OPERATIONAL RISK MANAGEMENT of LOADING and UNLOADING OPERATIONS in PORTS

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ABSTRACT

Operational risk management has an importance in every field today, but also it has a particular importance in the maritime sector, which takes great place in global trade. This article focuses on loading and unloading operations in ports, which are an important part of the maritime operational process, and risk analysis of the construction machinery used in these operations. Fuzzy Analytical Hierarchy Process (FAHP) is used for safety assessment. In this context, the potential risks of these machines used in ports are analysed and how these risks and effects could be reduced are evaluated.

Keywords: Risk management in shipping, operational risk, fuzzy AHP, loading-unloading operations, risks in construction machines.

1. Introduction

Shipping is one of the most important industries with its wide share in the global trade [9]. It is also one of the most cost-effective transportation methods, which enables to transfer an international cargo between two ports worldwide [10]. As originated in the nautical discipline, "risk" has always been considered as a major influencing factor in shipping ([1][3][9]). Because of this, operational risk management has an importance in every field today, but also it has a particular importance in the maritime sector, which takes great place in global trade. The interest of the academy in risk management has been reflected in numerous studies in the maritime industry ([2][4][6] [11]). The operational risks encountered in shipping should be considered first, in order to study on operational risk management in shipping. In this study, the operational risks encountered in shipping are divided into two groups, which are the risks encountered during transportation at sea, and the risks encountered during loading-unloading operations in ports, and each one is explained briefly. Then, failures in construction machines encountered during loading-unloading operations in ports are reviewed and, the risks encountered in five construction machines used in ports are examined. Subsequently, the risks are listed in order of importance with the Fuzzy Analytic Hierarchy Process (FAHP) method, and precautions to mitigate the risks and consequences listed are suggested for each risk. In addition, the potential risks may encounter in all of the five-selected construction machines are compared with Fuzzy AHP method. Finally, it is determined that what needs to be considered in the works to be carried out in ports in order to manage operational risks arising from construction machines. Thus, operational risk management in shipping can be evaluated on a more rational basis.

2. Operational Risk & Operational Risk Management

Operational Risk arises from inadequate or failed internal processes, people, and systems, or from external events, but is better viewed as the risk arising from the execution of an Organization's business functions. The operational risk components are shown in Figure 1.

Fig. 1. Operational Risk Components

Operational Risk Management (ORM) is defined as a continual cyclic process, which includes risk assessment, risk decision making, and implementation of risk controls, which results in acceptance, mitigation, or avoidance of risk [5]. In another word, operational risk management is the oversight of operational risk, including the risk of loss resulting from inadequate or failed internal processes and systems, human factors, or external events [12].

3. Operational Risks in Shipping

The origins and notions behind the word "risk" have a heritage rooted in operational risk and specifically the perils and uncertainty of sea commerce in Mediterranean culture, the losses from sea transit are deemed a risk and related to the unpredictable nature of the sea, but also the experience of the captain and the soundness of the ship in question [13]. The operational risks encountered in shipping are divided into two groups as shown in the Figure 2.

