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A slim based approach for human error probability of steel scrap cargo operations as a critical process in the maritime sector

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ABSTRACT

The transportation of steel scrap cargoes in global trade has been increasing over the years. According to the researches, the demand of steel scrap materials will be more than double in the late 21st century whereby forecasting of steel scrap production and so steel scrap cargo operations will also evenly rise in ports. Increasing steel scrap cargo operations will bring along several undesirable accidents and injuries. Investigations show that the most paramount reason for these incidents or accidents related with steel scrap cargo operations in maritime sector is human error. In this sense, it is aimed to identify human error probabilities (HEPs) for steel scrap cargo operation that is performed frequently in maritime sector, especially in bulk carrier vessels. In this study, Success Likelihood Index Method (SLIM), which is one of the methods for Human Reliability Analysis (HRA), is used to determine HEPs in steel scrap cargo operations due to the limited data availability on this topic. Accordingly, the most common error modes that are determined via detailed literature review are ranked in accordance with HEP values. It is put forward which and how much error mode is affected from Performance Shaping Factor (PSF) such as education, supervision, environmental condition, equipment and tool condition, and experience mostly. According to the analysis results, "the falling piece of steel scrap on the deck during steel scrap loading or unloading operation" has the most probability occurrence. Consequently, it is understood that training and experience factors are critically important for preventing errors in steel scrap cargo operation in overall view. On the other hand, environmental condition, supervision, and equipment and tool condition factors include the prominent level of significance to bring down the probability of accruing of some specific errors. Accordingly, the proposed approach not only make a theory-based contribution to the maritime literature, but also to active contribution to the sector involving P&I Clubs, shipping companies, and classification societies toward focusing point for minimizing the accidents about steel scrap cargo operations.

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1 Introduction

According to the report of United Nations Conference on Trade and Development (UNCTAD), global volumes in world seaborne trade reached 11 billion tons in 2018 and average volume grow annually for 2019-2024 years were stated as 3,4%. In 2018, tanker trade shipments (oil, gas, and chemicals), were 29% of world seaborne trade. Dry bulk shipments and containerized trade accounted for about 40% and 24% of total dry cargo shipments, respectively [1]. Accordingly, bulk carriers play a major role in the transportation of large volume raw materials and unpackaged cargoes in the world seaborne trade. According to the report of UNCTAD, the most transported cargoes by dry bulk carriers in 2018 were iron ore, coal, grain, steel products, and forest products with 1476 million tons, 1263 million tons, 471 million tons, 390 million tons, 378 million tons, respectively [1]. The steel scrap among them is the important raw material in the construction sector and in the manufacture of transportation equipment [1, 2]. Scrap consists of recyclable materials left from production and consumption, such as excess material, vehicle parts and building materials and it has high import and export rates [1, 2]. The Statista Research Department stated that

ABBREVIATION

ANOVA:	Analysis of Variance
BLU Code:	The Code of Practice for the Safe Loading and Unloading of Bulk Carriers
EM:	Error Mode
HEP:	Human Error Probabilities
HRA:	Human Reliability Analysis
ILO:	International Labor Organization
IMBSC:	International Maritime Solid Bulk Cargoes Code
ISM Code:	International Safety Management Code
MARPOL:	International Convention on Marine Pollution
P&I:	Protection and Indemnity
PSF:	Performance Shaping Factors
SLI:	Success Likelihood Index
SLIM:	Success Likelihood Index Method
SMART:	Simple Multi Attribute Rating Technique
SOLAS:	International Convention on Safety of Life at Sea
UNCTAD:	United Nations Conference on Trade and Development
UNECE:	United Nations Economic Commission for Europe

4 million metric tons steel scrap were exported and 19 million metric tons steel scrap were imported around the world in 2019 [3, 4]. As well as increasing demand of steel scrap cargo in the sector, it has been seen in the literature that there have been critically accidents and incidents during steel scrap loading or unloading process at the scrap terminals, such as cargo or crane falling on the deck or on the staff. According to researches, scrap operations fall into the business category that contains many risks in terms of having heavy workload and potentially causing irreversible damages to people in a minor carelessness [5, 6]. According to the Bureau of Labor Statistics, the most prevalent types of wounds when working with scrap metal are buckling and stresses, scotching and piercing skin, and cuts. Other potential hazards include workers being crushed by equipment used to transport scrap; amputation caused by this; respiratory diseases caused by scrap chemicals or dust [7]. The whole working process of steel scrap cargo operation is directly associated with the operating activities of the staff.

