Mersin University Journal of Maritime Faculty

Mersin University Journal of Maritime Faculty (MEUJMAF)
Vol. 3, Issue 1, pp. 17-27, June 2021
ISSN 2687-6612, Turkey
DOI: 10.47512/meujmaf.919762
Research Article

STATISTICAL ANALYSIS OF MARINE ACCIDENTS IN THE STRAIT OF İSTANBUL USING CHI-SQUARE TEST

Nur Jale ECE *[1]

[1] Mersin University, Faculty of Maritime, Department of Maritime Business Administration, Mersin, Turkey
ORCID ID 0000-0003-2048-5458
jalenur@mersin.edu.tr

* Corresponding Author
Received: 18/04/2021 Accepted: 15/06/2021

ABSTRACT
The Turkish Straits which comprise the Strait of İstanbul, the Strait of Çanakkale and the Sea of Marmara connect the Aegean and Mediterranean Seas and the Black Sea. The Straits are one of the most hazardous and crowded waterways in the world. The Straits are important from the point of international politics and commerce. The aim of the study is to analyse the accidents that occurred in the Strait of İstanbul from the implementation of the Maritime Traffic Regulations for the Turkish Straits and the Marmara Region in 1994 until 2019 using frequency distribution, Chi Square) and Cramer's V Tests. The main findings of the study have given as follows; the cargo ships were the most involved in the accident; accidents are mostly collision and respectively grounding; the most accident has been occurred in the hours 20:00-24:00, main reason of accidents is human error and a total of 71.5% of the ships involved in the accident have not taken a pilot in the Strait of İstanbul. There is a statistically significant relationship between accident type and accident year; between accident type and the ship types involved in the accident and between accident type and whether the ship involved in the accident had a pilot; relationship between ship type involved in the accident and whether to take a pilot or not. At the conclusion of the study suggestions are proposed to provide safety of environment and navigation in the Strait of İstanbul.

Keywords: *The Strait of İstanbul, Marine accidents, Accident analysis, Collision, Maritime pilot.*

1. INTRODUCTION

The Turkish Straits which comprise the Strait of İstanbul, the Strait of İstanbul and the Sea of Marmara connect the Aegean and and the Black Sea. The Straits are one of the most hazardous and crowded waterways in the world. The Straits have a geopolitic and strategic importance from the points of international politics and commerce. The geographical conditions and navigational constraints of the Strait of İstanbu which is l17 Nautical Miles long, such as currents, several sharp turns, wheather conditions and narrowness cause the accidents in the Straits (Yurtören, 2004 (Akten, 2003). Sharp turns force ships to change course at least 12 times, sometimes turning up to 80 degrees is required (Korçak and Balas, 2020). Nearly, 8.700 tankers annually transit in the Strait of İstanbul carrying a total of 138 million tons of oil and other dangereous cargo (Altan and Otay, 2017; Aslan and Otay, 2021). In 2020, 38.404 ships passed through the Strait of İstanbul, 8,435 of which were tankers and the rate of maritime pilot employed was 65% (UAB, 2021). Nearly 150 ships pass through the Strait of İstanbul every day, of which 27-28 ships carry dangerous goods (Bucak, 2021).

There have been many accidents in the the Strait of İstanbul in the past. Some of these were Independenta-1979 and the Nassia-1994 causing human loss and environment pollution. The legal regime of the Turkish Straits arranged the Montreux Convention in 1936 within the tframework the principle of freedom of passage and navigation with certain formalities for merchant vessels. "Maritime Traffic Regulations for the Turkish Straits and the Marmara Region" entered into force on 1 July 1994. (İnan, 2001). The regulations was revised in 1998 (İnan 2001). "Maritime Traffic Regulations for The Turkish Straits" entered into force on 06.11.1998 to regulate the maritime traffic scheme were adapted in 1998. The regulations shall apply to all vessels entering or navigating within the limits of Turkish Straits. The purpose of Vessel traffic regulations is to ensure safety of navigation, safety of life, property and marine environment by improving the safety of vessel traffic in the Straits. Turkey implemented the traffic separation schemes in the Turkish Straits on 01 July 1994.

The purpose of these Regulations, which shall apply to all ships navigating in the Straits and the Sea of Marmara, is to regulate the maritime traffic scheme in order to ensure the safety of navigation, life and property and to protect the environment in the region. The Vessel Traffic Management and Information System was installed and began to serve as operational on 30 December 2003 (Akten, 2003). Vessel traffic services (VTS) are shore-side systems which range from the provision of simple information messages to ships, such as position of other traffic, meterological hazard warnings, hydrological outlook, to extensive management of traffic within a port or waterway (IMO, 2021).

There were a total of 38.404 ships passed through the Strait of İstanbul, 8,435 of which were tankers in 2021 navigating the Strait of İstanbul (UBAK, 2021). Pilotage service within Turkish Straits is compulsory for vessels carrying nuclear cargo/waste and hazardous and/or noxious goods or waste (IMDG Code-7), for nuclear powered vessels and LPG tankers with length overall (L.O.A.) of 150 meters and above which passes through the Turkish Straits, for contracted and scheduled LNG tankers passing through Canakkale Strait and, foreign flagged vessels calling at or leaving any Marmara port.

The Pilotage Services in the Turkish Straits are carried out by the Directorate General of Coastal Safety in accordance with the principles of TSMTR and operational instructions of TSMTR (KEGM, 2021).

In the study maritime traffic of the Strait of İstanbul was examined and literature review was conducted.The accidents that occurred in the Strait of İstanbul were analysed. from the implementation of the Maritime Traffic Regulations for the Turkish Straits and the Marmara Region in 1994 until 2019 using frequency distribution, Chi Square) and Cramer's V Tests.