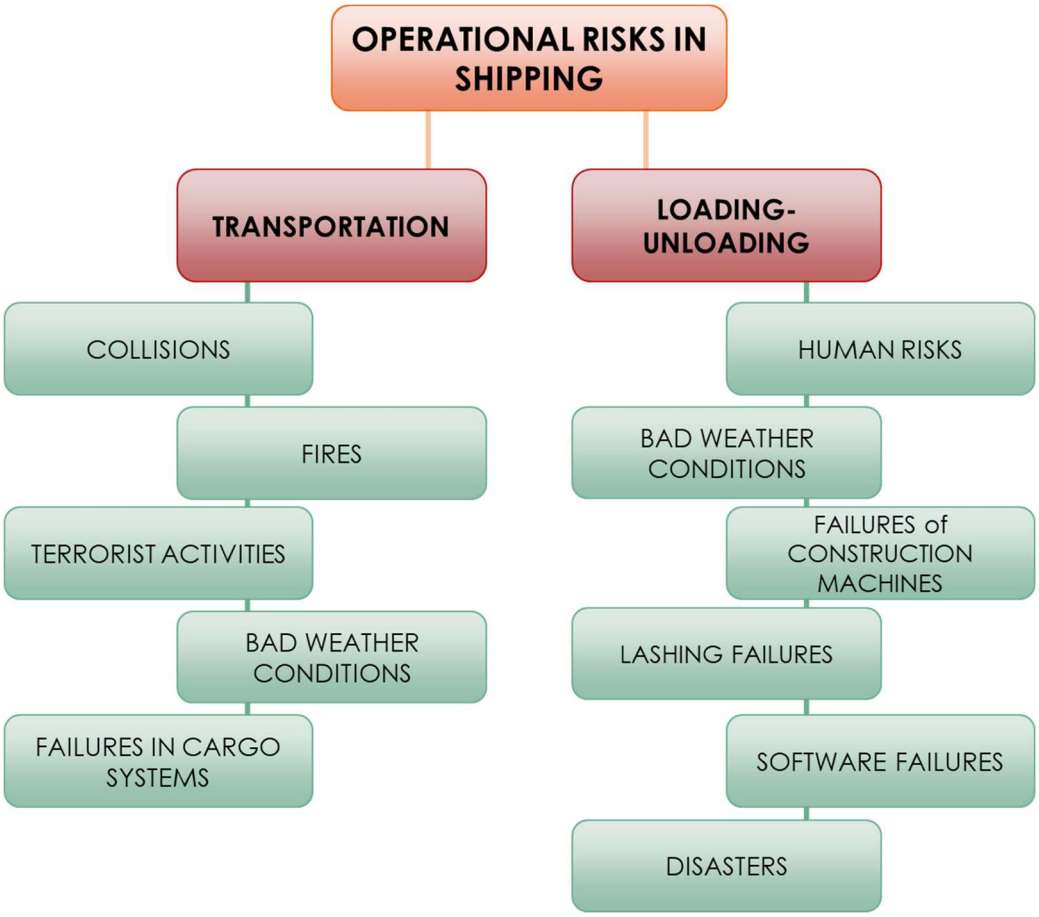

Fig. 2. Operational Risks in Shipping

As seen in the Figure 2, operational Risks in shipping can be subdivided into two heading which are "Risks encountered during transportation at sea" and "Risks encountered during loading-unloading operations in ports". The operational risks encountered during transportation at sea are collisions, fires, terrorist activities, bad weather conditions and failures in cargo systems. The operational risks encountered during loading-unloading operations in ports are human risks, bad weather conditions, failures of construction machines, lashing failures and software failures.

4. Examination of the Risks in Construction Machines with Fuzzy AHP Method

Failures in construction machines encountered during loading-unloading operations in ports are reviewed and the risks encountered in five construction machines used in ports are examined. Subsequently, the risks are listed in order of importance with the Fuzzy Analytic Hierarchy Process (FAHP) method, and precautions to mitigate the risks and consequences listed are suggested for each risk. In addition, the potential risks may encounter in all of the five construction machines are compared with Fuzzy AHP method.

4.1 Risks of Five Construction Machines are examined with Fuzzy AHP

Terminal Tractors, Excavators, Forklifts, Stackers (Full and empty container carriers), RTGs (Rubber-wheeled gantry cranes), RMGs (Gantry cranes mounted on rail), SSGs (Ship to shore

gantry cranes), MHC Mobile Port (Gottwald) Cranes, Portal Cranes are used in the loading-unloading operations in ports [7].

- R_1: Risks encountered in Terminal tractors
- R_2: Risks encountered in Gottwald cranes
- R_3: Risks encountered in Portal cranes
- R_4: Risks encountered in Stackers
- R_5: Risks encountered in Forklifts

Each criterion also represents one sub-factor set, with the expression of r, i.e. $R_i = \{ri_1, r_{i2}, ..., r_{ij}\}$.

4.1.1 Risks encountered in Terminal Tractors

A terminal tractor is a semi-tractor intended to move semi-trailers within a cargo yard, warehouse facility, or intermodal facility, much like a switcher locomotive is used to position railcars. The activities and the risks encountered in Terminal Tractor is shown below in Table 1. Fuzzy AHP steps of the risks encountered in the terminal tractor are shown in Table 2, Table 3, and Table 4.

Table 1. Activities/Risks encountered in Terminal Tractor

	Activities	Risks	Probability	Severity	Total
r_{11}	Refueling	Risk of fire / explosion as a result of approaching the refueling area with objects that will cause fire and explosion, and performing refueling without following the refueling instruction.	2	5	10
r_{12}	Transport of containers to stacking areas	Risk of acid contact or electric shock as a result of not using protective equipment or not following the instructions during the control of batteries, risk of explosion of batteries	2	4	8
r_{13}	The process of the electricians checking the battery system	Risk of acid contact or electric shock as a result of not using protective equipment or not following the instructions during the control of batteries, risk of explosion of batteries	4	2	8
r_{14}	Maintenance work to be carried out on the tractor by the technical department	The risk of injury to the personnel as a result of the parts such as pins and bearings removed during pin removal operations on the machine connection points.	5	1	5
r_{15}	Transport of containers to stacking areas	Risk of overturning of the terminal tractor and / or container as a result of fast maneuvering	2	3	6

