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AN APPROACH OF CANONICAL CORRELATION ANALYSIS, RISK ESTIMATE ANALYSIS AND RESPONSE SURFACE METHODOLOGY TOWARDS FACTORS THAT AFFECTING THE EFFICIENCY OF MANAGEMENT OF VESSELS

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ABSTRACT

Previously, there were many maritime casualties has been recorded particularly throughout the time when there were no appropriate regulations or guidelines on safety. Finally, International Safety Management Code (ISM Code) was introduced to enhance the maritime safety of vessels above 500 Gross Register Tonnage (GRT) while the ships below 500 GRT are exempted from this regulation. Thus, vessels below 500 GRT does not have regulations or a system to be referred for a safe navigation and management and increase the risk of exposing to hazards. Consequently, the purpose of this study is to find out the factors contributing towards ineffective management in the absence of proper management system on vessels below 500 GRT. A sample consists of 324 respondents (focused group) from varies field in shipping industry was collected using questionnaire forms as an instrument and analyzed using Canonical Correlation Analysis (CCA), Risk Estimate Analysis (REA) and Response Surface Methodology (RSM). In canonical correlation analysis, the summary table and correspondence map indicates that majority of the respondents strongly agreed that external factor is the most associated factor with the efficiency of the management, followed by human error and inefficient management factors in agree category and stability factors were placed under unsure category. In risk estimate analysis, human error obtained the highest probability ratio of 11.774 (p-value < 0.05, CI: 4.676-29.652), followed by external factor is the second highest factors by ratio of 11.019 (p-value < 0.05, CI: 4.391-27.651). In RSM, the counter and surface plots indicate that the highest value or impact of efficiency on management is obtained when the count of human error and external factor to be the contributing factor is agreed the most by respondent while stability factors does not affect the efficiency. In short, human error factor is the most contributing factor towards an ineffective management system followed by external factor, stability factor and inefficient management. Hence, a proper and valid safety management should be implemented for the sake of the bright future of maritime industry.

Keywords: safety management, risk estimate, canonical correlation

1. INTRODUCTION

Fundamentally, shipping industry or seafaring occupations is always considered very challenging and very risky. This is because the shipping industry was connected with risks and problems due to lack of proper regulations, policies, proper safety guidelines and many other important criteria for a ship. The absence of improper guideline has led towards ineffective and poor navigation [1]. For instance, the number of serious marine accident has increased vigorously. Due to this, the seafaring occupation has become one of the most dangerous jobs [2, 3]. Therefore, ISM Code is being the most appropriate regulation code that contributes in abundance to prevent and reduce the number of accidents. Many studies and research shows that there is more positive outcome of the ISM Code in term of Greek Shipping [4]. Thus, positive impacts were proven especially in the tanker and roll-on-roll-off passenger sectors which dropped drastically from 85% to 55%[4]. Finally, International Safety Management Code (ISM Code) was introduced to enhance the maritime safety of vessels above 500 GRT while the ships below 500 Gross Register Tonnage (GRT) are exempted from this regulation. Thus, vessels below 500 GRT does not have regulations or a system to be referred for a safe navigation and management. This, increase the risk of exposing to hazards and thus the accident rates among vessels below 500 GRT has raised. Consequently, the purpose of this study is to find out the factors contributing towards ineffective management as a result of lack of proper management system on vessels below 500 GRT. In accordance

with this, many other factors such as human error, stability factor, stability factor, inefficient factor and etc. have risen and thus have led to ineffective management. Therefore, the purpose of this study is to group the factors appropriately based on the scale (disagree strongly, disagree, unsure, agree and strongly agree) and estimate the difference between two populations by comparing the factors, such as human error, stability factor, inefficient factor and external factor.