2. LITERATURE REVIEW

Uğurlu and e*t al.* (2016) analyzed the marine accidents occurred in the Turkish Straits between the years of 2001 and 2010. The study indicates that employed a pilot on board is the most important measure to decrease the accidents. (Köse *et al.* (2003) developed model to investigate the traffic in the Strait of Istanbul. According to the result of the simulation, waiting time in the Strait would increase the probability of accident in the Straits.

Otay and Tan (1998) determined the probability of ship accidents by developing a stochastic model of tanker traffic. The results of the study are that the most accidents are collision and grounding. The ships proceeding without a pilot are major factor of the reason of accident in the Strait of İstanbul (Akten, 2006). Akten (2006) indicates that the ship accidents occurred in The Strait of İstanbul are the majority being collisions during the period 1953–2002. Koldemir (2009) defined the risk zones to define the accident black points. One of the results of the study is that employment of the pilotage by ships should be encouraged to reduce the accident risk.

Başar and Köse (2006) performed a simulation study for the accidents in the Strait of İstanbul. According to one of the results of the study, further increase of maritime traffic causes waiting times and accidents in the Strait. Ece analyses (2012) the marine accidents occured in The Strait of İstanbul during right-side up scheme period 1982-2010. According the one of the findings of the study the most accident is collision in the Strait.

Bayar et.al. (2008) analyzed the accidents in the Strait of İstanbul in different periods. The findings of the study are that the most accident type occurred in the Strait of İstanbul was collision, the general cargo ships were mostly involved in the accident and the accidents occurred in the Strait decreased after the installation of the VTS System.

Erol *et al*. (2017) analysed the accidents that occured in the Strait of İstanbul by using neuro-fuzzy method. The findings of the study showed that pilotage and the local traffic density are the most reasons which causes the accidents two main factors in the Strait. Altan and Otay (2017) developed a model concerning the collision probability in the waterways. The results of the study show that the collision probability increases in the narrow waterways. Uçan and Nas (2015) analysed the pilotage services in the Strait of Istanbul and indicated that employed pilots is an effective way for navigational safety in the Strait of İstanbul

Görçün and Burak (2015) analysed the accidents in the Strait of İstanbul using Formal Safety Assessment methodology. One of the results of the study, collision is the most common accident in the Strait . Ulusçu *et al*. (2009) performed) risk analysis for trtansit ship maritime traffic in the Strait of İstanbul.The result sof the study is that pilotage and local traffic density are reasons which cause the accident and taking a pilot are extremely important for navigational safety in the Strait to decrease the risks in the Strait.

Uluscu *et.all* (2015) analysed the accidents in the Turkish Straits using various methods, According to the results of the study collision, grounding and contact were the most significant accident types and human error is the most influential factor in the causes of accidents.

Korçak and Balas (2020) created a simulation model to define the probability of collision between the ships in the passage and the domestic ferries in the Strait of İstanbul in 2000-2019. Some of the findings of the study is that there is a significant collision probability between the ships in the passage and the domestic ferries. The collision and contact accidents have by %54 on the accident types in İstanbul Strait (Korçak and Balas, 2020).

Özdemir and Günerioğlu quantitatively evaluated based on expert knowledge and multiple criteria decision-making methodology to investigate the human factor in marittime accidents. The results of this study show that the most important reasons concerning people factor are “ability, skills, knowledge” (8.94%), and “physical conditions” (8.77%). The study indicates that there should be a focus on the types of human errors causing risks onboard a ship and try to enhance the technological infrastructure of merchant ships to reduce marine accident (Özdemir, Güneroğlu, 2015).

3. THE PASSAGE REGIME AND MARITIME TRAFFIC IN THE STRAIT OF İSTANBUL

The legal regime of the Turkish Straits was regulated by the Montreux Convention signed in 20 July 1936. The passage regime through the Turkish Straits is not a transit passage. The transit passage through the Turkish Straits is a sui generis innocent passage since the Montreux Convention (İnan, 2001). According to the The Montreux Convention merchant ships have freedom of passage. They must be subjected with certain formalities. However pilotage and towage remain optional (BASKENT-SAM, 2021; Ece, 2012). Maritime Traffic Regulations for the Turkish Straits and the Marmara Region which apply to all vessels passing in the Turkish Straits entered into force on 01.07.1994 and were implemented to enhance navigation safety, life and property and protection of the environment. The regulations was revised in 1998. (İnan 2001). “Maritime Traffic Regulations For The Turkish Straits” entered into force on 06.11.1998 to regulate the maritime traffic scheme were adapted in 1998.

The purpose of Vessel traffic regulations to ensure safety of navigation, safety of life, property and marine environment by improving the safety of vessel traffic in the Straits. These regulations shall apply to all vessels entering or navigating within the limits of Turkish Straits (Article 1).

Owners, Masters or Agents of the vessels with dangerous cargo or the vessels of 500 GRT and upwards, shall submit "Sailing Plan 1" in writing to the nearest Traffic Control Centers in IMO standard format at least 24 hours prior to entry into the Turkish Straits. After sending SP 1 and assuring himself that the vessel is in compliance with the requirements of Reg. 5, two hours or 20 miles (whichever earlier) before the entrance of the Turkish Straits, the Master shall submit Sailing Plan 2 in IMO standard format as defined by the Administration(Article 6).

All vessels with L.O.A of 20 meters and upwards, shall make a voice radio position report by VHF in IMO standard format to the nearest Traffic Control Station 5 miles before the entrance of the Straits (Article 6).

All vessels with a L.O.A. of 20 meters and upwards while proceeding within the Straits shall make a voice radio call point report by VHF in IMO standard format at the positions defined by Administration to the nearest Traffic Control Station. All vessels must be seaworthy according to the flag state and international legislation and regulations (Article 6).

