy indicates the subject of the evaluation. i.e. choice of the major risks. The second level shows the relevant criteria for the objective, namely the impact of risk and the level of mastery. The lowest level list shows the thirteen selected major risks in Table 2.

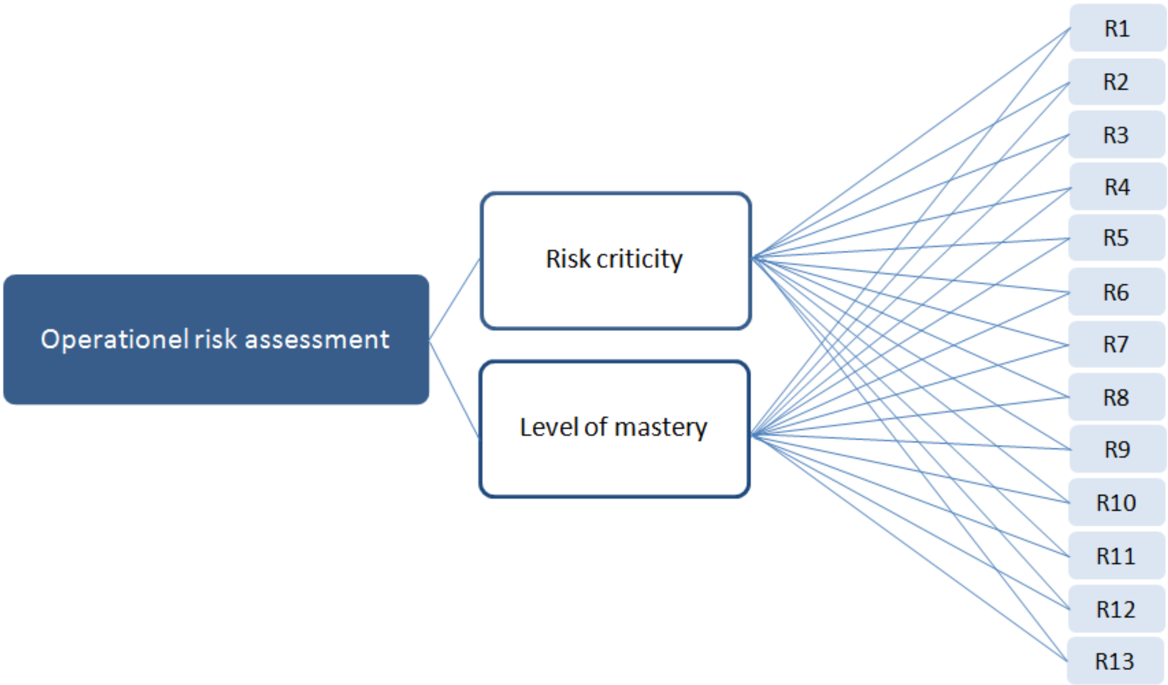

Fig. 7. Hierarchical tree of operational risk assessment problems (alternatives)

Judgments of criteria and alternatives were made using a scale of 1 to 9 following Saaty model, presented in Fig. 8.

Numerical Scale	Signification
1	The two elements have the same level of importance
3	One of the elements is a bit important
5	One of the elements is more important than the others
7	One of the elements is more important than all the others
9	One of the elements in much more important than all the others

Fig. 8. Saaty Scale

Judgments matrix as presented in the tables below were obtained in collaboration with the actors of field. The table shows a comparison of criteria to assess their weight of importance. Fig. 9. And Fig. 10 shows the pair wise comparison between alternatives against each criterion

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
R1		1,29	1,29	1,50	1,80	1,50	1,80	1,13	2,25	1,29	3,00	1,29	1,13
R2			1,00	1,17	1,40	1,17	1,40	1,14	1,75	1,00	2,33	1,00	1,14
R3				1,17	1,40	1,17	1,40	1,14	1,75	1,00	2,33	1,00	1,14
R4					1,20	1,00	1,20	1,33	1,50	1,17	2,00	1,17	1,33
R5						1,20	1,00	1,60	1,25	1,40	1,67	1,40	1,60
R6							1,20	1,33	1,50	1,17	2,00	1,17	1,33
R7								1,60	1,25	1,40	1,67	1,40	1,60
R8									2,00	1,14	2,67	1,14	1,00
R9										1,75	1,33	1,75	2,00
R10											2,33	1,00	1,14
R11												2,33	2,67
R12													1,14
R13													

• Fig. 9. judgment matrix of alternatives by the criteria «Risk criticity»

