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HUMAN FACTOR IN MARITIME TRANSPORTATION MANAGEMENT SYSTEM: THE ANALYSIS OF SHIP ACCIDENTS IN THE STRAIT OF İSTANBUL CAUSED BY HUMAN ERROR

Nur Jale ECE[1]

ABSTRACT

Maritime transportation is the backbone of economic development and world trade. Maritime transportation management system includes a set of procedures related ships, cargo and ports. Safety management in maritime transportation is one of the imperative topics of the shipping industry and marine environment. The principle factor in maritime safety is the human factor which influences maritime safety, security and marine environment. The maritime industry has suffered from accidents that caused by the human error as the primary cause. This paper aims to define maritime transportationmanagement and safety management system;to investigate human factor,the major factors influencing human behavior, the causes of human error contributing to ship accidents; to investigate physical specifications,maritime traffic and regulations of the Strait of İstanbul and major accidents occured in the Strait,to analyse human error contributing to ship accidents have occured in the Strait of İstanbul during 1982 and 2015 by using Pearson Chi Square Analysis (χ2), Cramer's V Test and Spearman's Rho Test. The paper's results as follows; human error remains the most important factor in marine accidents, human error mainly occurred in collisions and respectively grounding and ships without engagement of pilots caused most of the accidents. There is a statistical significant relationship between human error and the years, months, hours, types and region of accidents, ships without engagement of pilots. A general evaluation was conducted and suggestions are proposed to minimize human errors in maritime transportation to ensure safety of navigation and marine environment.

Key Words: Human factor, human error, maritime safety, maritime transportation, ship accidents, the Strait of İstanbul

INTRODUCTION

Maritime transportation is an important factor of economic development and world trade. Around 90% of world trade is conducted by the shipping industry. Maritime transportation system includes management of ships, ports and cargoes.The system covers the components of safe, secure, efficient and marine environmental protection.Safety management in maritime transportation is one of the imperative topics of the maritime industry and marine environment. The principle factor in maritime safety is the human factor which influences maritime safety, security and marine environment protection. The maritime industry has suffered from accidents that caused by the human error as the primary cause. Collisions which are the dominant type of ship accidents are also mostly caused by human error. International Maritime Organization focuses stronger on the human element to improve safety at sea and adopted some resolutions on the human element vision to prevent maritime accidents includes human factors.The Strait of İstanbul is one of the most narrow and risky

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waterways in the world. The Strait has also excessive traffic density. The ships carrying dangerous cargo is a serious threat for safe passage and environment. Many accidents have occured in The Strait of İstanbul which caused serious damage to the lives of crew, cargo and the marine ecosystem**.** In the study, Section 2 covers maritime transportation management and safety management system, human factor, the major factors influencing human behavior, the causes of human error contributing to ship accidents. Section 3 includes physical specifications, maritime traffic and regulations of the Strait of İstanbul and major accidents occured in the Strait, Section 4 presentsthe statistical methods and analysis results concerning human error contributing to ship accidents occured in the Strait of İstanbul in 1982-2015. In conclusion a general evaluation was conducted and suggestions are proposed to minimize human errors in maritime transportation to ensure safety of navigation and marine environment.

HUMAN FACTOR IN MARITIME TRANSPORTATION MANAGEMENT SYSTEM

Maritime transportation management system comprises of coaction and management of its sub-systems such as ships, ports, passengers and/or goods. The objective of the system provides the efficiency and safe movement of ships and cargoes through the destination ports [1]. The quality, efficiency and safety are the most important factors in terms of maritime transport. A safety management system is the organisation and arrangements organized by a transport operator to provide the safer management of its operations to reduce the accidents [2]. Human factor elements within the maritime transportation and safety management system consists of environmental, organisational and job factors [2]. Maritime accidents adversely affect both human and marine environments [3]. IMO reported that more than 75% of the ship accidents worlwide were due to human error [4]. The human role is vital in the shipping industry; ships require well trained and motivated crew in order to operate safely and efficiently[5]. "Salvendy (1997) has defined *"Human factor as a discipline regarding human abilities and limitations in relation to the design of systems, organizations, tools etc. Important parameters are safety, efficiency and comfort"[6]*.

