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Research Article

ANALYSIS OF MARINE ACCIDENTS IN THE STRAIT OF İSTANBUL USING QUALITATIVE&QUANTATIVE METHODS

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ABSTRACT
The Turkish Straits are one of the most hazardous and crowded waterways in the world. This study has been performed to analyze the accidents occurred in The Strait of İstanbul by using the statistical methods such as frequency distribution, Chi Square Test and Cramer's V for the "right-side up" scheme period 1982-2018 and regression analysis, t and F tests for significance of regression model and Durbin Watson Test to test autocorrelation in residuals between the years 1982 and 2003. In the study, traffic of the Strait of İstanbul and literature have been reviewed and literature review has been conducted. The results of the analysis 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 and main reason of accidents is human error in the Strait of İstanbul. There is a moderate level of statistical relationship between the type of ship involved in the accident and type of the accident; the independent variables given in the regression model increase estimated accident rate in the Strait of İstanbul. High value R-squared value (R2=0.997) indicates that the model fits the data well by the independent variables. At the conclusion of the study further suggestions are proposed to provide safety of environment and navigation and the Strait of İstanbul.

Keywords: *The Strait of İstanbul, Marine Accidents, Accident Analysis, Collision, Maritime Pilot.*

1. INTRODUCTION

Turkish Straits which links the Black Sea and the Mediterranean Sea is one of the most congested, narrow and risky waterways in the world from the point of view geographical conditions, navigational constraints such as deep, narrowness, currents, etc. and bad weather conditions contributes to marine accidents in the Strait(Ece, 2012; Başar, 2003). Turkish Straits has a vital importance from the point of jeo-politic, jeo-strategic and commercially. The Strait of İstanbul has massively rich in historical and cultural heritage and serves as a biological corridor (Ece, 2012).

Increasing tonnage and number of ships increase the accident risk and pose a risk from the point of human life and environment (Ece, 2012). It is expected to increase the marine traffic in the Straits (Ece. 2008).

The purpose of the study is to analyze the accidents occurred in The Strait of İstanbul for the period 1982-2018 and between the years 1982 and 2003. The paper is organized as follows: The second section consists of literature review, the third section is a review of maritime regime and traffic in the Strait of İstanbul. The fourth section performs material and methods involving data collection and statistical methods such as frequency distribution, Chi Square and Cramer's V Tests for the period 1982-2018, regression analysis, t and F Tests for significance of regression model and Durbin Watson Statistic to test autocorrelation in residuals between the years 1982 and 2003. At the conclusion of the study further suggestions are proposed to provide safety of environment and navigation in the Strait of İstanbul.

2. LITERATURE REVIEW

Köse, Başar, Demirci, Güneroğlu ve Erkebay (2003) developed the model which searches the traffic to simulate the traffic within the The Strait of İstanbul. One of the result of the study shows that the most type of accident are grounding and collision in the Strait of İstanbul. The majority of marine accidents is collision occurred in The Strait of İstanbul in 1953–2002 (Akten, 2006). Ulusçu and et al (2009) have analyzed safety risks for transit ship traffic in the Strait of İstanbul. The results of finding of the study are pilotage and traffic density in the Strait of İstanbul. Yazıcı and Otay (2009) improved a simulation model for unique traffic conditions. The results of the study; the Traffic Separation Schemes restrictions increase grounding risk and navigation difficulty in the Strait of İstanbul.

Uğurlu et al. (2015) have analyzed serious marine accidents in the Turkish Straits in 2001-2010. The finding of the study, human error is main reason of marine accidents in the Turkish Straits. The most of the accidents are occurred due to human error which involves fatigue, lack of adequate experience and knowledge, proper attention, technical etc. (Akten, 2006). Koldemir (2009) has defined the risky regions in the Strait of İstanbul by using accident black points method. One of the results of the study, the region located in Ortaköy - Beylerbeyi and Ahırkapı Feneri – İnciburnu Feneri is the most risky region. Birpınar et al (2009) have examined oceanographic and geographic features and explanes the Strait of İstanbul has faced many casualties and serious environmental problems. Uçan ve Nas (2015) analysed the Marine Pilotage Service to find the required number of marine pilots for ship traffic flow in the Strait of İstanbul by using Rockwell Arena Simulation Software. The findings of the analysis show that discrete simulation technique is efficient and reliable way of solving complex techno-nautical service allocation problems.