The System of Turkish Strait Vessel Traffic Services began to serve as operational in accordance with the Turkish Straits Maritime Traffic Regulations on 30 December 2003 to enhance the safety of maritime traffic and environment (KEGM, 2021).

As shown in Table 1, 38.404 ships passed through the Strait of İstanbul, 8,435 of which were tankers and the rate of maritime pilot employed was 65% in 2020 (UAB, 2021). The ships which are greater than 200 m. have taken a pilot at the rate of 100% (Tenker, 2021).

4. METHODOLOGY

The object of the study is to analyse marine accidens occured in the Strait of İstanbul after implementation of “Maritime Traffic Regulations for the Turkish Straits” in 1994-2019. The accident data for the Strait of İstanbul obtained from the Ministry of Transport and Infrastructure of The Republic of Turkey Main Search-Rescue Coordination Cenre and other resources (http://aakkm.udhb.gov.tr, 2016; www.turkishpilots.org, 2004); TurkSail, 2019; Habertürk, 2019 and Independent Türkçe, 2019). ; Turkish Pilots). In the study quantative methods such as frequency distribution, Chi Square Test and Cramer’s V Test have been used to test the null hypothesis (H0) and to determine the statistically significant relationship between the nonparametric data using Statistical Package Programme (SPSS 17). The accidents occured in the Strait of İstanbul data base contains 526 of accidents records including the ship name, year, month and hour of the accident, type and reason of accident, ship type and the ships with/without a pilot involved in the accident.

Table 1. Marine traffic in the Strait of İstanbul

Years	Ship traffic	Tanker traffic	The ships employed a pilot (%)
1994	18,720	-	-
1995	46,954	4,320	38
1996	49,952	4,248	41
1997	50,942	4,303	39
1998	49,304	5,142	38
1999	47,906	4,452	38
2000	48,079	6,093	40
2001	42,637	6,516	41
2002	47,283	7,427	42
2003	54,880	8,107	45
2004	56,606	9,016	41
2005	54,396	8,813	45
2006	54,880	10,153	48
2007	56,606	10,054	47
2008	54,396	9,303	50
2009	51,422	9,299	49
2010	50,871	9,184	51
2011	49,798	9,099	48
2012	48,329	9,028	47
2013	46,532	9,006	50
2014	45,529	8,745	49
2015	43,544	8,633	51
2016	42,553	8,703	52
2017	42,978	8,832	51
2018	41,103	8,587	57
2019	41,112	8,957	65
2020	38.404	8,435	65

Source: UBAK, 2018; UBAK, 2021.

4.1. Frequecy Distribution

Frequency Distribution for quantative data were used to provide informative and summarized data sets. The frequency distributions of the marine accidents by year, month and hours of accident, accident type, ship types and the ships with/without a pilot involved in the accident and reason of accident in the Strait of İstanbul in 1994-2019 have been given in the following tables.

4.1.1. Frequency of ship accidents by years

As shown in Table 2 total of 27.6% of the accidents were occured in the Strait after Maritime Traffic Regulations for the Turkish Straits and the Marmara Region implemented in 1994-1998, 23.0% of the accidents were occurred during the period in Maritıme Traffic Regulatıons for The Turkısh Straits implemented in 1998-2003, 49.4% of the accidents were occurred after The System of Turkish Strait Vessel Traffic Services (TSVTS) implemented on 30 December 2003.

Table 2. Frequency of ship accidents by years

Accident year	Freq.	Percent (%)	Total Cumulative (%)
1994 - 1998	145	27.6	27.6
1999 - 2003	121	23.0	50.6
2004 - 2019	260	49.4	100.0
Total	526	100.0	

4.1.2. Frequency of the marine accidents by accident type

A Total of 45.6% of the accidents occured in Strait of İstanbul were collision and respectively grounding (17.5%), contact (9.5%), fire/ explosion (6.3%), breakdown (5.1%), stranding (3.8%), foundering/capsizing (3.4%) and others (contact fishing nets, local traffic density etc.) (7.2%) as given in Figure 1. In the period 2000-2019, the collision and contact accidents in the Strait of İstanbul 54% (Korçak and Balas, 2020). The ratio of collision and contact accidents occurred in the Strait in 1994-2019 are %55.1.

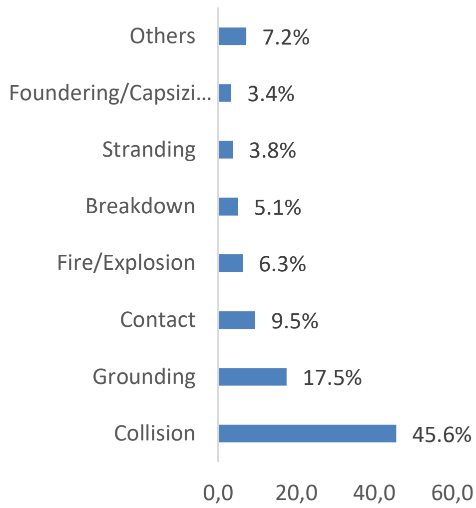

Figure 1. Frequency distribution of the marine accidents by the accident type (1994-2019)

Collision is the most accident type occurred in the Strait of İstanbul. The main reason of collision was human error.

4.1.3. Frequency of ship accidents by reasons

Frequency of the reason of ship accidents occurred in the Straitof İstanbul in 1994-2019 is given in Table 3.