When the accidents related to the scrap operation are examined, DeCamp stated that most of them are attributed to lack of safety rule implementation, unsafe operating procedures, and inadequate training [7]. For this reason, it is important that every worker must have awareness of the dangers for all the jobs in their field. They must be trained in safe working practices to track and understand for using any personal protective equipment required for their work. In addition, as well as training and education, the adoption of implementation of general safety principles, such as appropriate business practices, equipment, and controls, can help decrease workplace accidents related to the transportation, handling, and storage of scrap metal [8].

In the literature, it is seen that some of the maritime regulations, such as International Safety Management Code (ISM Code) and guides for steel scrap carriage make essential some measure to prevent these incidents [9, 10]. For instance, according to occupational safety standards of International Labor Organization (ILO), workers' safety is jeopardized by the absence of basic precautions and lack of work planning, insufficient training, inadequate monitoring of work operation, unsuitable personal protective equipment, and insufficiencies in facilities [11]. Hence, cargo operation should always be monitored by responsible officers and care should be taken that no unauthorized personnel are present on the working area of the deck during scrap operation. Persons who are involved in the cargo operation should wear protective clothing including hard hats, safety shoes and highly visible vests. In addition, the crane operator must be in close interaction with the machine and the ground staff.

From this point of view, it is aimed to identify human error probabilities (HEPs) for steel scrap cargo operation especially in bulk carrier vessels. Examining the literature, to the best of authors' knowledge, there is lack of academic study involving steel scrap loading, unloading, handling or storage processes related to the maritime industry. There are academic studies which include topics more related with environmental, energy and greenhouse gas impacts of scrap-metal handling [12, 13] consumption, demand and forecasting of steel scrap production [14-17], recycling of vehicle steel scrap [18, 19], bulk carrier stability risk resulted from carriage of steel scrap [20]. However, any study, which considers the human reliability analysis or risk analysis for steel scrap cargo operations, could not be encountered in the literature. Therefore, considering the above-mentioned infrastructure resulted from report, guidelines and national or international regulations related to the scrap cargo operation, it is understood that identifying the human error probabilities for steel scrap cargo operation in maritime domain is a requirement in terms of safety of ship's crew and employees in ports, as well as premiums of Protection and Indemnity (P&I) insurance clubs, and inspection of classification organizations.

When investigations are reviewed, Tu and Lou stated that the root cause of incidents or accidents related to lifting operations is human error [21]. They performed a Human Reliability Analysis (HRA) for general lifting operations and found the probabilities of errors that can occur throughout lifting operation via Success Likelihood Index Method (SLIM). Steel scrap cargo operation can be also considered as a type of lifting operation, and it can include the same errors as lifting operation. On the other hand, steel scrap cargo operation also involves ship and port side. Therefore, errors for steel scrap operation should be thought in regard with ship and port procedures differently from any lifting operation, as well.

SLIM used for finding human error probabilities of lifting operation previous is a HRA method based on expert opinion. In the middle of 1980s, expert decision methods have been well-liked and used in especially major hazard industries and safety-critical environments. Expert decision tools procure a constituted path for experts to conceive how likely an error is in a specific scenario. They are used in human reliability analysis in cases especially involving data constraints. When sources are researched, it is not observed that human error records for steel scrap operations are accessible [25]. Therefore, in this study, SLIM, which is one of the approaches based on expert opinion in HRA, is used to calculate HEP for steel scrap cargo operations. For this purpose, several human errors as well as five performance shaping factors (PSF) for steel scrap loading or unloading operations are determined via a brainstorm expert meeting by supplying also resources containing the subject of scrap in the literature. The experts in this study consist of oceangoing masters who have taken part in steel scrap cargo operations. They have experienced various incidents and accidents that endangered the safety of crew, equipment, and operation process during steel scrap cargo operation. Then, weights of PSFs are appointed by the experts and PSFs are rated according to error modes. Finally, Success Likelihood Index (SLI) values for each error mode are calculated and converted to HEP. In this way, the most common error for steel scrap cargo operation in maritime sector is put forward and relevant measures can be developed by personnel on vessels, ship company officers, or experts. In addition, this study contributes to the literature as a case study of SLIM method since by analyzing the literature, it is seen that SLIM is used in the exceptionally low numbers of HRA studies involving the maritime sector [22-24].

