RISK MANAGEMENT OF TERMINAL ON-SITE OPERATIONS FOR SPECIAL BULK CARGOS IN TAIWAN

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SUMMARY

The main purpose of this article was to study the risk management of terminal on-site operations for special bulk cargos in Taiwan. This study applied the concept of *Formal Safety Assessment* approach as the foundation of risk management assessment. At first, a total of four risk aspects with eighteen preliminary risk factors were generated from literature and experts interviews. Three methods – namely analytical hierarchy process (AHP), risk matrix model (RMM), and costs and benefit analysis (CBA) methods – were employed to perform an empirical study in Taiwan. The empirical results showed: (1) The most severe risk factor found using the AHP method was 'failure to perform periodic machinery maintenance and examination.' (2) Ten risk factors placed in the highest-risk area via the RMM method. (3) All risk control strategies were evaluated for applicability by using the CBA method. This study recommended that improvement and reinforcement of the staff aspect and the related risk factors for the on-site operation of special bulk cargos. Through implementation of risk control strategies, the risks of accidents can be controlled.

1. INTRODUCTION

Products and cargos are usually transported using container ships (Tran and Haasis, 2015) when traded internationally. However, container ships have limited space and are unable to carry large machines and materials (Lee et al., 2015) such as iron frames, iron bars, H-beams, iron plates, billet steel, aluminium ingots, and bulk bags. Multipurpose vessels (able to carry bulk cargos, containers, and large and cylindrical cargos) (Siahaan et al., 2013) are required to carry these special types of bulk cargos for the conductance of trade and business activities. Considerable differences exist in the technologies and standardisation associated with the loading and unloading processes (Kemme, 2013) of these special bulk cargos. Specifically, the non-uniformity of special types of bulk cargos leads to difficulty in performing such processes. Therefore, safe loading (Alyami et al., 2014) of special cargos onto a ship and unloading onto a dock requires not only modern machinery but also maritime personnel with specialist knowledge and operation skills (Ding and Tseng, 2013; Yang et al., 2016).

Cargo handling is a critical and complex task because a high level of technical skills and considerable knowledge (Ding and Tseng, 2013; Yang et al., 2016) are required to address the challenges posed by all types of machinery and cargos. Moreover, the operation of bulk and sundry goods (Tsai et al., 2017) is highly difficult and dangerous, and loaders may cause fatal accidents if they are not cautious. For example, 19 fatal work injuries have occurred in recent years (Lirn and Shang, 2015) in the port of Kaohsiung, Taiwan. Closer examination of these incidents reveals that the causes were mostly the inattentiveness of hatch cover commanders, incorrect lifting and suspension of cargos, the inattentiveness of loaders, and failure to follow standard operation procedures (SOPs).

Awareness of industrial safety (Nazir et al., 2015) has increased, prompting business managers to exhibit greater recognition of the value of safe operation. However, dockside cargos loading and unloading operations (Ding and Tseng, 2013; Yang et al., 2016) are not completely safe, and are associated with various risk factors (*e.g.*, human error factors, equipment factors, environmental factors) and risk incidents (injuries and death caused by cargos loading and unloading). These factors may not only lead to losses, such as cargos or machinery damage and personnel losses, but also adversely affect the overall operation efficiency and service quality (Lee et al, 2013) of a dock. Moreover, the movement of bulk and sundry goods is highly difficult and dangerous (Senol et al., 2015; Wang et al., 2014), and its accident rate is higher than that of other types of terminal operations. How risks of on-site operational accidents can be minimised remains a crucial topic for bulk carrier and stevedore companies. To investigate the safety of on-site special cargos handling and risk management issues, the relevant literature was examined in study, revealing that topics regarding risk management of terminal on-site operations for special bulk cargos have received little academic attention. Additionally, the factors that must be considered in on-site handling of special bulk cargos are more complicated than those relevant to standard container handling (Ding and Tseng, 2013; Yang et al., 2016). Therefore, how shipping carriers and stevedore companies can avoid damage when handling special bulk and sundry cargos and adopt improvement strategies to minimise the risks is a worthwhile topic of research.

To improve the safety of terminal operations, the concept of *Formal Safety Assessment* (FSA) approach conducted by the International Maritime Organization (IMO website) is employed in this article. The IMO's FSA approach is "a systematic method of enhancing maritime safety which is done through a careful process of risk assessment and evaluation (Singla, 2016)." Five steps of the FSA approach include identification of hazard, assessment of risks, risk control options, cost benefit assessment (CBA), and recommendations for decision-making. The FSA approach is an easy-to-use assessment tool and enables complete risk analysis (Kristiansen, 2013). Therefore, the FSA approach was used to conduct a risk assessment of terminal on-site operation for special bulk cargos and to provide relevant solutions accordingly.

In summary, the main purpose of this study was to evaluate the risk management of terminal on-site operations for special bulk cargos in Taiwan. More specifically, the content of this article mainly consists of three parts. Firstly, this article will identify the preliminary risk factors for damage of cargos during terminal operations for special bulk cargos. Subsequently, the risk assessment method will be used to categorize the risk factors. Finally, the cost benefit assessment will be applied to determine the applicability of risk strategies. The rest of this article is organized as follows: The second section presents the outline of evaluation processes, and the third section identifies preliminary risk factors. The fourth section describes the methodologies. The fifth section consists of an empirical study, and the final section presents some concluding remarks.

2. OUTLINE OF EVALUATION PROCESSES

To achieve the prior objectives, a synoptic diagram of the FSA approach is shown in Figure 1 (Tseng et al., 2015). The five-step evaluation process (IMO website; Singla, 2016) in this article are briefly described in the following.