Table 3. Frequency of ship accidents by reasons

Reason of Accident	Freq.	Percent (%)	Cumulative Percent (%)
Unknown	177	33.7	33.7
Human error	157	29.8	63.5
Traffic density	8	1.5	65.0
Bad whether condition/current	53	10.1	75.1
Fire	5	1.0	76.0
Contact fishing nets	34	6.5	82.5
Breakdown	68	12.9	95.4
Others	24	4.6	100.0
Total	526	100.0	

The main reason of accidents is human error (29.8%) and respectively breakdown (12.9%), bad wheather conditions and current (10.1%), contact fishing nets (6.5%) and traffic density (1.5%) in 1994-2019 as given in Table 3.

4.1.4. Frequency of the ship types involved in the accident

The cargo ships were mostly involved in the accident (49.8%) and respectively marine vehicles (20%), passenger ships and boats (18.8%) and tankers (9.3%) in 1994-2019 as shown in Figure 2.

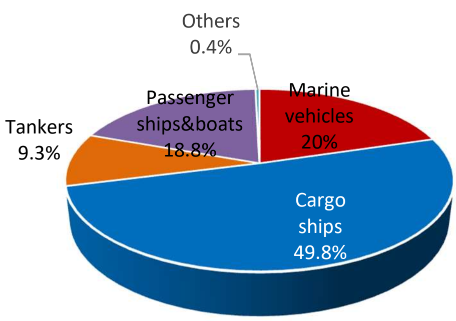

Figure.2. The frequency of the ship types involved in the accident in the Strait of İstanbul in 1994-2019.

4.1.5. Frequency of marine accidents by accident hours

The most accident were occured in the hours 20:00-24:00 (19.4%) and respectively 08:00-12:00 (15.8%), 12:00-16:00 (15.6%), 16:00-20:00 ((15.6%), 24:00-04:00 (15.4%), and 04:00-08:00 (12.4%) in the Strait of İstanbul in 1994-2019 as shown in Figure 3.

4.1.6. Frequency of ships with/without a pilot involved in the accident

A total of 71.5% of the ships involved in the accident have not employed a pilot. The ratio of ships without a pilot involved in the accident was 28.55% in the Strait of İstanbul as given in Table 4.

The pilotage is a profession which is required special experience and knowledge performed onboard ships in straits, channels, bays, harbors and other narrow. The engagement of a pilot is very important for navigation safety and reducing human error.

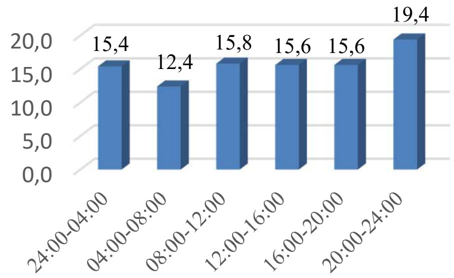

Figure 3. The frequency of marine accidents by accident hours in the Strait of İstanbul in 1994-2019.

Table 4. Frequency of ships with/without a pilot involved in the accident

The ships with/ without a pilot	Freq	Percent (%)	Cumulative Percent. (%)
The ships without a pilot	407	71.5	71.5
The ships with a pilot	162	28.5	100.0
Total	569	100.0	

4.2. The Chi Square (X^2) and Cramer's V Tests

In the study, Chi Square (χ^2) Test and Cramer's V Test were used to define a statistically significant relationship between observed and expected frequencies after implementation of "Maritime Traffic Regulations for the Turkish Straits" in 1994-2019. The Chi Square Test can be safely used when all individual expected counts are 1 or greater and no more than 20% of the expected counts are less than 5 and (Yates, *et all*, 1999). The Chi square (χ^2) Test formula is given as follows:

$$\chi^2 = \sum_{i=1}^{k} \frac{(Observedvalue - Expectedvalue)^2}{Expectedvalue} \quad (1)$$

Cramer's V Test which dispreads between 0 and 1 determines the relationship between nominal variables for strength test for the Chi-square (www.harding.edu). The formula for the Cramer's Vtest statistic is given as Equation (2) (McHugh, 2013).

4.2.1. Chi Square Test between accident type and accident year

The most of the accidents were collision in the period 1994-1998 (38.9%), in 1998-2003 (36.7%) and in 2004-2019 (71.7%) and respectively stranding/contact (25.2%) in 1994-1998, grounding (26.5%) in 1998-2003 and stranding/contact (13.1%) in 2004-2019 as given in Table 5.

Table 5. The crosstabulation between the accident type and accident year

Accident type/ Accident year	Count % within accident type	1994-1998	1999-2003	2004-2019	Total
Unknown	Count	5	2	0	8
	% within accident year	1.9%	4.1%	0.0%	1.5%
Collision	Count	102	18	71	240
	% within accident year	38.9%	36.7%	71.7%	45.6%
Grounding	Count	62	13	8	92
	% within accident year	23.7%	26.5%	8.1%	17.5%
Breakdown	Count	14	3	3	38
	% within accident year	5.3%	6.1%	3.0%	7.2%
Stranding/	Count	66	10	13	121
	% within accident year	25.2%	20.4%	13.1%	23.0%
Others	Count	13	3	4	27
	% within accident year	5.0%	6.1%	4.0%	5.1%
Total	Count	262	49	99	526
	% within accident year	100.0%	100.0%	100.0%	100.0%

Null hypotesis (H_0): There is not a statistically significant relationship between accident type and accident year and Alternatif hypotesis (H_1): There is a statistically significant relationship between accident type and accident year. The Pearson Chi Square value (χ^2) is 42.548 and minimum expected count (min. exp. count) is 1.84 and 16.7% of exp. counts are less than 5 as given in Table 6. Thus, Chi Square Test can be used to test correlated data.

Table 6. Chi-Square Test between accident type and accident year

	Value	df	Asymp. Sig. (2-sided)
χ^2	42.548[a]	10	0.000
Likelihood Ratio (LR)	44.675	10	0.000
Linear-by-Linear Relationship (LLA)	15.010	1	0.000
Cramer's V (Approx. Sig.)	0.201		0.000
Number of Valid Cases	526		

a 3 cells (16.7%) have exp. count less than 5. The min. exp. count is 1.84.