Görçüna and Selmin (2016) analyzed the risks concerning marine traffic in the İstanbul Strait between the years 2001 and 2010. The result of the analysis shows that are personnel, weather conditions and machines etc. are the main reasons of accidents (Ece, 2012). Yılmaz and Önaçan (2019) has been carried out a SWOT analysis regarding the developments in autonomous ship technology and its effects on the Turkish maritime and shipbuilding sector. One of the result of findings as follows; the that the risk of marine incident caused by human factors will be minimized for a fully autonomous ship but taking into account new kind of risks such as cyber-attacks, software errors and local aspects of strait passages etc. in addition to that MSC.1/Circ.1604 on interim guidelines for autonomous ship trials was adopted by IMO, additional safety and security measures regarding the passage of autonomous ships through the Turkish Straits should be considered (Yılmaz and Önaçan, 2019:57-86).

3. MARINE TRAFFIC IN THE STRAIT OF İSTANBUL

The number of ships is 41.103 and total tanker traffic is 8.587 passed through the Strait of İstanbul in 2018. The rate of maritime pilot employed is 57% in 2018 (ubak, 2018).

Table 1.Marine Traffic in The Strait of İstanbul

Years	Total Traffic	Total Tanker Traffic	Ratio of Ships Proceeding a pilot (%)
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

Resource: Undersecretariat for Maritime Affairs, 2010; Ministry of Transport and Infrastructure of The Republic of Turkey (UBAK), The Turkish Straits Vessel Traffic Statistics, 2019.

According to the Montreux Convention "pilotage and towage" remain optional (Article 2) (Akten, N). The maritime traffic regulations for The Turkish Straits have been implemented and the new schemes have been in use since 01 July 1994. The regulations were revised and adapted in 1998. "The System of Turkish Strait Vessel Traffic Services (TSVTS)" was installed at 31 December 2003 to provide safety of navigation and environment (Akten, N., 2003; www.kiyiemniyeti.gov.tr, 2019).

4. MATERIAL AND METHODS

4.1. Data Collection

The accident historical data for the Strait of İstanbul contains 857 accident records involving ship name, year, hour, type and accident reason, type of ship involved in the accident during "right-side up" scheme period 1982 and 2018. The ships and marine vehicles have been reported in the accident reports such as container, general cargo, tanker, dry bulk, fishing ships, tugboat, fishing ships, Ro-Ro, passenger ships, yacht, boat and others. The accident data for the Strait of İstanbul has been acquired from the Undersecretariat for Maritime Affairs (Undersecretariat for Maritime Affairs, 2003); Ministry of Transport and Infrastructure of The Republic of Turkey Main Search-Rescue Coordination Center (aakkm.udhb.gov.tr); Turkish Pilots (ww.turkishpilots.org, 2004; http://www.turkishpilots), PhD thesis and LLyod's Maritime Information Service's traffic and the articles (Kornhauster and Clark, 1995) (Baş, M., 1999) related to the accidents in the Strait of İstanbul. The Meteorological data has been acquired from General Directorate Of Meteorology (General Directorate Of Meteorology, 2004). The current data has been gathered from Republic Of Turkey Turkish Naval Forces Office Of Navigation, Hydrography And Oceanography concerning the Strait of İstanbul; Republic Of Turkey Turkish Naval Forces Office Of Navigation, Hydrography and Oceanography, 2004).