A Safety Management System (SMS), is always refers to organizations having a systematic approach in managing safety which includes organizations structures, accountabilities, policies and procedures. Moreover, SMS helps to create and develop a safety culture especially in the shipping industry. Generally, when comes to marine casualties, human error are frequently linked as the main contributing factors. Fundamentally, there are many factors favors the human errors. Based on a comprehensive analyze on the human elements, it is proved that mental and emotional factors and physical conditions for instance diet or illness are some of the main contributing factors of human errors [5]. In addition, the frequent consumption or intake of alcohol or drugs for the purpose of relaxation can lead to human errors [6]. On this side, an inappropriate or unstructured and incomprehensive operational procedure aboard ship is always leaded to trouble as well during distressed circumstances [7]. Moreover, the main problem solvent for human errors will be through safety management (Thematic Network for Safety Assessment of Waterborne Transport, 2003) [8]. Correspondingly, stability matter, on the other hand, is another prime factor that leads to maritime accidents and casualties. A successful voyage is always depends on the good conditions of the particular ship where stability matters plays a crucial role. Therefore, as mentioned by Kobylinski [9], stability criteria are considered as a factor contributing to loss of ship stability accidents (LOSA). An effective and efficient management is very essential for shipping industry specifically for sea-going vessels. The management of a vessel is potential to cause problems and stress to the seafarers in managing the vessel [10] and therefore a good management system is very important as it plays a crucial role in the industry. Climate change and weather conditions can be considered as a global problem [11] and equally has impacts on the maritime industry. Fundamentally, shipping industry is a risky industry and specifically ships are always exposed to various external factors or conditions such as bad weather, low visibility, currents and many more which will lead to maritime casualties such as collisions, stranding or groundings [12]. Statistics showed that, 74% of maritime accident which are happened due to fast current, heavy traffic and bad weather conditions, usually frequent on the month of April and May, as the bad weather falls on this two months respectively [13]. Thus, in the case of natural or external factors, a proper management or further actions should be taken in order to manage similar bad weather conditions in future.

The management of a vessel is potential to cause problems and stress to the seafarers in managing the vessel [10] and therefore a good management system is very important as it plays a crucial role in the industry. Correspondingly, in order to have a good management system, a good safety management system must exist. In fact, ISM Code has required all the shipping companies to develop and implement an effective safety management system (SMS) in order to have a safe operation at sea [14], and SMS do protect and prevent accidents from arising [15]. Safety management system (SMS) should be well documented and must be kept in every ship [16]. This is because the SMS would be very helpful during emergencies and any doubts regarding ship operation and management can be cleared by referring to the SMS. As described by [17], if an organization practices safety culture but without a SMS, then the organization is considered as it is on a risky path and obviously, SMS can be improved by identifying human factors and analyzing human interactions [18]. Therefore, to improve safety in shipping industry, management measures must be revised and assessed and come out with a good management system.

2. METHODOLOGY

A sample consists of 324 respondents from varies field in shipping industry was collected using questionnaire forms as an instrument and analyzed using Logistic Regression Modeling, Response Surface Methodology and Structural Equation Modeling techniques.

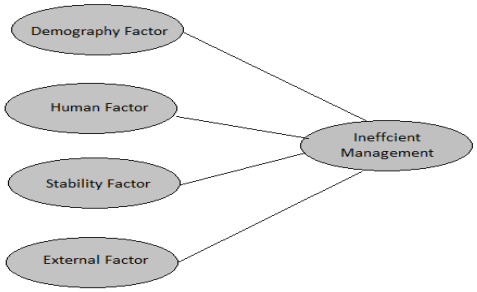

Fig. 1: Conceptual Framework of Factors Affecting Inefficient Management of Vessels [19]

2.1. Questionnaires

The questionnaire consists of five main sections. **Section A** comprises of the demography items such as sex, age, race, status, and education background of the respondents. **Section B** comprises of the 6 items for human error factor. They are [1]:

i. Human error is the main factor for maritime accidents.
ii. Crew should hire according to their competency level and qualification.
iii. Advanced technologies onboard cannot overcome human errors.
iv. Effective SMS can reduce human errors.
v. Human errors happen due to low qualifications of crews.

vi. Communication problem is the main factor of human error.

Section C consists of 6 items of stability factor which has occurred in the absence of proper safety management system. They are [1]:

i. Old vessels are difficult to be handle/operate.
ii. Old vessels are less safe.
iii. Improper ship designs can cause accidents.
iv. Lack of attention on stability matters can cause accidents.
v. Vessels should be built complying with rules and regulations to avoid stability problems.
vi. Vessels built using aluminium can get structural damage even in medium size waves.

Section D consists of 7 items of inefficient management and they are as follow [1]:

i. Good SMS practices can lower the accident rates.
ii. Clear safety management training for crews can prevent accidents.
iii. Management system which stressed on safe working procedures and wearing protective clothing can maintain save environment.
iv. Inappropriate ship management system can cause accidents.
v. Standard rules and operation procedures is an important factor to increase the safety of a ship.
vi. If there is a SMS but not in used, then the system will not be effective.
vii. Inefficient management system can cause human errors.