Likelihood Ratio (LR) Test is an alternative procedure to test the hypothesis of no relationship of columns and rows in nominal-level tabular data (Bal, et all, 2009). χ^2= 42.548, LR value is 44.675. P value (0.0000 < α= 0.0005.

Thus, the null hypothesis (H_0) is rejected, alternatif hypothesis (H_1) is accepted. It is concluded that there is a statistically significant relationship between accident type and accident year. Cramer's V value (20.1%) confirms that there is a moderate relationship between accident type and accident year.

4.2.2. Chi Square Test between accident type and ship type involved in the accident

The cargo ships were those most involved in collision (38.9%) and respectively stranding/contact (32.1%) and grounding (23.7%). Tanker&liquid hips were also those most involved in collision (36.7%) and respectively stranding/contact (28.6%) and grounding (26.5%). Passenger shişps&boats were those most involved in collision (71.7)% and respectively stranding/contact (20.2%) and grounding (8.1%) as shown in Table 7.

H_0: There is not a statistically significant relationship between accident type and the ship types involved in the accident, H_1 There is a statistically significant relationship between accident type and the ship type involved in the accident.

χ^2= 80.829 and min. exp. count is not more than 1 (0.33) and 36.7% of exp. counts are less than 5 as shown in Table 8. Thus, Chi Square Test can not be used to test correlated data.

4.2.3. Chi Square Test between accident type and reason of accident

All types of accidents are mostly caused by human error in The Strait of İstanbul in 1994-2019. The main reason of the collision is human error (54.7%) and respevctively most of the stranding/contact due to human error (22.6%), most of the grounding due to human error (17.6%) as given in Table 9.

H_0: There is not a statistical relationship between accident type and the reason of accident, H_1: There is a statistical relationship between accident type and reason of accident.

Table 7. The Crosstabulation between accident type and ship type involved in the accident

Accident type/ Ship type	Count % within ship type	Unknown	Cargo ships	Tanker&liquid bulk ships	Passenger ships&boats	Others	Total
Unknown	Count	0	5	2	0	1	8
	% within ship type	0.0%	1.9%	4.1%	0.0%	1.1%	1.5%
Collision	Count	12	102	18	71	37	240
	% within ship type	54.5%	38.9%	36.7%	71.7%	39.4%	45.6%
Grounding	Count	1	62	13	8	8	92
	% within ship type	4.5%	23.7%	26.5%	8.1%	8.5%	17.5%
Breakdown	Count	6	1	1	0	0	8
	% within ship type	27.3%	0.4%	2.0%	0.0%	0.0%	1.5%
Stranding/	Count	3	84	14	20	44	165
	% within ship type	13.6%	32.1%	28.6%	20.2%	46.8%	31.4%
Others	Count	0	8	1	0	4	13
	% within ship type	0.0%	3.1%	2.0%	0.0%	4.3%	2.5%
Total	Count	22	262	49	99	94	526
	% within ship type	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 8. Chi-Square Test between accident type and reason of accident

	Value	df	Asymp. Sig. (2-sided)
χ^2	80.829[a]	20	0.000
LR	76.091	20	0.000
LLA	0.014	1	0.904
Cramer's V (Approx. Sig.)	0.196		0.000
Num. of Val. Cases	526		

a. 11 cells (36,7%) have exp.count less than 5. The min. exp.count is 0,33.

Table 9. Crosstabulation between accident type and reason of accident

Accident type/ Reason of accident	Count	Unknown	Human Error	Others	Total
Unknown	Count	4	3	1	8
	% within reason of accident	2.4%	1.9%	0.5%	1.5%
Collision	Count	86	87	67	240
	% within reason of accident	51.2%	54.7%	33.7%	45.6%
Grounding	Count	19	28	45	92
	% within reason of accident	11.3%	17.6%	22.6%	17.5%
Breakdown	Count	1	5	2	8
	% within reason of accident	0.6%	3.1%	1.0%	1.5%
Stranding/	Count	53	36	76	165
Contact	% within reason of accident	31.5%	22.6%	38.2%	31.4%
Others	Count	5	0	8	13
	% within reason of accident	3.0%	0.0%	4.0%	2.5%
Total	Count	168	159	199	526
	% within reason of accident	100.0%	100.0%	100.0%	100.0%

Min. exp. count is 2.42, but 50.0% of exp. counts are less than 5 as shown in Table 10. Thus, the Chi Square Test can not be used to test correlated data.

Table 10. Chi-Square Test between accident type and reason of accident

	Value	df	Asymp. Sig. (2-sided)
χ^2	59.404[a]	10	0.000
LR	58.294	10	0.000
LLA	14.380	1	0.000
Cramer's V (Approx. Sig.)	.238		0.000
Num. of Val. Cases	526		

a. 9 cells (50,0%) have min. exp. count less than 5. The min. exp. count is 2,42.

4.2.4. *Chi Square Test* between the accident type and whether the ship involved in the accident had a pilot

The ships without a pilot were those most involved in collision (52.3%) and respectively stranding/contact (20.1%), grounding (14.1%) and breakdown (%7,9) as shown in Table 11.