The major factors influencing human behavior are mainly composed of psychological and physiological factors, technological and skillful factors, environmental factors, management factors and organizational factors[7,8]. *"Senders and Moray (1991) has defined "Human error is described as a result of observable behavior originated from psychological processes on different levels such as, perception, attention, memory, thinking, problem solving, decision making, evaluated against some performance standards, initiated by an event in a situation where it was possible to act in another way considered to be right"[9]*. There are many factors influencing human error. The major factors effects the role of human competence, attitude, motivation, life style, safe and secure working environment, self-actualization, moral values [6]. The causes of human error contributing to ship accident slack of situation awareness and complacency, fatigue, lack of experience, skill, abilities, alertness and memory, absence of p**e**rception, lack of motivation, incorrect decision by the master or crew, an improperly performed action, insufficient communication and knowledge, poor design of automation, economic pressure, disase, equipment design error, bad wheather conditions, organizational factors such as crew organization and company policies or practices[10].

Safety measures are therefore essential in preventing accidents; it is vital to learn lessons from previous accidents to safeguard life, property, and the environment at sea. The IMO takes previous maritime accidents into account when setting rules for ensuring safety at sea [3]. Elements of a Safety Management System are; a safety policy, organisational arrangements, a safety plan, means of reviewing safety and a feedback loop to enhance safety performance [11]. *"The IMO's Code for Investigation of Marine Casualties and Incidents defines marine accidents as, an occurrence or*

*event being caused by, or in connection with, the operation of a ship by which the ship or any person is imperiled, or as a result of which serious damage to the ship or structure or the environment might be caused"[*5,12]. Maritime accidents may involve more than one factor, such as human errors, mechanical failures, adverse weather conditions, and traffic density. Maritime accident analyses aim to describe the root reasons of accidents and recommend effective ways to protect similar accidents. *"The IMO's Resolution A.947(23) for "Human Element Vision, Principles And Goals For The Organization" defines the human element as a complex multi-dimensional issue that affects maritime safety, security and marine environmental protection"* [12].

PHYSICAL CHARACTERISTICS, MARITIME TRAFFIC AND MAJOR ACCIDENTS OF THE STRAIT OF İSTANBUL

The Strait of İstanbul which links the Black Sea to the Sea of Marmara is 31 km long, 1,6 km wide and depth of the Strait varies from 13 to 110 m [13]. The factors contributing to accidents in the Strait of İstanbul are narrowness, deep, sharp turns and currents reaching 7 or 8 knots and bad wheather conditions contributes to marine accidents in the Strait. The Strait of İstanbul have also valuable historical and cultural values and a biological corridor for the different marine species [14,15].

The total number of vessels passed through the Strait of İstanbul is 46.532 of which 19 percent was tankers in 2013, 45.529 ships of which 19 percent was tankers in 2014, 43.544 ships of which 20 percent was tankers in 2015 [16]. Many accidents which caused serious damage to human life, cargo and environment. The Montreux Convention which signed on 20 July 1936 regulates the regime of the Turkish Straits. The Traffic Separation Schemes have introduced in accordance with Rule 10 of the Convention on the *"International Regulations for Preventing Collisions at Sea (COLREG 72)"* in 1994 to enhance navigational safety [13]. Maritime Traffic Regulations For The Turkish Straits and the Marmara Region has applied to all ships navigating in the Turkish Straits to provide safety of navigation, life and property and to protect the environment. In 1998, the regulation was revised and reviewed regulation "*Maritime Traffic Regulations for the Turkish Straits"* was adapted [14]. Turkish Straits Vessel Traffic Service (VTS) was established in 31 December 2003 to ensure safety of navigation and environment [13,14,15,17]. The accidents result in human life, cargo damage or loss, enviroment disaster and pollution [18]. Many accidents have occurred in the Strait till today. Independenta tanker collied with a Greek freighter at southern enterence of the Strait in 1979. The Independenta burned for weeks and 95.000 tons of crude oil spilled, 43 crew members lost their life. Nassia tanker collied with a cargo ship and causing the release of 95.000 tonnes crude oil and 29 crew members lost their life [13]. The number of accidents decreased after the adaptation of Regulations, TSS and VTS [19].