Table 2. Pair-wise comparison matrix

	r_{11}	r_{12}	r_{13}	r_{14}	r_{15}
r_{11}	1	2	4	6	3
r_{12}	1/2	1	4	5	2
r_{13}	1/4	1/4	1	2	1/3

r_{14}	1/6	1/5	1/2	1	1/4
r_{15}	1/3	1/2	3	4	1

Table 3. Fuzzified Pair-wise comparison matrix

	r_{11}	r_{12}	r_{13}	r_{14}	r_{15}
r_{11}	(1,1,1)	(1,2,3)	(3,4,5)	(5,6,7)	(2,3,4)
r_{12}	(1,1/2,1/3)	(1,1,1)	(3,4,5)	(4,5,6)	(1,2,3)
r_{13}	(1/3,1/4,1/5)	(1/3,1/4,1/5)	(1,1,1)	(1,2,3)	(1/2,1/3,1/4)
r_{14}	(1/5,1/6,1/7)	(1/4,1/5,1/6)	(1,1/2,1/3)	(1,1,1)	(1/3,1/4,1/5)
r_{15}	(1/2,1/3,1/4)	(1,1/2,1/3)	(2,3,4)	(3,4,5)	(1,1,1)

Table 4. Fuzzy AHP Steps of Terminal Tractor

	Fuzzy Geometric Mean Value (ř)	Fuzzy Weight (w̃)	Weights(w)	Normalised Weight	Ranking
r_{11}	(1.97,2.70,3.35)	(0.307,0.465,0.640)	0.419	0.414	1
r_{12}	(1.64,1.82,1.97)	(0.256,0.313,0.378)	0.281	0.277	2
r_{13}	(0.56,0.53,0.50)	(0.087,0.091,0.094)	0.081	0.080	4
r_{14}	(0.44,0.33,0.28)	(0.069,0.058,0.053)	0.0531	0.052	5
r_{15}	(1.25,1.15,1.11)	(0.173,0.176,0.189)	0.179	0.177	3

4.1.1.1 Precautions to decrease risks and the effects of the risks encountered in Terminal Tractors

r_{11}: Risk of fire / explosion as a result of approaching the refueling area with objects that will cause fire and explosion, and performing refueling without following the refueling instruction.
p_{11}: Using explanatory signs in different languages in the refueling area, to close this area and to ensure that only authorized personnel can access it with cards, to have a fire fighting team and vehicle close enough to this area
r_{12}: The risk of collision of terminal tractors and vehicles due to unregulated traffic flow, the risk of crushing the employees of the terminal tractor vehicle
p_{12}: Using clear traffic warning signs in different languages, leaving a safe time between traffic lights changing, using barriers in locations where the traffic flow is very complex
r_{15}: Risk of overturning of the terminal tractor and / or container as a result of fast maneuvering
p_{15}: Loading a speed limit software on terminal tractors to their engines, assigning a field staff to check that the container loaded on the tractor is correctly fastened before departure
r_{13}: Risk of acid contact or electric shock as a result of not using protective equipment or not following the instructions during the control of batteries, risk of explosion of batteries
p_{13}: Providing regular trainings to personnel responsible for battery replacement and electrical maintenance works, providing personal protective equipment to personnel completely, having a well-equipped infirmary and health personnel present in the maintenance workshop.
r_{14}: The risk of injury to the personnel as a result of the parts such as pins and bearings removed during pin removal operations on the machine connection points.
p_{14}: Providing all personnel with the necessary personal protective equipment and assigning a field staff to supervise its use, having a well-equipped infirmary and health personnel present in the maintenance workshop.

4.1.2 Risks encountered in Gottwald Cranes

Gottwald cranes are the mobile harbor cranes that handle containers, general cargo and project cargo in the multi-purpose terminal mostly have a diesel-electric engine. The activities and the risks encountered in Gottwald crane are shown below in Table 5. Fuzzy AHP steps of the risks encountered in the Gottwald crane are shown in Table 6, Table 7, and Table 8.

Table 5. Activities/Risks encountered in Gottwald Crane

	Activities	Risks	Probability	Severity	Total
r_{21}	Loading and unloading	Risk of cable rupture and explosion as a result of vehicles and employees entering the crane movement area, crushing the high voltage cable of the vehicles	3	5	15
r_{22}	Maintenance, troubleshooting and control process	Risk of hydraulic hose explosion as a result of construction machine without removing high hydraulic pressure in the hydraulic pressure line and / or construction machine without taking safety precautions	3	4	12
r_{23}	Refueling the diesel generators which provides electricity to crane	Risk of fire & explosion due to fuel, oil splashes	2	4	8
r_{24}	Loading and unloading	Risk of breakage of winch ropes due to lack of maintenance of ropes and pulleys, risk of falling load as a result of breaking rope pulleys	2	5	10
r_{25}	Loading and unloading	The risk of damage to the lifting equipment such as ropes and hooks and falling of the load as a result of the operator using the crane above the carrying capacity by not complying with the specified crane operating instructions	1	5	5