2 Methodology

2.1 Success Likelihood Index Method (SLIM)

SLIM is a tool, which was offered by Embrey et al. in 1984 to evaluate the probability of a human error that occurs during the fulfilment of a particular task for usage around HRA [26]. SLIM method benefits from expert opinion for quantifying PSFs. PSFs can be considered as elements that positively or negatively affect the specific task, environment, or individuals [27]. The PSFs to be considered are formed by experts in a panel, which is organized to discuss specific tasks, and are accepted to be the most crucial factors about the context in question. Then, in the panel, experts determine the weight of PSFs with the idea that what factors affect that in general for the task to succeed. The weights of PSFs in this step reflect their relative effect on the task. In addition, experts rate the PSF according to error modes or specific situation. In this way, SLI is found for each error mode or specific situation. Finally, SLI is calibrated to derive HEP [28, 29]. The detailed application steps of the method are also presented in Section 2.2.

2.2 Analysis

2.2.1 Definition of task and identifying expert

In this study, the considered task is an operation of loading or unloading steel scrap to a bulk carrier in a port. During this operation, error modes that may affect or happen to the officer who keeps the shift due to any malfunctions, harsh environment condition, unawareness, or lack of knowledge are taken into consideration.

Five experts consisting of oceangoing masters who have previously taken part in the several operations for loading, unloading, storage, handling, and shipping scrap cargoes and heavy metal cargoes onboard ships and have been witness many accidents that endangered the safety of crew, equipment, and operation process during steel scrap cargo operation, are involved in this study. They have had at least ten years of experience in the maritime sector in terms of several navigation, maneuvering, and cargo operation. Based on their experience, they have determined the error modes that may occur during the operation and PSFs that affect the error modes. The weighting and rating scores of PSFs for each error mode have been shown in the study by taking the average of expert opinions.

2.2.2 Deriving error modes

The experts have thoroughly discussed the task evaluated to identify the error modes by considering numerous ways in which omission could occur.

Typical human errors that are valid for steel scrap cargo processes as well, are determined to identify potential PSFs associated process and potential accident types. As a result of expert discussions, 5 common error modes have been determined during the operation of loading or unloading of scrap (see Table 1).

Table 1 Common steel scrap cargo operation errors

No.	Errors Modes
1	Pieces of steel scrap can fall on the head of watch keeping officer
2	Pieces of steel scrap can fall on vessel deck
3	Crane can tip onto vessel deck because of the loss of strength of the wire
4	Crane can tip onto head of watch keeping officer because of the loss of strength of the wire
5	Hatch covers can dislocate because of tipping the crane on vessel deck.

Source: Authors

Table 2 PSF weights

PSF No	PSF	Assigned Weight	Normalized Weight
PSF 1	Training Level	100	100/250=0.4
PSF 2	Experience	60	60/250=0.24
PSF 3	Supervision	40	40/250=0.16
PSF 4	Environmental Condition	20	20/250=0.08
PSF 5	Equipment and Tool Condition	30	30/250=0.12
Total		250	1

Source: Authors

2.2.3 Identifying and weighting PSFs

In the study, PSFs in Table 2 are the major factors influencing success in the task being analyzed.