THE ANALYSIS OF SHIP ACCIDENTS IN THE STRAIT OF İSTANBUL CAUSED BY HUMAN ERROR

Material and methods

It has been created the ship accidentsdata base occured in the Strait of İstanbul from "right-side up" period 1982 to 2015 [20,21,22,23]. The ship accidents data base occured in the Strait contains 4.944 categorical data involving the years, months, hours, types and zones of accidents, ships without engagement of pilots. The Chi-Square (χ^2) Test was used to define if there is a statistically significant relationship between expected and observed accident data between the years 1982-2015 by using SPSS Statistical Package Programme SPSS 17.00. The asymptotic significance level was set at 5% [24,25]. The χ^2 formula is given as Equation (1):

$$\chi^2 = \sum_{k} \frac{(n_i - np_i^{(0)})^2}{} = \sum_{k} \frac{(\text{Observed Value} - \text{Expected Value})^2}{} \quad (1)$$

$i=1 \quad np_i^{(0)} \quad i=1 \qquad ExpectedValue$

Cramer's V Test which is used to determine the association between nominal variables for strength test for the Chi-square [26]. The formula for the Cramer's Vtest statistic is given as Equation (2) [27]. Spearman's Rank correlation coefficient (Spearman's Rho) is used to measure the strength between two variables. Spearman's Rho Test Formula is given as Equation (3) [28].

$$V = \sqrt{\frac{\chi^2}{n\ (k-1)}} \qquad (2) \qquad r_s = 1 - (6\sum d^2)/\ n3-n \qquad (3)$$

Cramer's V value dispreads between 0 and 1. The value of Cramer's V are; 0.10-0.20 weak association, 0.20-0.40 moderate, 0.40-0.60 relatively strong association, 0.60-0.80 strong association, 0.80-0.10 very strong association between the variables [29]. Spearman's Correlation Coefficient (Spearman's Rho) must lie between -1 and 1 where the value $r = 1$ means a perfect positive correlation and the value $r = -1$ means a perfect negative correlation [28]. The value of Spearman's Rho are; 0.10-0.19 very weak association, 0.20-0.39 weak, 0.40-0.59 moderate, 0.60-0.79 strong association, 0.80-0.10 very strong association between the variables [28].

Frequency distrubution, Chi Square Test (χ^2), Cramer's V Test and Spearman's Rho Test between accident year and reason of accident

The most of the accidents occured in the period of 1982-1993 (340 accidents) and respectively in 1994-2003 (266 accidents), 2004-2015 (227 accidents) as shown in Table 1. The most of the accidents occured due to human error (25,6%) in the period 1982-2015.

Table 1. Cross-Tabulation Between Accident Year And Reason Of Accident

Accident year/ Reason of accident	Count % within reason of accident	1982-1993	1994-2003	2004-2015	Total
Unknown	Count	164	92	74	330
	%	49,7%	27,9%	22,4%	100,0%
Human error	Count	67	98	48	213
	%	31,5%	46,0%	22,5%	100,0%
Bad wheather conditions&current	Count	50	23	30	103
	%	48,5%	22,3%	29,1%	100,0%
Breakdown	Count	14	9	56	79
	%	17,7%	11,4%	70,9%	100,0%
Others	Count	45	44	19	108
	%	41,7%	40,7%	17,6%	100,0%
Total	Count	340	266	227	833
	%	40,8%	31,9%	27,3%	100,0%

Hypotesis; H_0: There is not a relationship between accident year and reason of accident and H_1: There is a relationship between accident year and reason of accident. All individual expected counts are more than 1. The Chi Square value is 117,337 and minimum expected count is more than 1 (21,53) and 0,0% of expected counts are less than 5 (no more than 20% of expected counts should be less than 5) as shown in Table 2. Hence, Chi Square Test was used safely.

Table 2. The Chi Square, Cramer's V and Spearman's Rho Tests Between Accident Year And Reason Of Accident

	Value	df	Asymptote Significance (2 sided)
Pearson Chi-Square	117,337 [a]	8	0,000
Likelihood Ratio	105,868	8	0,000
Linear-by-Linear Association	32,517	1	0,000
Cramer's V	0,265		0,0 (Approx. sig.)
Spearman's correlation	0,174		0,0(Approx. sign.)
N of Valid Cases	833		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 21,53.