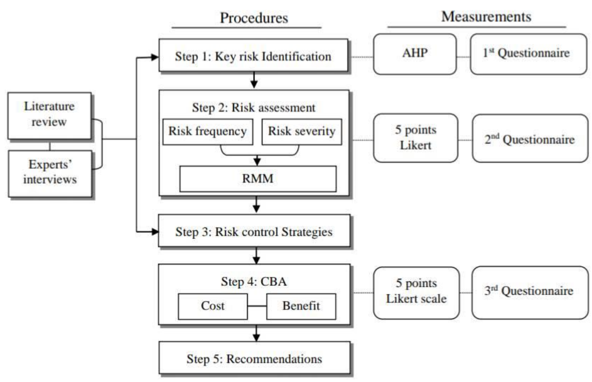

Figure 1. Framework of risk evaluation processes

- *Step 1: Key risk identification.* The first and most important step of the FSA approach is likened to deal with finding out all the possible things that can go wrong with a terminal operation and hinder in its safety (Singla, 2016); i.e., "what might go wrong? (IMO website)" This study first performs a literature review regarding the potential risk factors for damage of cargos during dockside loading and unloading for special bulk cargos. Subsequently, expert interviews were conducted to categorise the risk factors. We employed a qualitative approach to identify preliminary risk factors. Additionally, to discuss the key risk factors for special bulk cargos, the analytical hierarchy process (AHP) method (Saaty, 1980) was employed to evaluate the relative importance of the identified risk factors, allowing key factors where shipping carriers and stevedore companies must strive to enhance terminal safety to be determined.
- *Step 2: Risk assessment.* This step is likened to deal with understanding how the damages they can cause (Singla, 2016), i.e., "how bad and how likely? (IMO website)" The risk frequency and risk severity were used to construct a risk matrix model (RMM) and define the risk levels for on-site cargos handling. The RMM method can help risk managers formulate risk management strategies according to the various risk factors, thereby reducing the chances of a loss and minimising the negative impact on businesses when an incident occurs.
- *Step 3: Risk control strategies.* This step is likened to deal with understanding which of all the available risk control strategies can be selected for practical purposes (Singla, 2016), i.e., "can matters be improved? (IMO website)" Crucial risk strategies were compiled through a literature review of relevant measures for each risk factor and expert interviews. These risk strategies were evaluated using a CBA method in the next step.
- *Step 4: CBA.* This step is likened to deal with understanding what it would cost to use a particular method to evade a risk (Singla, 2016), i.e., "what would it cost and how much better would it be? (IMO website)" The CBA method involves assessing the value of an item by comparing the cost and benefit of each item. This study employed a questionnaire to determine the CBA values of risk strategies to assess the applicability of these strategies.
- *Step 5: Recommendations.* This step is likened to deal with making a final decision about the most suitable way to reduce risks and their consequences (Singla, 2016), i.e., "what actions should be taken? (IMO website)" Recommendations for decision-making: Through the CBA method, the strategies that have greater benefits than costs were identified and are recommended.

3. IDENTIFICATION OF PRELIMINARY RISK FACTORS

The crucial first step in this article was to identify the risk factors associated with on-site bulk cargos handling. Whether appropriate risk factors were identified first would affect the progress in the rest of the study. Risk identification methods (Shang and Tseng, 2010) included the past event experience method, flowcharts, field surveys, questionnaire surveys, and contract content (such as investigation of insurance policies), etc. The process flowchart of on-site operations for special bulk cargos was examined in this article. Through personally visiting professionals working at docks and discussing with them their experience of workplace accidents, we could analyse and identify the actual risk factors that are important in practical on-site operations of bulk cargos.

First of all, in order to obtain reliable risk aspects and risk factors for terminal on-site operations of bulk cargos, this study initially reviewed the literature relevant to cargos handling at various types of docks. Secondly, this study interviewed six professionals, each with more than 20 years of experience and expertise in on-site cargos handling and management. Moreover, compliance with the laws and regulations governing cargos handling in Taiwan was also addressed when proposing relevant strategies. Finally, based on the records of the related literature and suggestions of experts of shipping carriers and stevedore companies in the practical on-site operations of bulk cargos, this study identifies the important risk factors that affect terminal on-site bulk cargos handling, and summarizes the four risk aspects of staff, facility, environment, and managers and communication. The characteristics of these risk aspects and 18 risk factors are explained as follows; and their codes are shown in parentheses.

The first risk aspect is the 'staff (S)' (Chauvin et al., 2013; Fabiano et al., 2010; Fu et al., 2016; Ger and Lai, 2006; Hetherington et al., 2006; Kadir et al., 2017; Lirn and Shang, 2015; Lu et al., 2012; Shang and Tseng, 2010; Yu et al., 2014; national regulations; field investigation; interview with experts). This risk aspect includes five risk factors, as follows:

1. *Failure to fulfil pre-operation education* (S_1): Special cargo differs from normal cargo in its appearance, size, and packing method and the type of ship used to carry it. Therefore, on-site managers must educate workers and inform them about the points of safety for each mission before operations begin. Failure to implement pre-operation education may result in accidents during cargos handling.
2. *Failure to comply with the SOPs* (S_2): Taiwanese law and regulations require that all companies establish SOPs according to the characteristics of their business and that all operations should comply with the SOPs to avoid accidents. Failure to comply with the SOPs may result in cargos handling accidents due to human error.
3. *Inadequate knowledge of workers* (S_3): Highly experienced workers and technicians are required for the handling of special cargos. However, labour shortage and gap have become a problem for handling bulk cargos. New workers are less knowledgeable, leading to risks of cargos damage during operations.
4. *Workers' unfamiliarity with equipment on the ship* (S_4): The sailing schedule is uncertain for bulk cargos, and the ship that is rented may be different on each occasion. Consequently, workers are often unfamiliar with the equipment on a ship. Unfamiliarity with the effective carrying capacity of a machine is usually the cause of cargos damage.
5. *Workers' lack of safety awareness* (S_5): The cargos handling workers were not willing to comply with the company's relevant regulations because of their convenience in loading and unloading operations. As a result, the workers lacked safety awareness. Working pressures led to inconvenient operations and were prone to casualties.