Table 6. Pair-wise comparison matrix

	r_{21}	r_{22}	r_{23}	r_{24}	r_{25}
r_{21}	1	1	2	3	3
r_{22}	1	1	3	3	2
r_{23}	1/2	1/3	1	1/2	1
r_{24}	1/3	1/3	2	1	2
r_{25}	1/3	1/2	1	1/2	1

Table 7. Fuzzified Pair-wise comparison matrix

	r_{21}	r_{22}	r_{23}	r_{24}	r_{25}
r_{21}	(1,1,1)	(1,1,1)	(1,2,3)	(2,3,4)	(2,3,4)
r_{22}	(1,1,1)	(1,1,1)	(2,3,4)	(2,3,4)	(1,2,3)
r_{23}	(1,1/2,1/3)	(1/2,1/3,1/4)	(1,1,1)	(1,1/2,1/3)	(1,1,1)
r_{24}	(1/2,1/3,1/4)	(1/2,1/3,1/4)	(1,2,3)	(1,1,1)	(1,2,3)
r_{25}	(1/2,1/3,1/4)	(1,1/2,1/3)	(1,1,1)	(1,1/2,1/3)	(1,1,1)

Table 8. Fuzzy AHP Steps of Gottwald Crane

	Fuzzy Geometric Mean Value (ř)	Fuzzy Weight ($\bar{w}$)	Weights(w)	Normalised Weight	Ranking

r_{21}	(1.32,1.78,2.17)	(0.214,0.321,0.437)	0.324	0.319	1
r_{22}	(1.32,1.78,2.17)	(0.214,0.321,0.437)	0.324	0.319	1
r_{23}	(0.87,0.61,0.49)	(0.141,0.110,0.983)	0.116	0.115	3
r_{24}	(0.76,0.85,0.89)	(0.123,0.153,0.180)	0.152	0.150	2
r_{25}	(0.70,0.53,0.44)	(0.114,0.095,0.089)	0.099	0.098	4

4.1.2.1 Precautions to decrease risks and the effects of the risk encountered in Gottwald Cranes

r_{21}: Risk of cable rupture and explosion as a result of vehicles and employees entering the crane movement area, crushing the high voltage cable of the vehicles
p_{21}: Passing the high-voltage cable at a height that will prevent it from crushing / breaking, using mobile barricades to prevent vehicles from entering the Gottwald crane's work area, or assigning a trained field personnel
r_{22}: Risk of hydraulic hose explosion as a result of construction machine without removing high hydraulic pressure in the hydraulic pressure line and / or construction machine without taking safety precautions
p_{22}: Using a pressure sensor and software to prevent starting work without removing the hydraulic pressure, informing the personnel about this at regular intervals
r_{24}: Risk of breakage of winch ropes due to lack of maintenance of ropes and pulleys, risk of falling load as a result of breaking rope pulleys
p_{24}: Planning the regular maintenance of the crane ropes and pulleys and using a reminder software in order to prevent being forgotten
r_{23}: Risk of fire & explosion due to fuel, oil splashes
p_{23}: Ensuring that only authorized and trained personnel do the refueling, having sufficient emergency response equipment to prevent the fire from growing in the event of a fire
r_{25}: The risk of damage to the lifting equipment such as ropes and hooks and falling of the load as a result of the operator using the crane above the carrying capacity by not complying with the specified crane operating instructions
p_{25}: Installing sensors on the winch ropes and using a software that would allow the crane to stop automatically/alert authorized persons if the safe lifting limit is exceeded.

4.1.3 Risks encountered in Portal Cranes

A portal crane is a heavy-duty machine used to lift very large objects such as shipping containers and automobiles. Each portal crane consists of a pair of vertical steel supports with a long horizontal track connected to the top of each support. The activities and the risks (R_3) encountered in portal crane is shown below in Table 9. Fuzzy AHP steps of the risks encountered in the portal cranes are shown in Table 2, Table 3, and Table 4.