According to the result of Chi Square Test, the Null Hypothesis (H_0) is rejected due to P-value=0 < α =0.05 (significance level) as shown in Table 2. Thus, there is a statistical relationship between accident year and reason of accident. Cramer's V value (26,5%) confirms that there is a moderate association between accident year and reason of accident. The Spearman correlation coefficient value of 0,174 confirms that there is a very week association between accident year and reason of accident.

Frequency distrubution, Chi Square Analysis (χ2), Cramer's V Test and Spearman's Rho Test between accident month and reason of accident

The most of the accidents occured in December-February (242 accidents), respectively September-November (210 accidents) and June-August (205 accidents) for the period 1982-2015 as shown in Table 3. The most of the accidents occured due to human error in December-February (67 accident). H_0 is rejected due to P-value=0 < α =0.05 as shown in Table 3. There is a statistical relationship between accident month and reason of accident. The Chi Square value is 50,457, Cramer's V value (14,2%) confirms that there is a weak association between accident month and reason of accident. The Spearman correlation coefficient value of -0,051 confirms that there is a negative correlation between accident month and reason of accident.

Table3. Cross-Tabulation Between Accident Month And Reason Of Accident

Accident month/ Reason of accident	Count / % within reason of acc.	Dec-Feb	March-May	June-August	Sept-Nov	Total
Unknown	Count	84	68	78	100	330
	%	25,5%	20,6%	23,6%	30,3%	100,0%
Human error	Count	67	50	47	49	213
	%	31,5%	23,5%	22,1%	23,0%	100,0%
Bad wheather conditions&current	Count	40	23	15	25	103
	%	38,8%	22,3%	14,6%	24,3%	100,0%
Breakdown	Count	9	12	38	20	79
	%	11,4%	15,2%	48,1%	25,3%	100,0%
Others	Count	42	23	27	16	108
	%	38,9%	21,3%	25,0%	14,8%	100,0%
Total	Count	242	176	205	210	833
	%	29,1%	21,1%	24,6%	25,2%	100,0%

χ^2 = 50,457, P = 0,000, Likelihood Ratio =50,003, P= 0,000, Cramer'V : 0,142,Spearman's Correlation: -0,051.

Frequency distrubution, Chi Square (χ2), Cramer's V and Spearman's Rho Tests between accident hour and reason of accident

The most of the accidents occured in the hours between 20:00 - 24:00 (124 accident), respectively and 08:00 - 12:00 (114 accident) and 12:00 - 16:00 (109 accident) for the period 1982-2015 as shown in Table 4. The most of the accidents occured due to human error in 20:00 - 24:00 (46 accidents) and respectively in 24:00 - 04:00 (37 accidents), 08 – 12.00 (32 accidents). H_0 is rejected due to P-value=0 < α =0.05 as shown in Table 4. Thus, there is a statistical relationship between accident hour and reason of accident. The Chi Square value is 145,527, Cramer's V value is 20,9% confirms that there is a moderate association between accident hour and reason of accident. The Spearman correlation coefficient value of 0,227 confirms that there is a weak association between accident hour and reason of accident.

Table 4. Cross-Tabulation Between Accident Hour And Reason Of Accident

Accident hour/ Reason of accident	Count % within accident hour	Unknown	Human error	Bad wheather cond.&current	Breakdown	Others	Total
Unknown	Count	139	18	12	6	16	191
	%	72,8%	9,4%	6,3%	3,1%	8,4%	100,0%
24:00 - 04:00	Count	22	37	10	12	15	96
	%	22,9%	38,5%	10,4%	12,5%	15,6%	100,0%
04:00 - 08:00	Count	32	25	22	7	13	99
	%	32,3%	25,3%	22,2%	7,1%	13,1%	100,0%
08:00 - 12:00	Count	31	32	20	13	18	114
	%	27,2%	28,1%	17,5%	11,4%	15,8%	100,0%
12:00 - 16:00	Count	44	25	9	13	18	109
	%	40,4%	22,9%	8,3%	11,9%	16,5%	100,0%
16:00 - 20:00	Count	29	30	17	12	12	100
	%	29,0%	30,0%	17,0%	12,0%	12,0%	100,0%
20:00 - 24:00	Count	33	46	13	16	16	124
	%	26,6%	37,1%	10,5%	12,9%	12,9%	100,0%
Total	Count	330	213	103	79	108	833
	%	39,6%	25,6%	12,4%	9,5%	13,0%	100,0%

χ^2 = 145,527, P = 0,000, Likelihood Ratio =144,720, P= 0,000, Cramer'V:0,209,Spearman's Correlation: 0,227.