Table 11. Cross-Tab between the accident type and whether the ship involved in the accident had a pilot

Accident type	Count/ % with/without a pilot	The ships without employed a pilot	The ships with employed a pilot	Total
Unknown	Count/	5	3	8
	% with/without a pilot	1.4%	1.9%	1.5%
Collision	Count/	193	47	240
	% with/without a pilot	52.3%	29.9%	45.6%
Grounding	Count/	52	40	92
	% with/without a pilot	14.1%	25.5%	17.5%
Breakdown	Count/	29	9	38
	% with/without a pilot	7.9%	5.7%	7.2%
Stranding/Contact	Count/	74	47	121
	% with/without a pilot	20.1%	29.9%	23.0%
Others	Count/	16	11	27
	% with/without a pilot	4.3%	7.0%	5.1%
Total	Count/	369	157	526
	% with/without a pilot	100.0%	100.0%	100.0%

H_0: There is not a statistical relationship between the accident type and whether the ship involved in the accident had a pilot, H_1: There is a statistical relationship between the accident type and whether the ship involved in the accident had a pilot.

Table 12. Chi-Square Test between the accident type and whether the ship involved in the accident had a pilot

	Value	df	Asymp. Sig. (2-sided)
χ^2	27.358[a]	5	0.000
LR	27.551	5	0.000
LLA	12.520	1	0.000
Cramer's V (Approx. Sig.)	0.228		0.000
Num. of Val. Cases	526	526	

a 1 cells (8.3%) have exp. count less than 5. The min.exp. count is 2.39.

As given in Table 12, 8.3% of of exp. counts are less than 5 and min. exp. count is 2.39 and χ^2=27,358. The test result indicated that since the P-value (0.0000)<0.05). Thus, H_0 is rejected and H_1) is accepted. There is a statistically significant relationship between the accident type and whether the ship involved in the accident had a pilot. Cramer's V value (22.8%) confirms that there is a moderate relationship between the accident type and whether the ship involved in the accident had a pilot.

4.2.5. Chi Square Test between ship type involved in the accident and whether to take a pilot or not

The cargo ships involved in accident without a pilot were those most involved in accident (40.7%) and respectively passenger ships and boats (24.7%) as shown in Table 13.

Table 13. Cross-Tab between ship type involved in the accident and whether to take a pilot or not

Ship type/ the ships with/without a pilot	Count % with/without a pilot	The ships without a pilot	The ships with a pilot	Total
Unknown	Count	17	5	22
	% with/without a pilot	4,6%	3,2%	4,2%
Cargo ships	Count	150	112	262
(Dry bulk, general cargo Ro-Ro, reefer)	% with/without a pilot	40,7%	71,3%	49,8%
Tanker&liquid bulk	Count	31	18	49
	% with/without a pilot	8,4%	11,5%	9,3%
Passenger ships and boats	Count	91	8	99
	% with/without a pilot	24,7%	5,1%	18,8%
Others	Count	80	14	94
	% with/without a pilot	21,7%	8,9%	17,9%
Total	Count	369	157	526
	% with/without a pilot	100,0%	100,0%	100,0%

H_0: There is not a statistical relationship between ship type involved in the accident and whether to take a pilot or not. H_1: There is a statistical relationship between ship type involved in the accident and whether to take a pilot or not.

Table 14. Chi-Square Test between ship type involved in the accident and whether to take a pilot or not

	Value	df	Asymp. Sig. (2-sided)
χ^2	54.906[a]	4	0.000
LR	60.862	4	0.000
LLA	37.314	1	0.000
Cramer's V (Approx. Sig.)	0.323		0.000
Num. of Val. Cases	526	526	

a. 0 cells (0.0%) have exp. count less than 5. The min.exp. count is 6.57.

0% of exp. counts are less than 5 and min. exp. counts are 6.57 and χ^2=54.906. P-value (0.0000)< 0.05 as given in Table 14, Thus, H_0 is rejected and H_1 is accepted. There is a statistically significant relationship between ship type involved in the accident and whether to take a pilot or not. Cramer's V value (32.3%) confirms that there is a moderate relationship between ship type involved in the accident and whether to take a pilot or not.

5. CONCLUSION

The Strait of İstanbul is one of the most risky and narrow waterways in the World due to geographical features, navigational constraints and meteorological factors. In the study, accident analysis has been performed for the accidents occured in The Strait of İstanbul using frequency distribution, Chi Square Test and Cramer's V Test in 1994-2019. The study findings are given below;

Total of 27.6% of the accidents that occured in Strait of İstanbul were occured during "right-side up" scheme and Maritime Traffic Regulations for the Turkish Straits and the Marmara Region implemented in 1994-1998, 23.0% of the accidents that occurred were occurred during the period in Maritıme Traffic Regulatıons for The Turkısh Straits implemented in 1998-2003, 49.4% of the accidents were occurred after implementation of TSVTS in 2004-2019. A Total of 45.6% of the accidents that occured in Strait of İstanbul were collision and respectively grounding (17.5%), contact (9.5%), fire/ explosion (6.3%), breakdown (5.1%), stranding (3.8%), foundering/capsizing (3.4%), others (7.2%). The cargo ships were the most involved in the accident (49.8%) and respectively marine vehicles (20%), passenger ships and boats (18.8%) and tankers (9.3%) in 1994-2019. The most accident were occured in the hours 20:00-24:00 (19.4%) and respectively 08:00-12:00 (15.8%), 12:00-16:00 (15.6%), 16:00-20:00 ((15.6%), 24:00-04:00 (15.4%), and 04:00-08:00 (12.4%) in 1994-2019. The ships without a pilot is the most involved in the accident (71.5) in the Strait of İstanbul. The ratio of human error for ships without a pilot involved in the accident is 28.5%.