Table 9. Activities/Risks encountered in Portal Crane

	Activities	Risks	Probability	Severity	Total
r_{31}	Load handling and stacking	Risk of breakage of winch ropes due to lack of maintenance of ropes and pulleys, risk of falling load as a result of breaking rope pulleys	2	5	10
r_{32}	Gantry walk	The risk of the crane coming off the rails due to deformation of the crane wheels or	1	5	5

		rails and / or the rapid movement of the crane when loaded.			
r_{33}	Load handling and stacking	Risk of damage to the lifting equipment such as ropes and hooks and falling of the load as a result of the operator using the crane above the carrying capacity by not complying with the specified crane operating instructions	2	4	8
r_{34}	Gantry walk	Risk of collision as a result of loading / parking a vehicle on the crane walkway	4	2	8
r_{35}	Maintenance, repair and control works	Risk of personnel falling from height as a result of starting work without taking safety precautions during control and maintenance works to be carried out on the crane top	1	4	4

Table 10. Pair-wise comparison matrix

	r_{31}	r_{32}	r_{33}	r_{34}	r_{35}
r_{31}	1	1	2	4	3
r_{32}	1	1	2	4	3
r_{33}	1/2	1/2	1	2	1
r_{34}	1/4	1/4	1/2	1	1/3
r_{35}	1/3	1/3	1	3	1

Table 11. Fuzzified Pair-wise comparison matrix

	r_{31}	r_{32}	r_{33}	r_{34}	r_{35}
r_{31}	(1,1,1)	(1,1,1)	(1,2,3)	(3,4,5)	(2,3,4)
r_{32}	(1,1,1)	(1,1,1)	(1,2,3)	(3,4,5)	(2,3,4)
r_{33}	(1,1/2,1/3)	(1,1/2,1/3)	(1,1,1)	(1,2,3)	(1,1,1)
r_{34}	(1/3,1/4,1/5)	(1/3,1/4,1/5)	(1,1/2,1/3)	(1,1,1)	(1/2,1/3,1/4)
r_{35}	(1/2,1/3,1/4)	(1/2,1/3,1/4)	(1,1,1)	(2,3,4)	(1,1,1)

Table 12. Fuzzy AHP Steps of Portal Crane

	Fuzzy Geometric Mean Value (ř)	Fuzzy Weight (w̄)	Weights(w)	Normalised Weight	Ranking
r_{31}	(1.43,1.89,2.27)	(0.222,0.321,0.422)	0.322	0.318	1
r_{32}	(1.43,1.89,2.27)	(0.222,0.321,0.422)	0.322	0.318	1
r_{33}	(1.00,0.87,0.80)	(0.155,0.148,0.149)	0.151	0.149	2
r_{34}	(0.64,0.44,0.34)	(0.100,0.074,0.063)	0.079	0.078	4
r_{35}	(0.87,0.80,0.86)	(0.135,0.136,0.141)	0.138	0.136	3

4.1.3.1 Precautions to decrease risks and the effects of the risk encountered in Portal Cranes

r_{31}: Risk of breakage of winch ropes due to lack of maintenance of ropes and pulleys, risk of falling load as a result of breaking rope pulleys
p_{31}: Planning the regular maintenance of the crane ropes and pulleys, and using a reminder software to prevent being forgotten

r_{32}: The risk of the crane coming off the rails due to deformation of the crane wheels or rails and / or the rapid movement of the crane when loaded
p_{32}: Checking and maintaining crane wheels and rails at regular intervals, using reminder software to prevent disruption of these maintenance, using a software that will set speed limits on the cranes according to the weight of the load they carry.
r_{33}: The risk of damage to the lifting equipment such as ropes and hooks and falling of the load as a result of the operator using the crane above the carrying capacity by not complying with the specified crane operating instructions
p_{33}: Installing sensors on the winch ropes and using software that would allow the crane to stop automatically/alert authorized persons if the safe lifting limit is exceeded.
r_{35}: Risk of personnel falling from height as a result of starting work without taking safety precautions during control and maintenance works to be carried out on the crane top
p_{35}: Training periodically the personnel construction machine at heights on the cranes to work at heights and assigning a field staff to control the personnel construction machine at height for crane maintenance.
r_{34}: Risk of collision as a result of loading / parking a vehicle on the crane walkway
p_{34}: Using clear warning signs in different languages near the walkway of the crane, providing adequate lighting so that the crane rails can be seen at night

4.1.4 Risks encountered in Stackers

Stacker is a vehicle used for handling intermodal cargo containers in small terminals or medium-sized ports. Stackers are able to transport a container short distances very quickly and pile them in various rows depending on its access. The activities and the risks encountered in stacker is shown below in Table 13. Fuzzy AHP steps of the risks encountered in the stacker are shown in Table 14, Table 15, and Table 16.