Frequency distrubution, Chi Square (χ2), Cramer's V and Spearman's Rho Tests between type of accident and reason of accident

The most of the accidents were collision (366 accidents) and respectively grounding (166 accidents), stranding/contact (131 accidents) for the period 1982-2015 as shown in Table 5. Among accidents, collision is the most occurred accident type [14].

Table 5. Cross-Tabulation Between Type of Accident And Reason Of Accident

Type of accident/ Reason of accident	Count % within reason of acc.	Unknown	Collision	Grounding	Stranding/ Contact	Others	Total
Unknown	Count	11	158	44	55	62	330
	%	3,3%	47,9%	13,3%	16,7%	18,8%	100,0%
Human error	Count	3	116	40	38	16	213
	%	1,4%	54,5%	18,8%	17,8%	7,5%	100,0%
Bad wheather	Count	1	50	31	9	12	103
conditions&current	%	1,0%	48,5%	30,1%	8,7%	11,7%	100,0%
Breakdown	Count	0	14	21	10	34	79
	%	,0%	17,7%	26,6%	12,7%	43,0%	100,0%
Others	Count	3	28	30	19	28	108
	%	2,8%	25,9%	27,8%	17,6%	25,9%	100,0%
Total	Count	18	366	166	131	152	833
	%	2,2%	43,9%	19,9%	15,7%	18,2%	100,0%

$\chi^2 = 115{,}585$, P = 0,000, Likelihood Ratio =121,824, P= 0,000, Cramer'V: 0,186, Spearman's Correlation: 0,146.

All types of accidents are mostly caused by human error. The most of the collisions occured due to human error (116 accidents) in this period**.** The most of the groundings occured due to human error (40 accidents). H_0 is rejected due to P-value=0 < α =0.05 as shown in Table 5. Thus, there is a statistical relationship between accident type of accident and reason of accident**.** The Chi Square value is 115,585, Cramer's V value (18,6%) confirms that there is a weak association between type of accident and reason of accident. The Spearman correlation coefficient value of 0,146 confirms that there is a very weak association between type of accident and reason of accident.

Frequency distrubution, Chi Square (χ2), Cramer's V and Spearman's Rho Tests between zone of accident and reason of accident

The Strait of İstanbul is divided four regions due to many observation numbers at the accident regions. Region I: Haydarpaşa-Eminönü and Ortaköy-Çengelköy, Region II: Ortaköy-Çengelköy and Yeniköy-Paşabahçe, Region III: Yeniköy-Paşabahçe and Rumeli Kavağı-Kavak Burnu, Region IV: Rumeli Kavağı-Kavak Burnu and Anadolu Feneri-Rumeli Feneri. The most of the accidents occured in Region I (298 accidents) due to domestic traffic congestion and respectively in Region II (223 accidents) due to the currents, in Region III (122 accidents) and in IV. Region (91 accidents) for the period 1982-2015 [14]. The accidents occured in Regions I, II and III are mostly caused by human error. The most of the accidents occured due to human error (98 accidents) in Region I, respectively in Region II (54 accidents), in Region III (31 accidents) and Region IV (20 accidents) as shown in Table 6.

Table 6. Cross-Tabulation Between Zone of Accident And Reason Of Accident

Zone of accident/ Reason of accident	Count % within reason of acc.	The Strait of İstanbul	Region I	Region II	Region III	Region IV	Total
Unknown	Count	75	121	63	43	28	330
	%	22,7%	36,7%	19,1%	13,0%	8,5%	100,0%
Human error	Count	10	98	54	31	20	213
	%	4,7%	46,0%	25,4%	14,6%	9,4%	100,0%
Bad wheather conditions&current	Count	5	30	51	16	6	108
	%	4,6%	27,8%	47,2%	14,8%	5,6%	100,0%
Breakdown	Count	3	22	26	21	31	103
	%	2,9%	21,4%	25,2%	20,4%	30,1%	100,0%
Others	Count	6	27	29	11	6	79
	%	7,6%	34,2%	36,7%	13,9%	7,6%	100,0%
Total	Count	99	298	223	122	91	833
	%	11,9%	35,8%	26,8%	14,6%	10,9%	100,0%

χ^2 = 139,985, P = 0,000, Likelihood Ratio =127,894, P= 0,000, Cramer'V: 0,205, Spearman's Correlation: 0,236.