4.2. Methods

The statistical analysis has been used to analyse the accidents occured in Strait of İstanbul during "right-side up" scheme period 1982-2018 and before installing TSVTS 1982-2003 by using SPSS 17.00 and EVIEWS 5.0. The parametric data which is 4,285 contains year, hour, type, type of ship, reason of accident and marine vehicles (ship) involved in the accident. have been proceed in the analysis. The following methods such as Frequency Distribution, the crosstabulations, Chi Square Test (χ^2), Cramer's V, regression analysis have been used to analyse the accidents occurred in the Strait of İstanbul.

4.2.1. Frequecy distribution

The Descriptive Statistics such as Frequency Distribution has been used for summarizing categorical variables. The frequency distribution of the marine accidents by type of accident, type of ships involved in the accident, hours of accident and reason of accident in the Strait of İstanbul have been given the following tables.

a) Frequency distribution of marine accidents by type of accident

A Total of 44.5% of the accidents occured in Strait of İstanbul were collision (44.5%) and respectively grounding/stranding (19.3%), contact (15.6%), fire/ explosion (7.2%), breakdown (4.0%) and foundering/capsizing (2.9%) in 1982-2018 as shown in Table 2 (Ece, 2019)

Table 2. The Marine Accidents By Type of Accident

Type of Accident	Frequency	Percentage (%)	Percentage of Total Cumulative (%)
Unknown	18	2,1	2,1
Collision	381	44,5	46,6
Grounding/ Stranding	165	19,3	65,8
Fire/Explosion	62	7,2	73,0
Contact	134	15,6	88,7
Foundering/ Capsizing	25	2,9	91,6
Breakdown	34	4,0	95,6
Others	38	4,4	100,0
Total	857	100,0	

A Total of 45.6% of the accidents occurred in Strait of İstanbul were collision and respectively grounding/stranding (20.4%), contact (16.2%), fire/ explosion (7.9%), and foundering/capsizing (2.3%) in 1982-2003. The map of types of accident occurred in The Strait of İstanbul in 1928-2003 is given in Figure 1 (Ece, 2005; Ece, 2019)

Collision caused by human errors is the most occurred accident type. The main cause of the accidents is human error.

b) The frequency distribution type of ships involved ın the accident

The cargo ships (dry bulk, general cargo refeer, container, Ro-Ro were the most involved in the accident (44.9%) and respectively passenger ships and boats (passenger ship&boat,sea bus, ferryboat etc.) (17.7%), marine vehicles (boat, yatch, tugboat, research ship, others) (15.8%) and tankers (9.9%) in 1982-2018 as shown in Table 3.

Table 3.The Type of Ships Involved In The Accident

Types of ships Involved In The Accident	Frequency	Percentage (%)	Percentage of Total Cumulative (%)
Unknown	99	11.6	11.6
Boat,yatch,tugboat,research ship,others	135	15.8	27.3
General cargo,	385	44.9	72.2
Tanker,Liquid bulk	85	9,9	82,1
Passenger ship&boat ferryboat etc.	152	17.7	99.9
Others	1	.1	100.0
Total	857	100.0	