The most of the accidents were collision in the period 1994-1998 (38.9%), in 1998-2003 (36.7%) and in 2004-2019 (71.7%) and respectively stranding/contact (25.2%) in 1994-1998, grounding (26.5%) in 1998-2003 and stranding/contact (13.1%) in 2004-2019. Cargo ships were those most involved in collision (38.9%) and respectively stranding/contact (23.7%). Tanker&liquid ships were also those most involved in collision (36.7%) and respectively grounding (26.5%). Passenger shişps&boats were those most involved in collision (71.7)% and respectively stranding/contact (20.2%). The main reason of all type of accidents is human error such as collision (54.7%), stranding/contact (22.6%), grounding (17.6%) in The Strait of İstanbul in 1994-2019. All types of accidents are mostly caused by human error. The ships without a pilot were those most involved in collision (52.3%) and respectively grounding (14.1%) and breakdown (7,9%).

There is a statistically significant relationship between accident type and accident year; between accident type and the ship types involved in the accident; between the accident type and whether the ship involved in the accident had a pilot; relationship between the ship type involved in the accident and whether to take a pilot or not in the Strait of İstanbul in1994-2019. The comprehensive risk and accident analysis studies can be conducted by utilizing the findings of the study.

The accidents occurred in the Strait of İstanbul pose a serious risk interms of human life, and property, navigation and environment and cause oil spill. The ships without a pilot were the most involved in the accident occurred in the Strait. The ships passing through Turkish Straits are strongly recommended to take a pilot as per the IMO Resolution A.827 (19). The recommendations to provide safety of human life, and property, navigation and environment in the Strait of İstanbul are: the establishment of The Emergency Response Centre, encouragement of taking a pilot, defining the accident black points for the risky regions, establishment of the naval fire brigade, the establishment of 3D-three dimensional vessel tracking system to enhance situational awareness both from ashore and onboard perspectives, especially during pilotage operations.

REFERENCES

Akten, N. (2003). "The Strait of İstanbul (Strait of İstanbul): The seaway separating the continents with its dense shipping traffic.", *Turkish Journal of Marine Sciences*, Vol. 9, No. 3, pp. 241.

Akten, N. (2006), "Shipping accidents: a serious threat for marine environment". *J. Black Sea/Mediterranean Environment,* Vol. 12, pp. 297.

Altan, Y.C. and Otay, E.N. (2017). "Mapping of Ship Collision Probability using AIS data"*, in International Workshop on Nautical Traffic Models_ International Maritime Association of the Mediterranean 2017 proceedings of the international conference* in Lisbon.

Altan, Y.C. and Otay, E.N. (2017). Maritime traffic analysis of the Strait of Istanbul based on AIS data. *J. Navig*. Vol. 70, N0.6, pp. 1367–1382.

Aslan, M. and Otay, E.N. (2021). "Exchange of water and contaminants between the Strait of Istanbul and the Golden Horn". *Ocean Engineering*, Vol. 230, pp.108983.

Bal, C., Er, F. and Sönmez, H. (2009). "A Review of Statistical Techniques for 2x2 and RxC Categorical Data Tables in SPSS". *Journal of Pediatric Sciences*, pp.3.

Başar, E., Köse, E. and Güneroğlu, A. (2006). "Finding risky areas for oil spillage after tanker accidents at İstanbul Strait". *International Journal of Environment and Pollution,* Vol.27, No.4, pp.388.

Başkent University Centre for Strategic Resarch (BASKENT-SAM) (2021). *Montreaux Convention*. http://sam.baskent.edu.tr/belge/Montreux_ENG.pdf. [Accessed 08 Feb 2021].

Bayar, N., Ozum, S. and Yılmaz, H. (2008). Analysis of Accidents in İstanbul Strait. *The 16th Conference of the International Maritime Lecturers' Association,* IMLA, İzmir, Turkey, pp. 397-398.

Biochemia Medica (2013). "The Chi Square Independence Test", *The journal of Croatian Society of Medical Biochemistry and Laboratory Medicine*, http://www.biochemia-medica.com/2013/23/143, [Accessed 09 February 2021].

Bucak, U., Arslan T., Demirel, H and Balın, A. (2021). Analysis of Strategies to Reduce Air Pollution from Vessels: A Case for the Strait of Istanbul. *Journal of ETA Maritime Science (JEMS),* Vol.9, No.1, pp.23.

Directorate General of Coastal Safety (KEGM) (2021)," Vessel Traffic and Pilotage Services", https://www.kiyiemniyeti.gov.tr/vessel_traffic_and_pilotage_services, [Accessed 22 February 021].

Ece, N.J. (2012). "Analysis Of Ship Accidents in The Strait of İstanbul". *Dokuz Eylül Üniversitesi Denizcilik Fakültesi Dergisi,* Vol.4, No.2, pp.1,6.

Erol, S., Demir, M., Bayram Çetişli,B. and Eyüboglu, E. (2017). "Analysis of Ship Accidents in the İstanbul Strait Using Neuro-Fuzzy and Genetically Optimised Fuzzy Classifiers". *The Journal of Navigation,* Vol.71, No.2, pp. 1-3.

Görçün, Ö.F. and Burak, S. Z. (2015), "Formal Safety Assessment for Ship Traffic in the Istanbul Straits". *Procedia - Social and Behavioral Sciences,* Vol..207, pp.260.

Habertürk (2019). Boğazı'nda tekne yangını https://www.haberturk.com/son-dakika-istanbul-bogazi-nda-tekne-yangini-2506216 [Accessed 18 February 2021].

Harding University, Nominal Measures Of Correlation: Phi, The Contingency Coefficient And Cramer's V, http://www.harding.edu/sbreezeel/460%20files/statbook/chapter15.pdf. [Accessed 26 March 2021].

Independent Türkçe (2019). "İstanbul Boğazı'nda karaya oturan gemi kurtarıldı", https://www.indyturk.com/node/109666/haber/istanbul-bo%C4%9Faz%C4%B1%E2%80%99nda-karaya-oturan-gemi-kurtar%C4%B1ld%C4%B1, [Accessed 06 March 2021].