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
R1		1,33	1,50	3,00	6,00	6,00	1,20	1,20	2,00	6,00	6,00	3,00	6,00
R2			2,00	4,00	8,00	8,00	1,60	1,60	2,67	8,00	8,00	4,00	8,00
R3				2,00	4,00	4,00	1,25	1,25	1,33	4,00	4,00	2,00	4,00
R4					2,00	2,00	2,50	2,50	1,50	2,00	2,00	1,00	2,00
R5						1,00	5,00	5,00	3,00	1,00	1,00	2,00	1,00
R6							5,00	5,00	3,00	1,00	1,00	2,00	1,00
R7								1,00	1,67	5,00	5,00	2,50	5,00
R8									1,67	5,00	5,00	2,50	5,00
R9										3,00	3,00	1,50	3,00
R10											1,00	2,00	1,00
R11												2,00	2,00
R12													2,00
R13													

• Fig. 10. judgment matrix of alternatives by the criteria «Level of mastery»

Risk	Jugement value	Cumul in %
R3	0,199	18%
R2	0,198	36%
R1	0,149	50%
R7	0,124	61%
R8	0,124	72%
R9	0,060	78%
R12	0,050	82%
R4	0,050	87%
R5	0,036	90%
R6	0,036	93%
R11	0,026	96%
R10	0,025	98%
R13	0,024	100%

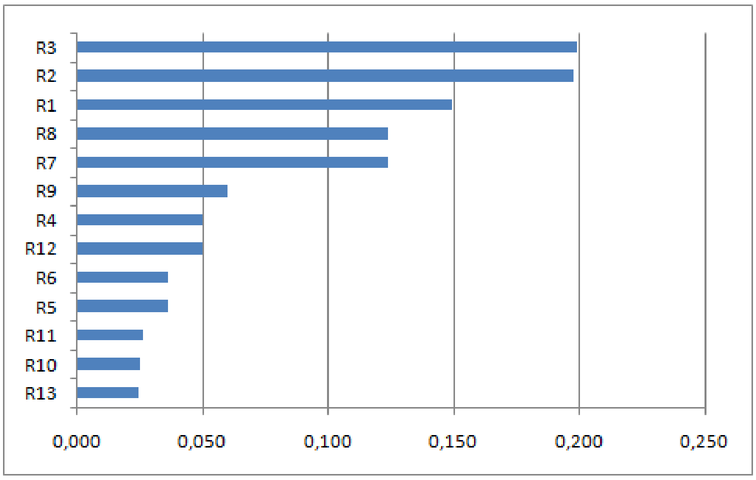

Fig. 11. Global judgment table by risk

At the end of the procedure, an analysis of the problem of operational risk assessment is approved, so that all solutions are multiplied by the weight of the simple decision criteria and the results are summarized in Figure 11. The alternatives which are more valuable, in fact, are the most probable risks. We note that the first six risks namely R3, R2, R1, R7, R8 and R9 generate almost 80% of risk. And, the risks R3, R2 and R1 generate 50% of all risks.

7. Conclusions

This paper study the problem of operational risk management within the RO-RO activity in port terminal. The approach is based on three steps. Firstly, the identification of risk factors. The brainstorming approach allowed us to find thirteen major risks. Then, a risk analysis has allowed us to determine the nature and level of risk. It aims to describe the risk quantitatively. Finally, selections of the most probable risks are assessed under the AHP method. The development of criteria and their weighting then allowed us to choose which of these solutions are the most interesting. The decision maker or planner is therefore invited to adopt action plans to correct the most probable alternatives.

References:

1. Alderton T., Winchester N., Flag states and safety: 1997‐1999, Maritime Policy and Management, vol. 29, n°2, pp. 151‐162, 2002.
2. Alderton, T., Winchester, N., Flag states and safety: 1997–1999. Maritime Policy and Management , vol. 29, n°2, pp. 151–162, 2002.
3. Attaccalite L. , Di Mascio P., Loprencipe G., Pandolfi C., Risk Assessment Around Airport, Procedia - Social and Behavioral Sciences, vol. 53, Issue 3, pp. 852-861, 2012.
4. Aven, T., Risk analysis: assessing uncertainties beyond expected values and probabilities, Wiley & Sons, New-York, 2008.
5. Balmat J.F. , Lafont F., Maifret R., Pessel N., Maritime RISk Assessment (MARISA), a fuzzy approach to define an individual ship risk factor, Ocean Engineering, vol. 36, Issues 15–16, pp. 1278–1286, 2009
6. Barnes P., Oloruntoba R., Assurance of security in maritime supply chains: Conceptual issues of vulnerability and crisis management, Journal of International Management, vol. 11, pp. 519–540, 2005.
7. Bubbicoa R., Doreb G., Mazzarottab B., Risk analysis study of road transport of ethylene oxide,Journal of Loss Prevention in the Process Industries, vol. 11, Issue 1, pp. 49–54, 1998.
8. Darbra, R.M., Casal, J., Historical analysis of accidents in seaports, Safety Science, vol. 42 , n°2, pp.85–98, 2004.
9. Degré T., L'importance d'une approche de la sécurité maritime fondée sur les modèles d'évaluation des risques Recherche Transports Sécurité, vol. 78, pp. 21–32, 2003.
10. Dorofee, A.J., Walker, J.A., Alberts, C.J., Higuera, R.P., Murphy, R.L. et Williams,