The second risk aspect is the 'facility (F)' (Alyami et al., 2016; Ger and Lai, 2006; Papanikolaou, 2014; Zhou et al., 2015; national regulations; field investigation; interview with experts). This risk aspect includes four risk factors, as follows:

1. *Failure to perform periodic machinery maintenance and examination* (F_1): Machines, such as lifters and derricks, should be periodically examined and a record of their maintenance kept. Machine malfunction is difficult to avoid during operations, and failure to perform period maintenance in compliance with the regulations can easily lead to accidents and cause cargos damage and human injury.
2. *Use of uncertified cargos handling equipment* (F_2): Use of uncertified equipment for cargos suspension and handling (using wire guys, bridle chains, and look fasteners) when handling special cargos (*e.g.*, cargo weighing over 45 tonnes) can easily lead to cargos damage during suspension.
3. *Failure to perform periodic maintenance and examination of trailers* (F_3): Special cargos are mostly carried using trailers from storehouses or owners to the vicinity of the boat for loading. If trailers are not periodically maintained and examined in compliance with the regulations, accidents can easily occur during operations, leading to risk of delay in loading and unloading the cargos.
4. *Unsatisfactory design of deck cabin* (F_4): The ship rented can be different on each occasion, with many ships only visiting at a dock once. When deck cabins are inadequately designed and when workers are unaware of potentially dangerous areas, worker injury can easily occur during operations.

The third risk aspect is the 'environment (E)' (Akamangwa, 2016; Alderton, 2014; Farr et al., 2012; Ger and Lai, 2006; Shang and Tseng, 2010; Yu et al., 2014; national regulations; field investigation; interview with experts). This risk aspect includes five risk factors, as follows:

1. *Reduction in the amount of protective equipment on site* (E_1): The ship owner and stevedore companies should install protective equipment to reduce the risk of damage caused by piling of cargos. A reduction in the amount of protective equipment incurs a risk of

damage when cargo is transferred from a ship platform to the dock.

2. *Unclear signage of operation flow line on terminal shore* (E_2): If the operation flow line for cargo handling is not planned, storehouses, trailers alongside the ship, and machinery may collide due to unclear signage. This not only causes damage to trailers and machinery, but also reduces the overall progress and efficiency of cargos handling.
3. *Unsatisfactory operating environment at cabin* (E_3): If the bottom of a cabin has limited space and a small operating environment (deck, tank bottom, and storehouses), there is usually a risk of human injury because of poor ventilation and illumination and slipperiness when wet.
4. *No signage for warning areas in the operation area of the ship* (E_4): The operation area of a ship may have no protective equipment set up due to workers' negligence. For example, warning area signs might not be set up when the hatch cover is opened. This results in serious incidents, including workers accidentally falling into the tank and dying.
5. *Operation under undesirable weather conditions* (E_5): Careful attention should be paid to the weather conditions when handling cargos. Cargos placed on the cabin bottom can have different characteristics. Some cargos are water-resistant whereas other cargos are not. Therefore, when it rains, the crew should close the hatch cover regardless of the rain intensity to prevent water damage to cargos and water logging in the hull, which is difficult to drain. Moreover, due to the nonuniformity of bulk cargos, if an operation is forced to meet a sailing schedule, a risk of cargo damage during handling might result.

The fourth risk aspect is the 'managers and communication (*M*)' (Chang and Wang, 2010; Ger and Lai, 2006; Gordon et al., 2005; Kovács et al., 2012; Wang and Liu, 2012; Yu et al., 2014; field investigation; interview with experts). This risk aspect includes four risk factors, as follows:

1. *Insufficient safety awareness of organization managers* (M_1): The safety awareness of workers on site, such as foremen and team leaders, is determined by the business managers and directors. When business managers' lack safety awareness in organization, they are not able to correctly convey safety information regarding cargos handling to on-site workers. Consequently, the workers cannot implement the safety management policies of the business, which increases the risk of a cargo handling accident.
2. *Organization managers have insufficient knowledge of workers' expertise* (M_2): Organization managers, especially on-site managers, should have adequate knowledge of their subordinate workers' expertise and experience. Inappropriate allocation of cargos handling tasks due to inadequate knowledge of workers' experience may easily lead to accidents.
3. *Poor communication and notification mechanism* (M_3): Each work unit should have a regular point of contact to ensure compatibility between team members. Without a proper communication and notification mechanism for the cargos handling process, accidents can easily occur.
4. *Secondment lack of professional skills and unfamiliarity with team operations* (M_4): The amount of cargos to be handled is not fixed. Stevedore companies do not employ too many workers but only sufficient to ensure basic functioning. If a sailing schedule is delayed, operations become concentrated to one day, during which stevedore companies borrow human resources from other companies. The borrowed workers are thus temporary and have varying ability. They are unfamiliar with the teamwork of existing team and have problems communicating, which can easily lead to accidents.

4. METHODS

In this section, some concepts and methods—namely AHP, RMM, and CBA methods— are briefly introduced.

4.1 AHP METHOD

The AHP method (Saaty, 1980) is a decision-making method to systematize complex problems. It is mainly used in uncertain situations and decision-making problems with multiple attributes. The AHP method has been widely used in various management fields such as behavior science, marketing management, and risk management.