International Maritime Organization (IMO) (2021). Vessel Traffic Services, https://www.imo.org/en/OurWork/Safety/Pages/VesselTrafficServices.aspx, [Accessed 21 May 2021].

İnan, Y. (2001). "The Current Regime of The Turkısh Straits", *Journal of Internatiıonal Affairs,* Vol.6, No. 1, pp.3, http://repository.bilkent.edu.tr/bitstream/handle/11693/51482/The_Turkish_straits.pdf?sequence=3 [Accessed 22 February 2021].

Koldemir, B. (2009). "Seyir Güvenliği Açısından İstanbul Boğazı'nda Riskli Bölgelerin Belirlenmesi; Kaza Kara Noktalarının Güncellenmesi", *Dokuz Eylül Üniversitesi Denizcilik Dergisi*, Vol. No. 1, pp.25.

Korçak, M. and Balas, C. (2020). Reducing the probability for the collision of ships by changing the passage schedule in İstanbul Strait. *The International Journal of Disaster Risk Reduction (IJDRR)*, Vol.48, pp. 101593.

Köse, E., Başar E., Demirci, E., Güneroğlu, A. and Erkebay, Ş. (2003). "Simulation of maritime traffic in İstanbul Strait". *Simulation Modelling Practice and Theory,* Vol. 11, pp. 606.

McHugh, M.L. (2013). "The Chi-square test of independence", *Biochemia Medica*, Vol. 23, No.2, pp.143

Otay, E.N. and Tan, B. (1998). Stochastic Modeling of Tanker Traffic through Narrow Waterways, *Proc. 1st International Conference on Oil Spills in the Mediterranean and Black Sea Regions,* İstanbul,Turkey*,* pp. 85.

Özdemir, U. and Güneroğlu (2015). "A. Strategic Approach Model for Investigating the Cause of Maritime Accidents", *Promet-Traffic & Transportation Research*, Vol.27, No.2, pp.115, 121-122.

Tenker, S. (2020). "İstanbul Boğazı'ndaki kazalar ve Kanal İstanbul" *Denizcilik Dergisi*, http://www.denizcilikdergisi.com/yazarlar/kapt-sedat-tenker/istanbul-bogazindaki-kazalar-ve-kanal-istanbul/ [Accessed 09 February 2021].

The Republic of Turkey Ministry of Transport and Infrastructure of (UBAK), Türk Boğazları Gemi Geçiş İstatistikleri (Maritime Traffic in the Turkish Straits), https://denizcilikistatistikleri.uab.gov.tr/turk-bogazlari-gemi-gecis-istatistikleri [Accessed 08 Feb 2021].

The Republic of Turkey Ministry of Transport and Infrastructure of (UBAK), Denizcilik İstatistikleri (Shipping Statistics), https://atlantis.udhb.gov.tr/istatistik/gemi_gecis.aspx [Accessed 06 June 2018].

The Republic of Turkey Ministry of Transport and Infrastructure of (UBAK) Main Search-Rescue Coordination Center(2019). General Directorate of Maritime Trade The Turkish Straits Vessel Traffic Statistics, http://aakkm.udhb.gov.tr, [Accessed 08 July 2016].

The Republic Of Turkey Ministry of Transport And Infrastructure Directorate General of Coastal Safety (KEGM) (2019). User's Guıde of Turkısh Straıts Vessel Traffic Servıce, https://kiyiemniyeti.gov.tr/Data/1/Files/Document/Documents/9S/6R/yY/wu/TSVTS_User_Guide_21.05.20.pdf, [Accessed 22 May 2021].

The Republic of Turkey Ministry of Transport And Infrastructure Directorate Deniz mevzuat, 1998, https://denizmevzuat.uab.gov.tr› guidelines › tur... [Accessed 20 May 2021].

Turkish Maritime Pilots Association, List of Casualties Which Occured in the Strait of İstanbul During the Period 01/07/1994 to 31/08/2000, available at:http://www.turkishpilots.org [accessed 06 February 2004].

TurkSail (2019), "İstanbul Boğazı'nda garip bir kaza", http://www.turksail.com/genel-haberler/16575-istanbul-bogaz-nda-garip-bir-kaza [Accessed 10 July 2016].

Uçan, E. and Nas, S. (2015). "Analysing Istanbul Strait Maritime Pilot Capacity by Simulation Technique", *The Journal Of Navigation*,Vol. 69, No.4, pp.816-817.

Uğurlu, Ö, Erol, S. and Başar, E. (2016). "The analysis of life safety and economic loss in marine accidents occurring in the Turkish Straits. *Maritime Policy&Management*,Vol.43, No.3, pp.367.

Uğurlu, Ö., Kaptan, M., Kum S. and Yıldız, S. (2017). "Pilotage services in Turkey; key issues and ideal pilotage". *Journal of Marine Engineering & Technology,*Vol.16, No.2, pp. 51.

Ulusçu, Ö. S., Özbaş, B., Altıok, T. and Or, İ. (2009). "Risk Analysis of the Vessel Traffic in the Strait of İstanbul", *Risk Analysis*, Vol. 29, No.10, pp.1454.

United Nations Law of the Sea (National legislation), https://www.un.org/Depts/los/LEGISLATIONANDTREATIES/PDFFILES/TUR_1994_Regulations.pdf, [Accessed 22 May 2021].

Yates, D., Moore, Moore, D. and McCabe, G. (1999). *The Practice of Statistics (1st Ed.),* W.H. Freeman, New York:, USA, pp. 734.

Yurtören, C. (2004). A Study on Maritime Traffic Management in the Strait of İstanbul., PhD Thesis. Kobe University, Maritime & Transportation System Science, Kobe, Japan.