The determination of the relative importance of the PSFs can be accomplished by several procedures. In the initial feasibility study, Embrey implemented the simple multi attribute rating technique (SMART) to estimate weights [26]. A variant of this technique was used in the phase I evaluation experiment to he described shortly. In this particular variant of SMART, experts are first asked to consider the task being assessed and to visualize a situation where all the PSFs are as bad as they could credibly be in a real plant. Then, they are asked to decide which single PSF will have the most significant impact in increasing the likelihood of success. For this decided single PSF, weight of 100 is assigned. After that, the PSF, which will have the next most important impact on success, is selected and a weight is assigned to it relative to the most important PSF. Thus, if the second PSF were decided half as important as the first in terms of its effect on success likelihood, it would be given a weight of 50. This process is then repeated for all the PSFs. The importance weights of PSFs, which are decided by experts for the application, are showed in Table 2 by taking average of expert points. In the expert score average, intermediate values such as 14, 38, 44 are rounded to numbers between 0 and 100, such as 10, 40, 40, which increase by ten. Since, in the Embrey's method, SLI is calculated for ratings and weightings that are exact values between 0 and 100 scale, this rounding process has been carried out to avoid any errors in the transformation equation.

The normalized weights are obtained by dividing each individual weight by the sum of the weights. The sum of normalized weights is equivalent to one and reflect the relative importance of each PSF in the sense of how strongly it affects the possibility of success.

2.2.4 Rating PSFs

The weights indicate the relative importance of the PSFs in terms of their overall effect on the success likelihood, and are, therefore, not independent of one another. The ratings represent the experts' opinions regarding the actual situation in the steel scrap loading or unloading for the task being analyzed. The rating assigned to each PSF is independent of all the others in the set of PSFs being assessed. The ratings of PSFs according to error modes, which are decided by experts for the application, are showed in Table 3 by taking average of expert points.

Table 3 Rating PSF according to error modes

Error Modes	PSF 1	PSF 2	PSF 3	PSF 4	PSF 5
1	20	40	60	20	10
2	10	20	20	60	40
3	20	40	20	10	60
4	20	10	60	20	40
5	20	40	20	10	60

Source: Authors

Table 4 Calculation of the SLI

PSF	Normalized Weight	Error Mode 1		Error Mode 2		Error Mode 3		Error Mode 4		Error Mode 5	
		PSF Rating	Product 1	PSF Rating	Product 2	PSF Rating	Product 3	PSF Rating	Product 4	PSF Rating	Product 5
Training Level	0.4	20	8	10	4	20	8	20	8	20	8
Experience	0.24	40	9.6	20	4.8	40	9.6	10	2.4	40	9.6
Supervision	0.16	60	9.6	20	3.2	20	3.2	60	9.6	20	3.2
Environmental Condition	0.08	20	1.6	60	4.8	10	0.8	20	1.6	10	0.8
Equipment and Tool Condition	0.12	10	1.2	40	4.8	60	7.2	40	4.8	60	7.2
Total	1		SLI 1 = 30		SLI 2= 21.6		SLI 3= 28.8		SLI 4= 26.4		SLI 5= 28.8

Source: Authors

2.2.5 Calculating SLI

The calculation procedure for each SLI is shown in Table 4. The process of calculating each SLI includes multiplying of the ratings and the normalized weights for each PSF and then summing the results. The SLI can range from 0 to 100. If the steps analyzed include the process of the task, then 0 shows that step of task has a high probability of failing for, and 100 demonstrates it has a high probability of success. However, in this study, since the errors that may occur during the task are analyzed, this situation is considered as the opposite. Because, the experts score by considering which PSF is the most effective in order to avoid each error. Therefore, it is tried to make an evaluation to make the task (it means error modes) not successful.

2.2.6 Transform SLI to HEP

The transformation of SLI for each error mode to HEP is actualized by using Eq. (1) [26]. Eq. (1) is a general calibration equation for the group of tasks evaluated by experts.

$$\textit{Log of the Probability of Success} = a\ SLI + b \quad (1)$$

However, it is difficult to know a and b constants. In this case, the method of absolute probability judgement is used for endpoints. The reason for using this procedure is that in many situations, particularly rare-event scenarios, calibration tasks estimated by frequency data may not be available. The technique requires the experts to make absolute probability judgements of the best and worst cases for the scenario being evaluated. For example, the situation where all the PSFs are as bad as they can credibly be in steel scrap cargo operation errors, and conversely, where they are all as good as they can credibly be in steel scrap cargo operation errors are considered. Then, experts estimate human error probabilities of the worst case and the best case of steel scrap cargo operation these two scenarios are assigned SLI values of 0 and 100, respectively. Finally, they are used to define the endpoints of the SLI continuum. These boundary conditions are put into the general SLIM calibration equation and "a" and "b" constant values are found. Hence, unknown HEPs of the evaluated steel scrap cargo operation are found by using known SLI and "a" and "b" constant value in the calibration equation [26].