H_0 is rejected due to P-value=0 < α =0.05 as shown in Table 6. There is a statistical relationship between zone of accident and reason of accident as shown in Table 6. The Chi Square value is 139,985, Cramer's V value (20,5%) confirms that there is a moderate association between zone and reason of accident. The Spearman correlation coefficient value of 0,236 confirms that there is a weak association between zone of accident and reason of accident.

Frequency distrubution, Chi Square (X2), Cramer's V nd Spearman's Rho Tests between ships without engagement of pilot and reason of accident

A total of 78,3% of the ships involved in the accident were without engagement of pilot, 21,7% of the ships involved in the accident were with engagement of pilot. The ratio of human error in ships without engagement of pilot involved in the accident was 74,2%.

Table 7. Cross-Tabulation Between Ships Without Engagement Of Pilot And Reason Of Accident

Ships with/without engagement of pilot/Reason of accident	Count % within reason of acc.	Ships without engagement of pilot	Ships with engagement of pilot	Total
Unknown	Count	295	35	330
	%	89,4%	10,6%	100,0%
Human error	Count	158	55	213
	%	74,2%	25,8%	100,0%
Others	Count	199	91	290
	%	68,6	31,4%	100,0%
Total	Count	652	181	833
	%	78,3%	21,7%	100,0%

χ^2 = 53,256, P = 0,000, Likelihood Ratio =44,718, P= 0,000, Cramer'V: 0,253, Spearman's Correlation: 0,231.

H_0 is rejected due to P-value=0 < α =0.05 as shown in Table 7. There is a statistical relationship between ships without engagement of pilot and reason of accident. The Chi Square value is 53,256, Cramer's V value is 25,3% confirms that there is a moderate association between ships without engagement of pilot and reason of accident. The Spearman correlation coefficient value of 0,231 confirms that there is a weak association between ships without engagement of pilot and reason of accident. IMO Resolutions encouraging the engagement of pilots on board ships in certain locations [30].

CONCLUSION

Maritime transportation management system depends on interaction and management of ports, passengers and goods covers the components of safe, secure, efficient and marine environmental protection. Safety management in maritime transportation has vital importance on maritime industry and marine environment. The principle factor in maritime safety is the human factor that influences safety navigation, human life and marine environment protection.The growing number of the ships and expecially tankers in the Strait of İstanbul have become a serious threat to safety of navigation, human life and environment.This paper's findings concerning accidents occured in the Strait of İstanbul in 1982-2015 consist of the following; the most of the accidents occured in the period of 1982-1993. After adaptation of The Maritime Traffic Regulations, TSS and VTS, the accidents in the Strait of İstanbul have dropped dramatically. All types of accidents are mostly caused by human error and human error mainly occurred in collisions and respectively grounding in the period 1982-2015.The most of the accidents occured due to human error in December-February. The most of the accidents occured due to human error in the hours 20:00 - 24:00. The most of the accidents occured in Region I (Haydarpaşa-Eminönü and Ortaköy-Çengelköy). The accidents occured in Regions I, II and III (Haydarpaşa-Eminönü and Anadolu Feneri-Rumeli Feneri) are mostly caused by human error. A total of 78,3% of the ships involved in the accident were without engagement of pilot. The ratio of human error in ships without engagement of pilot involved in the accident was 74,2%. There is a statistical significant relationship between human error and the years, months, hours, types, regions of accidents, ships without engagement of pilots involved in the accident. The results of the analysis indicate that the primary reason of accidents was human error and most of the ships involved in the accident have not taken a pilot. The pilots are at the most importance for navigation safety and reducing human error and the ships without engagement pilots substantially increase the accidents risks in the Strait. Therefore, the use of pilots on board ships should be encouraged to ensure innocent passage, human life and marine enviromental protection. Furthermore, Safety Management System for the Strait of İstanbul should be build up including safety policy, organisational arrangements, a safety plan, safety regulations, risk assessment and improve safety measurements to provide navigation and environmental safety.

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