The last section of the questionnaire is the **section E** which comprises of 5 items of external factor. They are [1]:

i. Heavy rain, fog and strong wind are hazardous towards navigation.
ii. Natural factor is an important factor in causing maritime accidents.
iii. Most of the accidents occurred during months of bad weather.
iv. Small vessels frequently involved in accidents than large vessels during bad weather.
v. All captains should get the weather forecast before starting a voyage.

Table 1: Sample Size Calculation

Previous research	Anticipated population proportion, p	Absolute precision (Δ)	Level of significance	Sample size
Safety culture aboard fishing vessels [20]	0.838	5%	5%	209 respondents
Calculation	$n=\left(\frac{1.96}{0.05}\right)^2 0.838(1-0.838) = 208.6 \approx 209$ respondents			

3. FINDINGS AND DISCUSSION

3.1. Sample Size Calculation

The calculation was solved by using a single proportion formula with anticipated population proportion, (p) = 0.838, level of significance = 5% and absolute precision (Δ) = 5% [21-23].

$$n=\left(\frac{1.96}{0.05}\right)^2 p(1-p)$$

Based on the formula given above, p is expected proportion of individuals in the sample with the characteristic of interest at the 100(1-α) % confidence interval.

From the Table 1, we can see that the sample size needed is 209(Jon, 2010)[20]. Therefore, after adding 25% more data, the minimum sample needed to be collected is 209 + (209 x 0.25) = 261 respondents.

3.2. Biplot Analysis

Based on the summary in Table 2, the Singular Value column displays the canonical correlation between the two variables for each dimension. The Inertia column displays the inertia value for each dimension and the total inertia value. The inertia shown by a particular dimension can be evaluated by comparing it to the total inertia. In accordance with this, the first dimension displays 72.2% (0.011/0.015) of the total inertia; whereas the second dimension displays only 25.2% (0.004/0.015). Lastly, the third dimension obtained only 2.6% of the total inertia (0.015). Moreover, the p-value is less than 0.05 (0.000<0.05), which indicates that the total inertia is significantly different from zero.

Finally the above Figure 2 of correspondence map shows each category score on both dimensions for satisfaction scale and the contributing factors. The interpretation of the plot is fairly simple as the row and column points that are close together are more alike than points that are far apart.

The symmetrical normalization makes it easy to examine the relationship between contributing factors and the satisfaction level. Firstly, the external factor is near to the Strongly Agree scale, while human error and inefficient management seems to be near to the Agree scale. Meanwhile, stability factors are near Unsure scale. However, none of the contributing factors were present near the Disagree and Strongly Disagree column.

Therefore, based on the summary table and correspondence map, it is clear that majority of the respondents Strongly Agreed that external factor is the most associated factor with the efficiency of the management. On

the other hand, human error and inefficient management factors was Agreed to be the contributing factors that affects the efficiency of the management of a shipping organization or the vessels. However, the stability factors were placed under unsure category by the respondents, meaning this factor does not cause any huge effects towards the efficiency of the management.

Table 2: Summary Table

Dimension	Singular Value	Inertia	Chi Square	Sig.	Proportion of Inertia		Confidence Singular Value	
					Accounted for	Cumulative	Std Deviation	Correlation 2
1	0.104	0.011			0.722	0.722	0.011	0.016
2	0.061	0.004			0.252	0.974	0.012	
3	0.020	0.000			0.026	1.000		
Total		0.015	116.378	0.000[a]	1.000	1.000		

a. 12 degrees of freedom

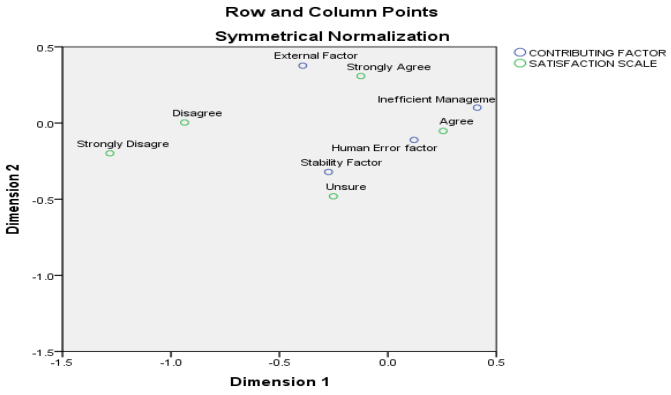

Fig. 2: Correlation Map

3.3. Risk Estimation Analysis

Table 3 above explains the odds ratio and risk value of the inefficient management which has the tendency of resulting in ineffective management or effective management. Based on the probability ratio, human error is the highest factor among the other factors by the ratio of 11.774. This means that human error has the odds to contribute towards inefficient management than not contributing towards inefficient management. In addition, the p-value of human error is at a significant level, *p*-value < 0.05 (CI: 4.676-29.652). In conclusion, human error is an important factor and it has the odds of contributing towards inefficient management compare to other factors.