Table 13. Activities/Risks encountered in Stacker

	Activities	Risks	Probability	Severity	Total
r_{41}	Load Stacking	Risk of collision as a result of vehicles such as car, trucks, and the employees entering the stacker work area	1	4	4
r_{42}	Load Stacking	Accident risk as a result of rapid maneuver of stacker operators in the port area and / or exceeding the determined speed limit	2	3	6
r_{43}	Load Stacking	Risk of dropping the container and damage to the machinery and equipment as a result of improper operation of lamps indicating the position of the spreader twist locks	3	3	9
r_{44}	Refueling	Risk of fire / explosion as a result of approaching the refueling area with objects that will cause fire and explosion, and performing refueling without following the refueling instruction	1	5	5
r_{45}	Control and maintenance of battery system	Risk of acid contact or electric shock as a result of not using protective equipment or not following the instructions during the control of batteries, risk of explosion of batteries	4	2	8

Table 14. Pair-wise comparison matrix

	r_{41}	r_{42}	r_{43}	r_{44}	r_{45}
r_{41}	1	1/2	1	1/3	4
r_{42}	2	1	2	1	3
r_{43}	1	1/2	1	1/2	3
r_{44}	3	1	2	1	5
r_{45}	1/4	1/3	1/3	1/5	1

Table 15. Fuzzified Pair-wise comparison matrix

	r_{41}	r_{42}	r_{43}	r_{44}	r_{45}
r_{41}	(1,1,1)	(1,1/2,1/3)	(1,1,1)	(1/2,1/3,1/4)	(3,4,5)
r_{42}	(1,2,3)	(1,1,1)	(1,2,3)	(1,1,1)	(2,3,4)
r_{43}	(1,1,1)	(1,1/2,1/3)	(1,1,1)	(1,1/2,1/3)	(2,3,4)
r_{44}	(2,3,4)	(1,1,1)	(1,2,3)	(1,1,1)	(4,5,6)
r_{45}	(1/3,1/4,1/5)	(1/2,1/3,1/4)	(1/2,1/3,1/4)	(1/4,1/5,1/6)	(1,1,1)

Table 16. Fuzzy AHP Steps of Stacker

	Fuzzy Geometric Mean Value (ř)	Fuzzy Weight ($\bar{w}$)	Weights(w)	Normalised Weight	Ranking
r_{41}	(1.08,0.92,0.84)	(0.170,0.158,0.157)	0.162	0.160	4
r_{42}	(1.15,1.64,2.05)	(0.180,0.282,0.382)	0.281	0.278	2
r_{43}	(1.15,0.94,0.85)	(0.180,0.162,0.159)	0.167	0.165	3
r_{44}	(1.52,1.97,2.35)	(0.237,0.338,0.439)	0.338	0.335	1
r_{45}	(0.46,0.35,0.29)	(0.072,0.061,0.054)	0.062	0.062	5

4.1.4.1 Precautions to decrease risks and the effects of the risk encountered in Stackers

r_{44}: Risk of fire / explosion as a result of approaching the refueling area with objects that will cause fire and explosion, and performing refueling without following the refueling instruction
p_{44}: Using explanatory signs in different languages in the refueling area, to close this area and to ensure that only authorized personnel can access it with cards, to have a fire fighting team and vehicle close enough to this area
r_{42}: Accident risk as a result of rapid maneuver of stacker operators in the port area and / or exceeding the determined speed limit
p_{42}: Loading a speed limit software on stackers to their engines
r_{43}: Risk of dropping the container and damage to the machinery and equipment as a result of improper operation of lamps indicating the position of the spreader twist locks
p_{43}: Checking and maintaining spreader twist lock lights regularly, providing adequate lighting to the work area during night work
r_{41}: The risk of collision as a result of vehicles such as car, trucks, and the employees entering the stacker work area
p_{41}: Using clear warning signs in different languages, using barriers around the stacker construction machine area

r_{45}: Risk of acid contact or electric shock as a result of not using protective equipment or not following the instructions during the control of batteries, risk of explosion of batteries
p_{45}: Providing regular trainings to personnel responsible for battery replacement and electrical maintenance works, providing personal protective equipment to personnel completely, having a well-equipped infirmary and health personnel present in the maintenance workshop

4.1.5 Risks encountered in Forklifts

Forklift is an industrial truck used to lift and move materials over short distances. The activities and the risks encountered in forklift is shown below in Table 17. Fuzzy AHP steps of the risks encountered in the forklift are shown in Table 18, Table 19, and Table 20.

Table 17. Activities/Risks encountered in Forklift

	Activities	Risks	Probability	Severity	Total
r_{51}	Maintenance, reparir and control works	Risk of injury to the personnel as a result of the parts such as pins and bearings removed during pin removal operations on the machine connection points	4	1	4
r_{52}	Tire changing	Risk of crushing the employee during the removal of the tire as a result of damage to the components that fix the tires or if the tires are not fixed correctly	3	1	3
r_{53}	Load handling and stacking	Risk of falling of the transported or suspended load or the truck overturning as a result of not loading the load safely	4	3	12
r_{54}	Load handling and stacking	Risk of collision of forklifts and vehicles as a result of uncontrolled entry of workers and vehicles in the forklift construction machine area, the risk of crushing employees	2	4	8
r_{55}	Refueling	Risk of fire / explosion as a result of approaching the refueling area with objects that will cause fire and explosion, and performing refueling without following the refueling instruction	1	5	5