The AHP method decomposes a complex evaluation system and converts it into a clear hierarchical structure through systemised hierarchy. Pairwise comparison is one of the most effective ways of organizing judgements. Therefore, the AHP method evaluates the relative importance of each evaluation criterion on a numerical scale ranging from 1 to 9. Subsequently, a comparison matrix is created, the eigenvalues and eigenvectors of which are calculated. Finally, the maximum eigenvalue is used to verify the consistency of the criteria, and the relative importance of each criterion can be obtained. Moreover, this study employed the AHP method as the main means of evaluating key risk factors.

4.2 RMM METHOD

The Australian and New Zealand Risk Managing Standard (AS/NZS 4360, 2004) was a risk managing standard formulated, which originated from Australia and New Zealand. The risk managing standard has been recognized by many countries and international organizations. The FSA approach proposed a risk assessment concept for risk rating matrix, where the matrix divides the main factors of analysis risks into frequency (or likelihood) and severity (or consequences) aspects. The severity is divided into four classes while the frequency is divided into seven classes. However, the severity and frequency do not follow the above classification (Markowski and Mannan, 2008; Tseng et al., 2012). For example, we can divide the risk matrix into frequency with five classes and severity of four classes, in risk matrix of twenty cells. Or we can divide the frequency and severity into five classes respectively to construct the risk matrix of twenty five cells.

To construct the risk matrix of the terminal on-site operations for special bulk cargos damages, this study applies the standards of FSA approach through questionnaire survey to conduct assessment standards based on five classes of frequency and of severity as the main model (Ding and Tseng, 2013; Shang and Tseng, 2010) for the risk assessment and segmenting area for risk factors. Here we firstly define the loss frequency (*LF*) value and loss severity (*LS*) value as follows.

1. The *LF* value. The term refers to a specific risk within a certain period of time. The number of times for a specific risk incident to occur in a risk unit (probability) is divided into five levels (*i.e.* 1-5). The definitions of the *LF* value ranged from "1" for "very rare" to "5" for "very often."
2. The *LS* value. The term refers to the severity of loss caused from a specific risk occurring within a certain period of time, which is also divided into five levels (*i.e.* 1-5). The definitions of *LS* value are "1" for "extremely slight" to "5" for "very serve."

Once the values of *LF* and *LS* have been obtained, the risk value (*RV*) (Ding and Tseng, 2013; Shang and Tseng, 2010; Tseng et al., 2012) must be defined. This study defines the *RV* as the value after the multiplatinum of risk frequency and severity ($RV = LF \times LS$), and using the *RV*, the level of risk can be categorised. The risk matrix of this study is displayed in Figure 2. In the risk matrix, the level of risk is categorised according to differences in the *LF* and *LS*. Finally, the *RV* was divided into three risk areas in this study according to Shang and Tseng's (2010) advices including: (1) the risk belongs to low-risk (*L*) area when the *RV* is between grades 1-4; (2) the risk belongs to medium-risk (*M*) area when the *RV* is between grades 5-10; and (3) the risk belongs to high-risk (*H*) area when the *RV* is between grades 11-25. Moreover, the risk grade matrix can help organizations with establishing effective risk management strategies and effective allocation of resources on the various risks.

		LS value				
		1	2	3	4	5
LF value		Extremely slight	Slight	Acceptable	Serve	Very serve
5	Very often	***M***	***M***	***H***	***H***	***H***
4	Sometime	***L***	***M***	***H***	***H***	***H***
3	Passable	***L***	***M***	***M***	***H***	***H***
2	Seldom	***L***	***L***	***M***	***M***	***M***
1	Very rare	***L***	***L***	***L***	***L***	***M***

Figure 2. The risk grade matrix

4.3 CBA METHOD

Lois et al. (2004) applied a useful cost and benefit method to cruise ship operation using the following steps: (1) evaluation of benefits, (2) estimation of costs, (3) combination of costs and benefits to classify costs and benefits into five classes (as shown in Table 1), and (4) division of benefit by the cost to yield a cost-benefit analysis. Soares and Teixeira (2001) proposed that the implied cost of averting a fatality (ICAF) can be calculated as △cost /△risk, which signifies the risk control cost required to reduce accident risk by one unit. The higher the ratio, the more effective the method in reducing risks. These steps are also employed in this article.

5. EMPIRICAL STUDY

The identification of key risk factors using the AHP method, the risk assessment applying the RMM method, and the evaluation of risk control strategies using the CBA method are empirically studied in the following.

5.1 RESULTS OF KEY FACTORS USING AHP METHOD

This study used the AHP method in conjunction with the first-stage questionnaire (the AHP expert questionnaire) to identify key risk factors. The AHP expert questionnaire was based on the risk aspects and risk factors shown in Section 3, and was used to investigate the relative weights of all risk factors. Questionnaires were distributed to experts, including employees of the stevedoring and warehousing departments of Taiwan International Port Corporation (TIPC), shipping companies, stevedoring companies, cargos tally corporations, and claim adjusters and other related businesses. We visited the experts in person and asked them to complete the AHP expert questionnaire.

Table 1. Cost and benefit levels

Levels	Definition	Description of cost	Description of benefit
1	Very low	The cost of implementation is very low.	The benefit of implementation is very low.
2	Low	The cost of implementation is low.	The benefit of implementation is low.
3	Medium	The cost of implementation is medium.	The benefit of implementation is medium.
4	High	The cost of implementation is high.	The benefit of implementation is high.
5	Very high	The cost of implementation is very high.	The benefit of implementation is very high.