In this context, experts are asked to estimate the probability of human error for the two scenarios, considering the possible best and worst situations in a steel scrap cargo operation. While experts estimate the HEP of the best and worst cases, their experience and knowledge items are trusted. The estimated HEP values by experts regarding the best and worst cases for five errors of steel scrap cargo operation are as Table 5. The estimated HEP values in Table 5, SLI values as 0 and 100 for the worst and best cases respectively, are used in Eq. (1). Finally, "a" and "b" constant values are obtained and presented in Table 5. In Table 6, unknown HEP values for evaluated items are presented by using SLI values in Table 5 and "a" and "b" constant values.

Table 5 SLIs and HEP for error modes

Error Modes	Estimated HEP for the Best Case	Estimated HEP for the Worst Case	"a" Constant Value	"b" Constant Value
1	10^{-5}	10^{-3}	0.00000431	-0.000435
2	10^{-5}	10^{-1}	0.000459	-0.046
3	10^{-3}	10^{-2}	0.0000393	-0.00436
4	10^{-4}	10^{-1}	0.000459	-0.046
5	10^{-4}	10^{-2}	0.0000432	-0.00436

Source: Authors

Table 6 SLIs and HEP for error modes

Error Modes of Operation	SLI	Log (Probability of Success)	Probability of Success	HEP
Pieces of steel scrap can fall on the head of watch keeping officer	30	-0.0003057	0.999296347	0.000703653
Pieces of steel scrap can fall on vessel deck	21.6	-0.0360856	0.920268168	0.079731832
Crane can tip onto vessel deck because of the loss of strength of the wire	28.8	-0.00322816	0.992594444	0.007405556
Crane can tip onto head of watch keeping officer because of the loss of strength of the wire	26.4	-0.0338824	0.924948601	0.075051399
Hatch covers can dislocate because of tipping the crane on vessel deck.	28.8	-0.00311584	0.992851188	0.007148812

Source: Authors

2.3 Findings and Discussions

The probability values obtained for the failure of the error modes, that is, for the successful completion of the evaluated task are included in the "probability of success" column in Table 6. The values in the "probability of success" column are subtracted from 1 and the probabilities of failures, that is the success of the error modes, are obtained in the "HEP" column.

According to results, the probability of falling piece of steel scrap on the deck during steel scrap loading or unloading operation is 0.07973. This means that it is expected that approximately in eight of every 100 events, a piece falls on the deck once. This error mode has the most probability of being among the error modes examined for steel scrap loading or unloading operation. This is followed by falling the crane onto the officer because of the loss of strength of the crane wires which has the probability of 0.07505. After that, falling the crane onto the deck as a result of the loss of strength of the crane wire and erupting the chain of hatch covers because of falling the crane on the deck occur with the probability of about 7 per 1000 events. Finally, the probability of a falling piece of steel scrap on the head of officer on deck is 0.00070. This error mode has the less probability of being among the error modes examined for steel scrap loading or unloading operation. In accordance with the results, the most significant PSF for avoiding each error mode is as follows: (i) environmental condition affects to the EM2 more than others, (ii) there is more impact of supervision on preventing the EM4 and EM1, (iii) well-maintained equipment and tool condition can reduced the occurrence probability of EM3 and EM5. Consequently, it is understood that training and experience factors are critically important for preventing errors in steel scrap cargo operation in general. On the other hand, environmental condition, supervision, and equipment and tool condition factors include the elevated level of significance to bring down the probability of accruing of some specific errors.

Considering environmental condition, according to cargo operations procedures, shipboard crew should be mindful of the tasks to be performed if inclement weather is experienced during cargo operations. Such preparations should include allowing for sufficient time to fully close the cargo hatch covers before the onset of precipitation, to prevent damage to both cargo and people whereby accidents caused by people who are distracted by the effect of bad weather or caused by reduced vision or equipment failure due to harsh weather are prevented. For this reason, monitoring of the weather during cargo operation through visual observation, shipboard radar and the internet on local meteorological sites that show rain activity on actual radar/satellite pictures is also important preventing failures on task or possible accidents. "Rain letters" alone, issued at the discharge port, may not be sufficient and should be supplemented with additional sources.