Table 18. Pair-wise comparison matrix

	r_{51}	r_{52}	r_{53}	r_{54}	r_{55}
r_{51}	1	1	1/2	1/4	1/5
r_{52}	1	1	1/2	1/4	1/5
r_{53}	2	2	1	1/2	1/3
r_{54}	4	4	2	1	1/2
r_{55}	5	5	3	2	1

Table 19. Fuzzified Pair-wise comparison matrix

	r_{51}	r_{52}	r_{53}	r_{54}	r_{55}
r_{51}	(1,1,1)	(1,1,1)	(1,1/2,1/3)	(1/3,1/4,1/5)	(1/4,1/5,1/6)
r_{52}	(1,1,1)	(1,1,1)	(1,1/2,1/3)	(1/3,1/4,1/5)	(1/4,1/5,1/6)

r_{53}	(1,2,3)	(1,2,3)	(1,1,1)	(1,1/2,1/3)	(1/2,1/3,1/4)
r_{54}	(3,4,5)	(3,4,5)	(1,2,3)	(1,1,1)	(1,1/2,1/3)
r_{55}	(4,5,6)	(4,5,6)	(2,3,4)	(1,2,3)	(1,1,1)

Table 20. Fuzzy AHP Steps of Forklift

	Fuzzy Geometric Mean Value (ř)	Fuzzy Weight (w̄)	Weights(w)	Normalised Weight	Ranking
r_{51}	(0.61,0.48,0.41)	(0.091,0.078,0.072)	0.080	0.080	4
r_{52}	(0.61,0.48,0.41)	(0.091,0.078,0.072)	0.080	0.080	4
r_{53}	(0.87,0.70,0.61)	(0.130,0.114,0.108)	0.117	0.116	3
r_{54}	(1.55,1.74,1.90)	(0.232,0.285,0.338)	0.285	0.282	2
r_{55}	(2.00,2.72,3.37)	(0.299,0.445,0.597)	0.447	0.443	1

4.1.5.1 Precautions to decrease risks and the effects of the risk encountered in Forklifts

r_{55}: Risk of fire / explosion as a result of approaching the refueling area with objects that will cause fire and explosion, and performing refueling without following the refueling instruction
p_{55}: Using explanatory signs in different languages in the refueling area, to close this area and to ensure that only authorized personnel can access it with cards, to have a fire fighting team and vehicle close enough to this area
r_{54}: The risk of collision of forklifts and vehicles as a result of uncontrolled entry of workers and vehicles in the forklift construction machine area, the risk of crushing employees
p_{54}: Using clear warning signs in different languages, having enough surveillance staff on the field
r_{53}: Risk of falling of the transported or suspended load or the truck overturning as a result of not loading the load safely
p_{53}: Loading a speed limit software on the engine of forklift, assigning a field staff to check that the loading on the forklift is correctly, providing regular trainings to forklift operators
r_{51}: The risk of injury to the personnel as a result of the parts such as pins and bearings removed during pin removal operations on the machine connection points
p_{51}: Providing regular trainings to personnel responsible for maintenance works, providing personal protective equipment to personnel completely, having a well-equipped infirmary and health personnel present in the maintenance workshop
r_{52}: Risk of crushing the employee during the removal of the tire as a result of damage to the components that fix the tires or if the tires are not fixed correctly
p_{52}: Providing regular trainings to personnel responsible for tire maintenance works, providing personal protective equipment and necessary technical equipment to personnel completely, having a well-equipped infirmary and health personnel present in the maintenance workshop

4.2 Comparison of the Potential Risks Encountered in Selected Construction Machines (with Fuzzy AHP)

Potential operational risks encountered in all of the five selected construction machines used in loading-unloading operation in ports are determined as listed below and given in Table 21. The steps of Fuzzy AHP analysis and ranking of the risks are shown in Table 21, Table 22 and Table 23.

r_1: Risk of collision as a result of pedestrians / vehicles entering the working area of the machine or leaving a load on the working area

r_2: Risk of fire / explosion while refueling the construction machine

r_3: Risk of dropping the transported load as a result of the operator not following the instructions

r_4: The risk of injury to the maintenance personnel due to electric shock, moving parts throwing, exposure to acid during maintenance operations

r_5: The risk of damage to the lifting equipment as a result of the operator using the machine above the carrying capacity

r_6: The risk of fatigue of the machine parts and damage to the machine as a result of using the construction machine for a long time without resting

r_7: Risk of accident / collision as a result of operator carelessness / incompetence