A total of 20 questionnaires were distributed, and 18 were recovered, for a recovery rate of 90%. The returned questionnaires were checked to identify whether both the consistency index (*C.I.*) and the consistency ration (*C.R.*) of each matrix of every layer were lower than 0.1 (Saaty, 1980). When the *C.I.* and *C.R.* values of a matrix are higher than 0.1, this implies that the respondent had made an inconsistent pair-wise comparison of two risk aspects or risk factors. To prevent the occurrence of errors, the authors helped such respondents to correct their judgments until the *C.I.* and *C.R.* values of each matrix were lower than 0.1. Since the AHP questionnaire was an expert questionnaire, Robbins (1994) recommendation that 5-7 experts are ideally required in studies of group decision-making questions suggests that the valid recovered questionnaires in this study provided representative views. In addition, the demographic data gathered through the questionnaire indicated that 66% had worked at stevedoring industry for more than 15 years, and most of them were middle or senior managers. This suggested that the questionnaire was highly representative.

The paper used the AHP method to calculate the relative weights of risk aspects and risk factors, as shown in the results in Table 2. The integrated weights and ranking of damage cargos risks in terminal on-site operations for special bulk cargos have been obtained.

Table 2. The relative weights of risk aspects and factors

Risk aspects	Normalized / Integrated weights (A)	Risk factors	Normalized weights (B)	Integrated weights (C=A*B)
S	0.368 (1)	S_1	0.216 (3)	0.079 (4)
		S_2	0.236 (2)	0.087 (3)
		S_3	0.186 (4)	0.068 (6)
		S_4	0.118 (5)	0.044 (12)
		S_5	0.244 (1)	0.090 (2)
F	0.269 (2)	F_1	0.373 (1)	0.100 (1)
		F_2	0.263 (2)	0.071 (5)
		F_3	0.183 (3)	0.049 (10)
		F_4	0.181 (4)	0.049 (11)
E	0.173 (4)	E_1	0.212 (2)	0.037 (14)
		E_2	0.127 (5)	0.022 (18)
		E_3	0.309 (1)	0.053 (9)
		E_4	0.179 (3)	0.031 (16)
		E_5	0.173 (4)	0.030 (17)
M	0.190 (3)	M_1	0.308 (1)	0.059 (7)
		M_2	0.304 (2)	0.058 (8)
		M_3	0.205 (3)	0.039 (13)
		M_4	0.183 (4)	0.034 (15)

Remark: (1) Numbers in parentheses are ranks. (2) Please refer to Section 3 concerning risk aspects and risk factors terminology.

The results of empirical study in Table 2 are shown as follows:

1. 'Satff (*S*),' ranking 1, is the most important risk aspect affecting risks in terminal on-site operations for special bulk cargos in Taiwan. The risk aspects of 'facility (*F*)' and 'managers and communication (*M*)' are ranked in the second and third places. 'Environment (*E*)' is the lowest ranked.
2. The top three key risk factors are 'failure to perform periodic machinery maintenance and examination (F_1),' 'workers' lack of safety awareness (S_5),' and 'failure to comply with the SOPs (S_2),' respectively. However, at the same time, the lowest weights of three risk factors are 'no signage for warning areas in the operation area of the ship (E_4),' 'operation under undesirable weather conditions (E_5),' and 'unclear signage of operation flow line on terminal shore (E_2),' respectively.

Based on the above results, the 'staff' was considered the most important risk aspect by all the experts interviewed. The relative importance of all factors revealed that even though the highest risk factor was not in the 'staff' aspect, however, the second and third highest risk factors were. Therefore, pre-operation education regarding on-site operation of special cargos should be ensured, and the relevant SOPs should be strengthened. The 'environment' aspect had the lowest weight, and the three least important risk factors were from the 'environment' aspect. Evidently, the 'environment' aspect and its related risk factors have relatively weak influence on the risk during terminal on-site operations.

5.2 RESULTS OF RISK ASSESSMENT USING RMM METHOD

The second-stage questionnaire included the foregoing 18 risk factors, and sought to assess the risk levels of these risk factors, and encompassed five *LF* values and five *LS* values. The RMM questionnaire was filled in by the related employees of various stevedoring industry in Taiwan, including stevedoring and warehousing departments of TIPC, shipping companies, stevedoring companies, cargos tally corporations, and claim adjusters. The surveys were completed through e-mails, phone calls, and in-person interviews conducted by the authors. A total of 104 valid samples were collected from the 150 questionnaires, which represents 69.33% of the total questionnaires. In addition, the demographic data gathered through this stage questionnaire indicated that 84.50% had worked at stevedoring industry for more than 10 years, and most of them were on-site operational workers.

The fact that Cronbach's α of the *LF* and *LS* values of each risk factor exceeded 0.6 indicated that the questionnaire possessed adequate reliability and consistency (Hair et al., 2010). After conducing reliability analysis, the Cronbach's α value for each risk factor reached to 0.646~0.884, and it is therefore an adequate reliability value. Due to the fact that the questionnaire of this study introduces questionnaires with literature or practical verifications collected by related experts, and hence the paper contains reasonable content validity (Hair et al., 2010).

The RMM method was used to measure the risk values of 18 risk factors, the results of the *LS*, *LF*, and *RV* values are shown in Table 3.