R.C., *Continuous Risk Management Guidebook*, 1st ed. Pittsburgh: The Software Engineering Institute of Carnegie Melon University, 553 p, 1996.

11. Elms D., Rail safety, Reliability Engineering & System Safety, vol. 74, Issue 3, pp. 291–297, 2001.
12. Forta E., Pourcelc L., Daveziesa P., Renauxa C., Chironc M., Charbotela B., Road accidents, an occupational risk, Safety Science, vol. 48, Issue 10, pp. 1412–1420, 2010.
13. Gheorghea A.V., Birchmeiera J., Dan Vamanub, Ioannis Papazoglouc, Wolfgang Krögera Comprehensive risk assessment for rail transportation of dangerous goods: a validated platform for decision support Reliability Engineering and System Safety, vol. 88, pp. 247–272, 2005.
14. Hallikas J., I. Karvonen, U. Pulkkinen, V.M. Virolainen, M. Tuominen, Risk management processes in supplier networks, International Journal of Production Economics, vol.90, pp. 47–58, 2004.
15. Janic M. , An assessment of risk and safety in civil aviation, Journal of Air Transport Management, vol. 6, Issue 1, pp. 43-50, 2000.
16. Kirkland I.D.L., R.E. Caves, I.M. Humphreys, D.E. Pitfield, An improved methodology for assessing risk in aircraft operations at airports, applied to runway overruns, Safety Science, vol. 42, Issue 10, pp. 891-905, 2004.
17. Kristiansen, S., Maritime Transportation: Safety Management and Risk Analysis. Elsevier, Oxford, 2005.
18. Mokhtari K., Jun Ren,, C. Roberts, J. Wang, Application of a generic bow-tie based risk analysis framework on risk management of sea ports and offshore terminals, Journal of Hazardous Materials, vol. 192, Issue 2, pp. 465–475, 2011.
19. OECD, Security in Maritime Transport: Risk factors and Economic Impact. Maritime Transport Committee, Directorate for Science, Technology and Industry. July , 2003
20. Raemdonck K.V., C. Macharis, O. Mairesse , Risk analysis system for the transport of hazardous materials , Journal of Safety Research, vol. 45, pp. 55-63, 2013.
21. Roelen A.L.C., P.H. Lin, A.R. Hale, Accident models and organisational factors in air transport : The need for multi-method models, Safety Science, vol. 49, Issue 1, pp. 5-10, 2011.
22. Royer, P., 2000. From My Experience - Risk Management: The Undiscovered Dimension of Project Management. Project Management Quarterly.31, 6.
23. Scenna N.J., A.S.M. Santa Cruz, Road risk analysis due to the transportation of chlorine in Rosario city , Reliability Engineering & System Safety, vol. 90, Issue 1, pp. 83-90, 2005.
24. Talley, W.K., Jin, D., Kite-Powell, H., Determinants of the severity of passenger vessel accidents, Maritime Policy and Management, vol. 33, Issue 2, pp. 173–186, 2006.
25. Talley, W.K., Maritime safety and accident analysis. In: Grammenos, C.T. (Eds.), The Handbook of Maritime Economics and Business, LLP, pp. 426–442 (Chapter 9), 2002.
26. Tang C.S., Perspectives in supply chain risk management, vol. 103, Issue 2, pp. 451–488, 2006.
27. Tixier J., G. Dusserre, O. Salvi, D. Gaston, Review of 62 risk analysis methodologies of industrial plants, Journal of Loss Prevention in the process industries, vol. 15, pp. 291–303, 2002.
28. Trbojevic, V.M., Carr, B.J., Risk based methodology for safety improvements in ports. Journal of Hazardous Materials, vol. 71, n°1–3, pp. 467–480, 2000.
29. Vose, D., Risk Analysis: A Quantitative Guide, 3rd ed. Wiley& Sons, New-York, 2008
30. Yang Y.-C. , Risk management of Taiwan's maritime supply chain security, Safety Science 49 (2011) 382–393
31. Yip T. L., Port traffic risks – A study of accidents in Hong Kong waters , Transportation Research Part E, vol. 44, pp. 921–931, 2008.