In terms of equipment and tools conditions, prior to loading and discharging operations for steel cargoes, master and crew should determine whether hatch covers, and cranes are in good working order, if the latter are to be used in cargo operations. Shipboard crew should be fully aware of the required closing time for every hatch cover prior to the commencement of cargo operation.

In addition, during loading and discharge operations, master and crew should be aware of the risks associated with stevedores' loading and discharging of steel cargoes. These risks include rough handling of steel cargo products that can lead to physical damage and improper placement of steel cargo in the hatch due to not taking into account proper dunnage, stowage and lashing principles. Actions on lowering and lifting of heavy slings of steel cargo should be monitored to ensure that cargo is properly handled. By this way, falling piece of steel scrap on the head of officer or on the deck or on the any system on the deck such as pipe system, fire system, hydraulic system can be prevented with high level of focusing and monitoring. Besides, master should consider arranging a pre-load/pre-discharge meeting with the stevedore's foreman, inspectors and/or surveyors assigned by the charterer or shipper to agree on a procedure to be adopted if there is a threat of rain. If the vessel's cranes are being used to load or discharge cargo, it is important to prevent stevedores abandoning from their stations. During this time, they should not leave bundled cargo hanging on a crane wire or within a hold. Stevedores should ensure that load/discharge cargo in a uniform manner throughout the hold and not leave high piles of cargo in the wings and hold corners which may then collapse, which not only damages the cargo, but would also present a risk of injury to people working in the holds.

In brief, safe operating processes during scrap cargo operation in a port must be considered as follows: (i) crane hooks, wires and hydraulic system or operating mechanism must be checked before they are put into service; (ii) the loads must be connected and lifted in accordance with the crane hook capacity; (iii) the sharp edges must be closed down to prevent cutting slings; (iv) while the cargoes are lifted by the crane and put into hatch, people around must be clear of them; (v) when crane move suspended loads, sudden crane acceleration and deceleration is prevented.

On the other hand, if heavy weather has been encountered during the vessel's passage, or if damage was observed at the time of loading, the P&I club should be given timely notification of the vessel's estimated time of arrival at its intended port(s) of discharge since the appointment of an experienced surveyor at that point is highly advisable. If a cargo claim is presented by cargo interests, master or the vessel owner should immediately contact its P&I club and advise it of the allegations of cargo loss, damage, or shortage. The P&I club may then instruct its local correspondent and/or lawyers to attend to the matter and protect the vessel owner's interests as best as possible.

Accordingly, the proposed approach not only make a theory-based contribution to the maritime literature, but also to active contribution to the sector involving P&I Clubs, shipping companies, and classification societies toward focusing point for minimizing the accidents about steel scrap cargo operations.

2.4 Reliability analyses

2.4.1 Inter-judge consistency

For the measure, two-way analysis of variance (ANOVA) using the individual log HEPs as the dependent variable and error modes evaluated and the experts as the factors [26]. For this analysis, the SLIM steps are performed separately for each expert evaluation instead of arithmetic means of them to obtain individual log HEP. The result of ANOVA is as Table 7.

The result of ANOVA test indicates that most of the variability in the log HEPs is due to differences between error modes evaluated. There are no significant differences between experts.

The interclass correlation coefficient, representing the average correlation between the estimates of each pair of experts, can also be calculated as Eq. (2).

$$r = \frac{F-1}{F+(n+1)} = \frac{28561-1}{28561+(5+1)} = 0.9997 \quad (2)$$

"F" value in Eq. (2) represents "F" value of Expert in Table 7 and "n" shows number of experts. The result of Eq. (2) indicates a prominent level of agreement between experts.

2.4.2 Sensitivity analysis

To make design recommendations, it is important to be able to identify which PSFs have the greatest effect on the probability of success or failure. SLIM's ability to provide this information is an important advantage over other approaches.