Table 3. The results of the *LS*, *LF*, and *RV* values

Risk factors	***LS***			***LF***			***RV***	
	Mean (A)	**S.D.**	**Rank**	**Mean (B)**	**S.D.**	**Rank**	**RV (A×B)**	**Rank**
S_1	3.67	0.999	6	**3.38**	**1.159**	**2**	**12.40**	**3**
S_2	**3.84**	**0.893**	**2**	**3.39**	**1.118**	**1**	**13.02**	**1**
S_3	3.76	0.940	4	3.03	1.161	12	11.40	8
S_4	3.62	1.055	7	3.01	1.250	13	11.84	5
S_5	**3.88**	**0.948**	**1**	3.27	1.125	6	**12.69**	**2**
F_1	3.54	0.903	8	3.23	0.927	7	11.43	7
F_2	3.34	1.011	12	2.82	1.012	18	9.42	15
F_3	3.16	0.956	16	2.87	0.882	17	9.07	17
F_4	3.23	1.036	15	3.07	1.073	10	9.92	13
E_1	3.53	0.892	9	3.00	1.000	14	10.59	11
E_2	3.27	0.947	14	2.95	0.989	16	9.65	14
E_3	3.40	0.887	11	**3.34**	**0.866**	**3**	11.36	9
E_4	3.33	0.855	13	3.33	0.918	4	11.09	10
E_5	3.51	1.132	10	2.99	1.211	15	10.50	12
M_1	3.71	0.921	5	3.28	1.074	5	12.17	4
M_2	**3.80**	**1.009**	**3**	3.09	1.208	9	11.74	6
M_3	3.01	0.865	17	3.04	0.902	11	9.15	16
M_4	2.92	0.972	18	3.10	1.128	8	9.05	18

Remark: Please refer to Section 3 concerning risk aspects and risk factors terminology.

It can be seen from Table 3 that the three risk factors with the greatest *LS* values, and that thus entail the greatest monetary losses when a risk event occurs, are "workers' lack of safety awareness (S_5)," "failure to comply with the SOPs (S_2)," and "organization managers have insufficient knowledge of workers' expertise (M_2)."

Table 3 also shows that the three risk factors with the highest *LF* values, and that have the greatest average number of risk events per each risk unit, are "failure to comply with the SOPs (S_2)," "failure to fulfil pre-operation education (S_1)," and "unsatisfactory operating environment at cabin (E_3)."

The results of Table 3 show that risk factors with higher RVs, in other words, the number of specific risk incidents for each risk unit in average, the most severe top three risk factors are "failure to comply with the SOPs (S_2)," "workers' lack of safety awareness (S_5)," and "failure to fulfil pre-operation education (S_1)," respectively.

Finally, this study marked the risk levels of 18 risk factors on a risk grade matrix (Figure 3) based on the results in Table 3. The Figure 3 shows: (1) ten risk factors, *i.e.*, S_1, S_2, S_3, S_4, S_5, F_1, E_1, E_5, M_1, and M_2, place on the high-risk (*H*) area; (2) eight risk factors, *i.e.*, F_2, F_3, F_4, E_2, E_3, E_4, M_3, and M_4, place on the medium-risk (*M*) area; and (3) there is no risk factor places on the low-risk (*L*) area.

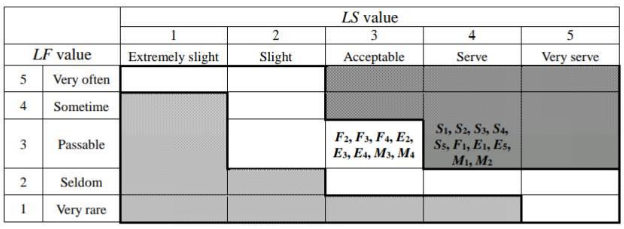

Figure 3. Risk grade matrix of the on-site operations for special bulk cargos in Taiwan

5.3 RESULTS OF RISK CONTROL STRATEGIES USING CBA METHOD

The above results revealed 10 risk factors in the *H* area and 8 in the *M* area (Figure 3). Because the characteristics of these factors differed, defining different risk management strategies for different areas was necessary. For example, the *H*-area risk factors had high *LS* values but normal *LF* risk. Thus, the frequency of accident occurrence is normal, but when an accident occurs, the consequence is severe. Therefore, terminal operation managers should adopt risk management strategies that focus on risk control. Conversely, the *M*-area risk factors had moderate *LS* values and normal *LF* risk. Risk management strategies for risk factors in *M* areas should consider risk prevention and risk control simultaneously, given that the cost of implementing relevant measures is reasonable.

This study assumed that if an accident occurred in the *H* area, the consequences would be severe. Therefore, this study first focused on the 10 *H*-area risk factors and identified 25 recommendations for risk management of terminal on-site operation for special bulk cargos after conducting a review of the relevant literature and expert interviews. To measure the implementation order of various risk control strategies, this study then used the CBA method in conjunction with a third-stage questionnaire. The CBA questionnaire employs a five-point Likert scale (in Table 1) to gauge the cost versus benefit of implementing the 25 risk control strategies. A total of 23 valid questionnaires were recovered during this stage survey. The Cronbach's α for questionnaire validity was 0.853, indicating adequate reliability and consistency (Hair et al., 2010). Because the survey items in this study were collected from relevant literature in Taiwan and also from senior experts at bulk cargos terminal, and the respondents also consisted of terminal on-site supervisors of larger-scale bulk stevedoring companies, the survey items were sufficiently representative and possessed sample relevance, and therefore met content validity requirements.

As discussed in Section 4.3, when the benefit of implementing a risk control strategy divided by the cost yields a value greater than 1, this indicates that the risk control strategy is feasible. The results of the third-stage questionnaire are shown in Table 4. As shown in Table 4, all risk control strategies are feasible. The five risk control strategies with the highest benefit to cost ratios are "discuss the type of cargos, type of ship, and the operating mode of the machine deployment before the stevedoring operations (S_8)," "formulate assessment procedures rewards and penalties (S_2)," "strengthen staff education training and implementation of professional manpower training programs (S_1)," "formulate a checklist for on-site staff to confirm before terminal operations (S_5)," and "pre-operation education for workers before operations to enhance safety awareness (S_{13})." Conversely, the five risk control strategies with the lowest benefit to cost ratios are "provides workers with safety shoes, insulated gloves, miner's caps (including lighting equipment) and reflective vests (S_{19})," "establish a dedicated risk/safety management department (S_{21})," "arrange managers to obtain relevant security certificates (S_{23})," "stevedoring company purchases protective equipment (S_{18})," and "arrange mechanical equipment replacement insurance (S_{16})."