In accordance with that, external factor is the second highest factors by ratio of 11.019. This shows that external factor has about 11.019 times of odds to contribute towards inefficient management. Besides that, the p-value of external factor is at a significant level, *p*-value < 0.05 (CI: 4.391-27.651). Therefore, stability factor has also become an important factor in contributing towards inefficient management.

Furthermore, the probability ratio for stability factor is 5.949. This point out that stability factor has the odds to contribute towards inefficient management as much as5.949 times compared to not contributing towards inefficient management. In addition, the p-value of stability factor is at a significant level as the *p*-value < 0.05 (CI: 2.428-14.578). Thus, this proves that stability factor is a significant and animportant factor.

Table 3: Risk Estimation

Dependent Variable	Independent Variables	Odds Ratio (OR)	95% Confidence Interval	
			Lower	Upper
Inefficient Management	Human Error	11.774	4.676	29.652
	Stability Factor	5.949	2.428	14.578
	External Factor	11.019	4.391	27.651

3.4. Analyzing Response Surface Designs

The response surface method is an ideal method for analyzing several numbers of independent variables which is affecting one dependent variable

In this case, the response surface method can be used to analyze the independent variables namely human error, external factor, and stability factor that are affecting the efficiency of the management. Generally, the result of response surface can be viewed graphically and also through variance analysis.

The analysis of variance table summarizes the linear terms, the squared terms, and the interactions. As overall, the p-value for lack-of-fit is 0.132, indicates that this model is adequately fits the data.

The residuals plot procedure generates four plots in one graph window. In the normal plot, it is shown an approximately linear pattern that is consistent with a normal distribution meaning that the data comes from a normal distribution. Similarly, the histogram of the residual is used to

check whether the variance is normally distributed. As a result, a symmetric bell-shaped histogram is formed which is evenly distributed around zero indicates that the normally assumption is likely to be true. The pattern of the graph of residuals versus the fitted values is not normally distributed. Besides that, in the residuals versus the order of the data graph, the residuals are balanced and close to the zero line, meaning there is no effect due to data collection order.

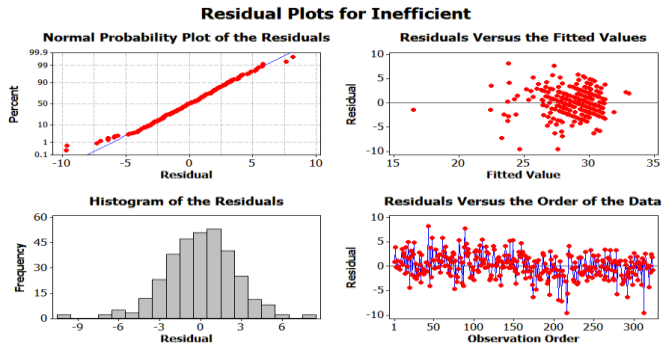

Fig. 3: Residual Plots for Inefficient Management

Table 4: Analysis of Variance for Inefficient Management

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	9	1109.20	1109.20	123.245	18.14	0.000
Linear	3	1021.03	71.98	23.993	3.53	0.015
Square	3	21.66	40.99	13.662	2.01	0.112
Interaction	3	66.51	66.51	22.171	3.26	0.022
Residual Error	314	2133.35	2133.35	6.794		
Lack-of-fit	260	1837.27	1837.27	7.066	1.29	0.132
Pure Error	54	296.08	296.08	5.483		
Total	323	3242.56				

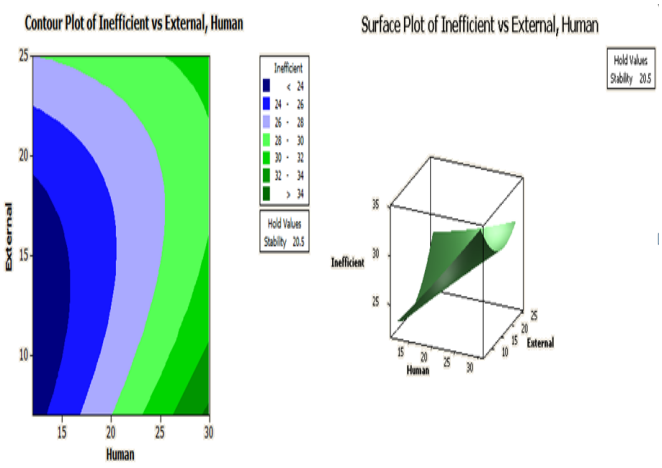

Fig. 4: Response Contour and Surface Plot for Inefficient Management vs Human Error, External Fcator