Table 21. Pair-wise comparison matrix

	r_1	r_2	r_3	r_4	r_5	r_6	r_7
r_1	1	1/3	1	4	2	3	2
r_2	3	1	2	5	3	4	2
r_3	1	1/2	1	4	3	3	2
r_4	1/4	1/5	1/3	1	1/2	1/3	1/3
r_5	1/2	1/3	1/2	2	1	1	1/3
r_6	1/3	1/4	1/2	3	1	1	1/2
r_7	1/2	1/2	1/2	3	3	2	1

Table 22. Fuzzified pair-wise comparison matrix

	r_1	r_2	r_3	r_4	r_5	r_6	r_7
r_1	(1,1,1)	(1/2,1/3,1/4)	(1,1,1)	(3,4,5)	(1,2,3)	(2,3,4)	(1,2,3)
r_2	(2,3,4)	(1,1,1)	(1,2,3)	(4,5,6)	(2,3,4)	(3,4,5)	(1,2,3)
r_3	(1,1,1)	(1,1/2,1/3)	(1,1,1)	(3,4,5)	(2,3,4)	(2,3,4)	(1,2,3)
r_4	(1/3,1/4,1/5)	(1/4,1/5,1/6)	(1/2,1/3,1/4)	(1,1,1)	(1,1/2,1/3)	(1/2,1/3,1/4)	(1/2,1/3,1/4)
r_5	(1,1/2,1/3)	(1/2,1/3,1/4)	(1,1/2,1/3)	(1,2,3)	(1,1,1)	(1,1,1)	(1/2,1/3,1/4)
r_6	(1/2,1/3,1/4)	(1/3,1/4,1/5)	(1,1/2,1/3)	(2,3,4)	(1,1,1)	(1,1,1)	(1,1/2,1/3)
r_7	(1,1/2,1/3)	(1,1/2,1/3)	(1,1/2,1/3)	(2,3,4)	(2,3,4)	(1,2,3)	(1,1,1)

Table 23. Fuzzy AHP steps of the potential risks

	Fuzzy Geometric Mean Value (ř)	Fuzzy Weight (w̄)	Weights(w)	Normalised Weight	Ranking
r_1	(1.17,1.49,1.72)	(1.426,1.669,1.795)	1.630	0.170	3
r_2	(1.74,2.56,3.31)	(2.112,2.874,3.445)	2.813	0.293	1
r_3	(1.43,1.67,1.87)	(1.739,1.873,1.949)	1.854	0.193	2
r_4	(0.52,0.37,0.29)	(0.635,0.414,0.302)	0.451	0.047	7
r_5	(0.82,0.66,0.58)	(1.000,0.743,0.599)	0.781	0.081	5
r_6	(0.85,0.67,0.58)	(1.042,0.756,0.605)	0.801	0.083	6
r_7	(1.22,1.12,1.04)	(1.486,1.261,1.086)	1.276	0.133	4

5. Conclusion

In order to examine the operational risk management in shipping, the operational risks encountered in shipping are divided into two main headings which are the risks encountered during transportation at sea, and the risks encountered during loading-unloading operations in ports, and each one is explained briefly. Then, the risks encountered in five construction machines used in loading-unloading operations in ports are examined and listed in order of importance with the Fuzzy Analytic Hierarchy Process (FAHP) method. Then, precautions to mitigate the risks and consequences listed are suggested for each risk. Also, the potential risks may seen in all of the five selected construction machines are compared with Fuzzy AHP method.

The most crucial risk encountered in the terminal tractors is determined as the risk of fire / explosion as a result of approaching the refueling area with objects that will cause fire and explosion, and performing refueling without following the refueling instruction of the terminal tractor. The most crucial risk encountered in the Gottwald cranes is determined as the risk of cable rupture and explosion as a result of vehicles and employees entering the crane movement area, crushing the high voltage cable of the vehicles. The most crucial risk encountered in the portal cranes is determined as the risk of breakage of winch ropes due to lack of maintenance of ropes and pulleys / risk of falling load as a result of breaking rope pulleys. The most crucial risk encountered in the stackers is determined as the risk of fire / explosion as a result of approaching the refueling area with objects that will cause fire and explosion, and performing refueling without following the refueling instruction of the stacker. The most crucial risk encountered in the forklifts is determined as the risk of fire / explosion as a result of approaching the refueling area with objects that will cause fire and explosion, and performing refueling without following the refueling instruction of the forklift. According to order of importance of the risks are calculated with FAHP method, the risk of fire / explosion while refueling the construction machines are determined the most crucial risk seen on the selected construction machines. In order to manage operational risks in shipping, it can be started with managing the operational risks in the construction machines used in loading-unloading operations.

Operations can be carried out more efficiently and safely by taking the precautions by taking the precautions presented in the study, according to the order of importance of the risks frequently encountered every day in ports.

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