Table 4. Cost and benefit analysis of risk control strategies

High risk factors	Risk control strategies	Cost		Benefit		CBA values	
		Mean (*C*)	S.D.	Mean (*B*)	S.D.	*B*/*C*	Rank
Failure to fulfil pre-operation education (S_1)	S_1: Strengthen staff education training and implementation of professional manpower training programs	1.74	0.619	3.78	0.600	**2.172**	**3**
	S_2: Formulate assessment procedures rewards and penalties	1.52	0.790	3.65	0.573	**2.401**	**2**
	S_3: Making warning signs at workplaces	2.13	0.548	3.48	0.947	1.633	12
Failure to comply with the SOPs (S_2)	S_4: Implementing pre-, mid- and post-operational health and safety education	2.00	0.739	3.39	0.583	1.695	10
	S_5: Formulate a checklist for on-site staff to confirm before terminal operations	1.70	0.559	3.35	0.714	**1.971**	**4**
	S_6: Establish reward and punishment mechanisms to strengthen the safety of personnel and reduce the occurrence of unsafe behaviour	2.04	0.706	3.70	0.559	1.814	6
Inadequate knowledge of workers (S_3)	S_7: Appointing senior staff to teach workers relevant knowledge from time to time	2.26	0.810	3.48	0.665	1.539	15
	S_8: Discuss the type of cargos, type of ship, and the operating mode of the machine deployment before the stevedoring operations	1.57	0.728	3.83	0.388	**2.439**	**1**
Workers' unfamiliarity with equipment on the ship (S_4)	S_9: Senior staff lead junior staff to teach from the side	2.13	0.548	3.61	0.499	1.695	11
	S_{10}: Provide on-board mechanical operation technical manuals and require the crew to teach the workers how to operate them	2.09	0.733	3.65	0.573	1.746	8
Workers' lack of safety awareness (S_5)	S_{11}: Implement safety and health education and training from time to time to improve the safety knowledge of workers	2.22	0.736	3.57	0.590	1.608	13
	S_{12}: Through posters, slogans, and warning signs, workers can raise awareness of safety	1.91	0.515	3.39	0.941	1.775	7
	S_{13}: Pre-operation education for workers before operations to enhance safety awareness	1.96	0.562	3.70	0.470	**1.888**	**5**
Failure to perform periodic machinery maintenance and examination (F_1)	S_{14}: Formulate a schedule for the regular maintenance of machines and request maintenance work	2.43	0.662	3.57	0.788	1.469	16
	S_{15}: Daily assignment of technicians to perform inspections and records prior to assignment	2.35	0.832	3.7	0.765	1.575	14
	S_{16}: Arrange mechanical equipment replacement insurance	3.48	0.790	3.74	0.689	**1.075**	**25**

Table 4. Cost and benefit analysis of risk control strategies (*Continued*)

High risk factors	**Risk control strategies**	**Cost**		**Benefit**		**CBA values**	
		Mean (*C*)	**S.D.**	**Mean (*B*)**	**S.D.**	***B*/*C***	**Rank**
Reduction in the amount of protective equipment on site (E_1)	S_{17}: Shipping agents require security measures on board	2.26	1.054	3.26	0.689	1.442	18
	S_{18}: Stevedoring company purchases protective equipment (such as protective nets, guardrails, etc.)	3.44	0.941	3.48	0.665	**1.116**	**24**
Operation under undesirable weather conditions (E_5)	S_{19}: Provides workers with safety shoes, insulated gloves, miner's caps (including lighting equipment) and reflective vests	3.00	0.674	4.09	0.793	**1.363**	**21**
	S_{20}: Before the operation, the agent is required to perform cleaning work on the work area	2.30	1.020	3.35	0.714	1.457	17
Insufficient safety awareness of organization managers (M_1)	S_{21}: Establish a dedicated risk/safety management department	2.96	0.878	3.39	0.783	**1.145**	**22**
	S_{22}: Regularly start safety meetings, implement education and training, and require managers to implement operational safety concepts	2.61	0.583	3.57	0.843	1.368	20
	S_{23}: Arrange managers to obtain relevant security certificates	3.04	0.878	3.43	0.788	**1.128**	**23**
Organization managers have insufficient knowledge of workers' expertise (M_2)	S_{24}: Regularly hold the work safety meeting and the company's safety awareness communication	2.48	0.730	3.57	0.843	1.440	19
	S_{25}: Establishment of operating personnel safety assessment mechanisms (such as expertise, accident rate and experience information login)	1.96	0.562	3.35	0.775	1.709	9

5.4 DISCUSSIONS

The terminal on-site operations of special bulk cargos in ports, face different aspects of risk factors, such as stuff factors, port operation environment and the risk-percept of operation team members. Any single form of risk factor may contribute to frequency and loss severity accidents. This study engages in general discussion on aforementioned research conclusions through complete description of key risk factors, risk grade matrix, and adaptive risk control strategies in order to be used as reference for loading operations of special bulk cargos. Explanations to key points are elaborated below:

First, in terms of stuff factors, although container shipping transportation has become the mainstream form of delivery, bulk cargos delivery still retains a large scale market demand, with the procedures and risks of port operations being different for containers shipping and bulk cargos delivery. Although automated shipping operations have become the modern trend, bulk cargos delivery terminals by comparison still retain a more traditional operation model and hence require more labor (from base level stevedores, cargo processing personnel, crane operators to agents of the shipping company). Bulk cargos terminals often employ temporary contracting workers. As the skill level of workers is uneven, accidents are more prone to occur.