3.5. Response surface Method for Linear Regression

The contour plot and surface plot in the Figure 4 above shows that the efficiency of the management gets affected when the value of human error is high while the value of external factor is low. This area appears at the right bottom corner of the plot. The contour plot and surface plot in the Fig. 5 shows that the efficiency of the management gets affected when the values of both stability factor and human error are high. This area appears at the right top corner of the plot. The contour plot and surface plot in the Figure 6 above shows that the efficiency of the management gets affected when the stability factor obtains the highest value and the external factor obtains the low values or in other word, the external factor does not influent the efficiency of the management. This area appears at the left top corner of the plot.

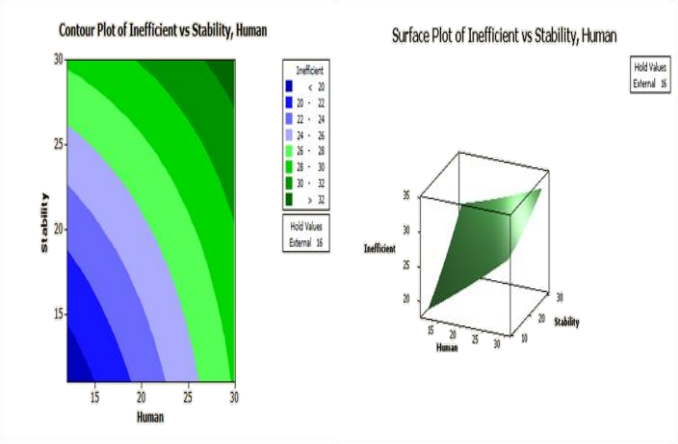

Fig. 5: Response Contour and Surface Plot for Inefficient Management vs Human Error, Stability Factor

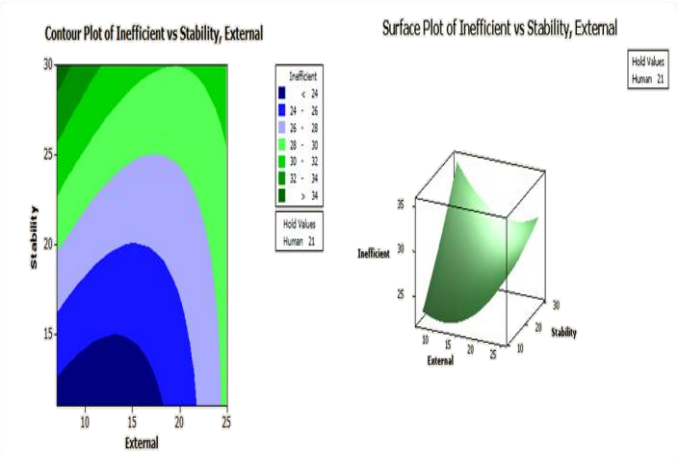

Fig. 6: Response Surfaces and Response Contour for Inefficient Management vs Stability Factor, External Factor

Therefore, based on the observations of the three figures, it is concluded that the efficiency of the management of a shipping organization or a vessel is affected the most due to the human error and stability factors whereas external factor does

not give a very big implications to the efficiency of the management.

4. CONCLUSION

Therefore, as a overall, it can be concluded that, human error factor is the most contributing factor towards an ineffective management system compare to other factors, as it has been proven in the results from all analysis that been carried out. Followed by external factor, as, most of the analysis has proved that this factor has a huge potential in affecting the productivity of a management. Whereas, stability factor and inefficient factors are also affecting the efficiency of a management, but the impact is not has heavy as human error and external factor. Hence, in order to combat the inefficiency problem in shipping organization and sailing vessels particularly onboard above 500GRT or in short, in domestic shipping industry, a proper and valid safety management should be implemented. The implementation of a good safety management system can eradicate many problems in the initial stage as it will evade the arisen of new factors that can affect the efficiency of the management and thus lead to maritime casualties or accidents. Then, in future, a safer voyage with an effective management system can be evolved.

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