Two-way ANOVA is performed using the PSF weights as the dependent variable and the PSF categories and the error modes evaluated as the two factors. The result of analysis is produced as Table 8.

Table 7 ANOVA results for inter-judge consistency

Tests of Between-Subjects Effects					
Dependent Variable: Individual logHEPs					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Model	,006a	9	,001	19191,612	,000
Experts	4,212E-8	4	1,053E-8	,320	,861
Error_Mode	,004	4	,001	28561,192	,000
Error	5,270E-7	16	3,294E-8		

[a]. R Squared = 1,000 (Adjusted R Squared = 1,000)

Source: Authors

Table 8 ANOVA results for sensitivity analysis

Tests of Between-Subjects Effects					
Dependent Variable: Weights					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	1,389[a]	24	,058	82,431	,000
Intercept	5,000	1	5,000	7122,507	,000
PSF	1,389	4	,347	494,587	,000
Error_Mode	,000	4	,000	,000	1,000
PSF * Error_Mode	,000	16	,000	,000	1,000
Error	,070	100	,001		
Total	6,459	125			
Corrected Total	1,459	124			

[a]. R Squared = ,952 (Adjusted R Squared = ,940)

Source: Authors

Table 9 ANOVA results for rating analysis

Tests of Between-Subjects Effects					
Dependent Variable: Ratings					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	40320,000[a]	24	1680,000	53,165	,000
Intercept	115520,000	1	115520,000	3655,696	,000
PSF	11272,000	4	2818,000	89,177	,000
Error_Mode	352,000	4	88,000	2,785	,031
PSF * Error_Mode	28696,000	16	1793,500	56,756	,000
Error	3160,000	100	31,600		
Total	159000,000	125			
Corrected Total	43480,000	124			

[a]. R Squared = ,927 (Adjusted R Squared = ,910)

Source: Authors

The ANOVA suggests that there are significant differences between the importance weights assigned to the different PSFs.

2.4.3 Analysis of rating data

In the two-way ANOVA analysis, the PSF ratings are the dependent variables and the PSF categories and the error modes evaluated are two factors. The result of ANOVA is shown in Table 9.

The existence of significant differences between the error modes evaluated indicates that the mean ratings, when all the PSFs are aggregated together, differ between the scenarios. The means of the PSF ratings can be regarded as a measure of the overall quality of the steel scrap cargo operation with regard to the scenarios under consideration.

3 Conclusion

Human error is one of the most important items for many safety operations in the maritime sector. Due to the limitation of data, the studies related with human error in maritime domain are generally conducted via using expert opinion. Because the human errors for the specific scenarios for maritime field are analyzed to make more contributions both literature and private sector.

The maritime industry is an untouched area for academic work that addresses the issue of steel scrap cargo operation. This paper has an approach for human error probability of steel scrap loading or unloading operations, which inquire the effect of a range of performance shaping factors. Because of the low amount of experimental data, the method for evaluating HEPs of steel scrap loading operation is improved based on expert knowledge. The proposed model formally combines expert estimates, thus using information from experts to help create a computable model to measure the probability of human failure accurately. For computable models, in a panel, the experts determine the error modes and related PSFs and the PSFs are weighted and rated to obtain relative impact on steel scrap operation. After the estimated SLIs are transformed into HEP by using the calibration equation, the purpose is achieved. At the end of any HRA methods, such as SLIM, the likelihood of errors that can occur within a system can be caused to fall by taking countermeasures and thus overall safety levels can be risen. Accordingly, scrap cargo operations must be conducted by dry bulk carriers according to international rules and contracts which include "International Maritime Solid Bulk Cargoes Code (IMBSC), The Code of Practice for the Safe Loading and Unloading of Bulk Carriers (BLU Code), International Convention on Safety of Life at Sea (SOLAS) and International Convention on Maritime Pollution (MARPOL)" that are specifically for the maritime area, and "Recommendations on Monitoring and Response Procedures for Radioactive Scrap Metal of the UNECE".

For future studies, pre, during, and pro tasks about steel scrap cargo operation can be identified in detail. Then, the human error probabilities of these tasks can be achieved via SLIM or more state of art methodologies such as machine learning, or Bayesian network method etc. According to results, safety measurement can be developed for each step of tasks.

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