As the specifications and appearances of bulk shipment cargo vary, professional knowledge and skills are needed in its operation. Accidents tend to happen when the staff operators are not equipped with adequate professional skill or knowledge regarding the cargo type or hoisting machinery. A vast number of researches indicate that negligence of staff operators is a very influential risk factor, especially for new on-board personnel with inadequate experience. The risk management of terminals should frequently conduct training for new personnel. Moreover, senior staff operators also often neglect operating regulations, confident that their experience can assist them in managing related danger risks and completely ignoring the company's safety regulations, hence resulting in increased occurrence rate of accidents. Thus, the risk control strategy suggestions of terminal on-site operations should appropriately implement operation SOP's so as to avoid accidents.

Second, in terms of the risk factors of special bulk cargos working environment, inappropriate operation flow line on terminal shore, poor ship operating environment at cabin, and poor weather conditions might all result in operation accidents. As the bottom of ship cabin has limited spacing, poor ventilation, illumination and slippery surfaces caused by water will result in injury for workers. When ships arrive at ports and machinery and trailer operations start, poor planning of operation routes can lead to unclear warehouse, ship side automobile and machinery flow labels, which will result in collision risks of trailers and other machinery as well as resulting in damages for the machinery, trailer or cargos. Research advices implementing a ship shape introduction before executing loading operations, labeling more dangerous areas as well as implementing warning lights and markings. When hatches are open, personnel control should be implemented, prohibiting all personnel from approaching. Ships should be asked to provide danger notifications so as to ensure pre-operation briefing for operators.

Last, in terms of risk perception of team organization operations, communication is vital. The communication between vendors, conductors and crane operators, on-site supervisors and subordinates all affect the progress accident occurrence rate. The safety awareness of operators is decided by the management of loading and unloading operations (e.g. company's internal manager, directors etc). Lack of safety awareness on the management's behalf will result in inability to implement safety management. Inability to teach terminal operators the appropriate safety means an increase in risk of operating accidents. The risk control strategy suggestions of this study is for companies to established a department dedicated to the management of risk safety, which regularly holds meetings and implements training, to ensure operation safety. Management personnel should undergo training and should be required to acquiring relevant safety licenses.

In addition, engineering safety has significantly improved in modern times, with past accident data indicating that the accident occurrence rate is higher for bulk terminal operations compared to others. Company management realizing the value of operation safety, such as how to implement preventative management and reduce post-accident losses is an important risk management issue. The results of this study can provide bulk shipment enterprises and on-site loading and unloading personnel, appropriate management and suggestions in tackling accident occurrence rate.

6. CONCLUSIONS

Cargo handling is an essential part of terminal operations. The complexity and difficulty of this task is particularly evident when handling special types of cargos with varying shape and sizes. Moreover, the danger and difficulty of handling bulk cargos are very high, and cargos damage or human injury can occur if the task is not managed with careful attention. Therefore, how shipping and stevedore companies may avoid damage when handling special bulk and sundry goods cargo and adopt strategies to minimise the risks merits further investigation.

In light of this, the main purpose of this article is to study the risk management of terminal on-site operations for special bulk cargos in Taiwan. The study applies the concepts of FSA approach as the foundation of risk management assessment. An empirical study was performed in this article. Firstly, a total of four risk aspects with eighteen preliminary risk factors are generated from literature and experts interviews. Furthermore, the study applied the AHP method with the first-stage questionnaire to evaluate key risk factors. Then, the RMM method with the second-stage questionnaire was used to study the risk assessment. Subsequently, the CBA method was to evaluate the applicability of risk control strategies. Finally, the results showed that:

1. By using the AHP method, the top three key risk factors are 'failure to perform periodic machinery maintenance and examination,' 'workers' lack of safety awareness,' and 'failure to comply with the SOPs,' respectively.
2. By using the RMM method, ten risk factors place on the high-risk (*H*) area, and eight risk factors place on the medium-risk (*M*) area.
3. By using the CBA method, all risk control strategies are feasible. The top five risk control strategies with higher benefit and cost ratios are 'discuss the type of cargos, type of ship, and the operating mode of the machine deployment before the stevedoring operations,' 'formulate assessment procedures rewards and penalties,' 'strengthen staff education training and implementation of professional manpower training programs,' 'formulate a checklist for on-site staff to confirm before terminal operations,' and 'pre-operation education for workers before operations to enhance safety awareness,' respectively.

Moreover, this study discovered the following: (1) The "staff" aspect and its related risk factors had the strongest influence on the on-site operation of special cargos; (2) the five risk factors in this risk aspect were related to the *H* area; and (3) in this risk aspect, 13 recommendations can be made regarding risk management strategies, 9 of which are ranked in the 10 most crucial priorities for risk strategy implementation. Therefore, we recommend improvement and reinforcement of human factors and the related risk factors for on-site operation for special bulk cargos, such as strengthening of safety awareness, SOPs, and pre-operation education. Through improved training and education, stronger compliance with the SOPs, and periodic maintenance of machinery and equipment, the risks of accidents can be controlled.

In addition, this article specifically investigated risk management in connection with terminal on-site operations for special bulk cargos in Taiwan. Special cargos also include mechanical parts, dry bulk goods, and different types of products and goods. Since different types of goods have different modes of operations, they necessitate different risk strategies. Because of this, it is recommended that follow-up research can be conducted and studied in the field operations of mechanical parts or dry bulk goods, which will provide terminal operators and academic researchers further reference information. Furthermore, this study focuses on investigating the issues of Taiwan's terminal of special bulk cargos. Thus it may not generalize to the same terminals in the other countries. We hope our article can contribute to the risk management in the terminal on-site operations for special bulk cargos in Taiwan. If the readers are interested in the similar cases in the future, they can apply the same procedures of the risk management to such special cargos.

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