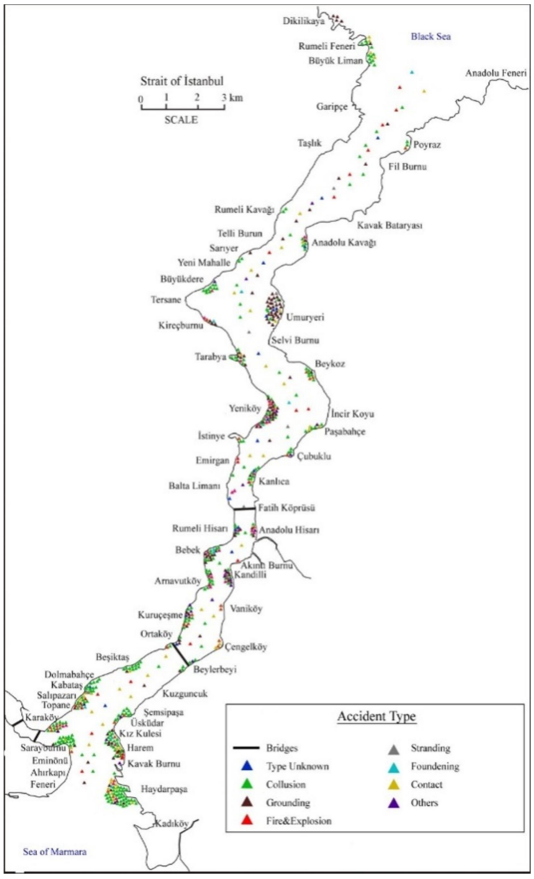

Figure 1. Map of Types of Accident Occurred in The Strait of İstanbul in 1928-2003
Resource: (Ece, 2015)

c) The Frequency Distribution of Marine AccidentsBy Accident Hours

The most accident were occured in the hours 20:00-24:00 (15.2%) and respectively 08:00-12:00 (13.9),12:00-16:00 (12.8%), 24:00-04:00 (12.3%), 16:00-20:00 (11.8%) and 04:00-08:00 (11.7%) in 1982-2018 as shown in Table 4 (Ece, 2019)

Table 4.Marine Accidents By Accident Hours

Accident Hours	Frequency	Percentage (%)	Percentage of Total Cumulative (%)
Unknown	192	22.4	22.4
24:00-04:00	105	12.3	34.7
04:00-08:00	100	11.7	46.3
08:00-12:00	119	13.9	60.2
12:00-16:00	110	12.8	73.0
16:00-20:00	101	11.8	84.8
20:00-24:00	130	15.2	100.0
Total	857	100.0	

d) Frequency Distribution of Marine Accidents By Reason of Accident

Human error is the major cause of accidents (25.4%), respectively bad wheather conditions and current (12.0%), breakdown (7.8%), contact fishing nets (7.6%) and traffic density (2.6%) in 1982-2018 as shown in Table 5.

Human error is the main reason of the accident (Ece, 2012; Ece, 2019).

Table 5.Frequency Distribution Of Ship Accidents By Reasons

Reason of Accident	Frequency	Percentage (%)	Total Cumulative (%)
Unknown	341	39.8	39.8
Human error	218	25.4	65.2
Traffic density	22	2.6	67.8
Bad whether conditions and Cur	103	12.0	79.8
Fire	18	2.1	81.9
Contact fishing net	65	7.6	89.5
Breakdown	67	7.8	97.3
Others	23	2.7	100.0
Total	857	100.0	

4.2.2. Chi Square Test

The Chi square (χ^2) Test has been used to analyze the relationship between the non parametric variables.

The formula for the Chi Square *T*est is given as follows:

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

Hypotesis; H_0: There is not a relationship between type of the accident and the type of ships involved in the accident, H_1: There is a relationship between type of the accident and the type of ships involved in the accident. The Table 6 shows that all type of ships were involved in the most collision in 1982-2018.

Table 7.Chi-Square Test Between Type Of Accident And Type of Ships Involved In the Accident

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	138.479[a]	24	0.000
Likelihood Ratio	127.184	24	0.000
Linear-by-Linear Association	1.433	1	.231
N of Valid Cases	857		

a. 7 cells (20,0%) have expected count less than 5. The minimum expected count is 1.79.

The Chi-Square Test result indicated that The Pearson Chi -Square value is 138.479, minimum expected count is more than 1 (1.79) as shown in Table 7. The null hypothesis (H_0) has been rejected and alternative hypothesis (H_1) is accepted. There is a statistical relationship between type ofthe accident and the type of ships involved in the accident (Ece, 2019).

4.2. 3. Cramer's V Test

Cramer's V Test has been used to describe the magnitude or association between categorical variables (nominal) between the variables.

Table 6. Cross-Tab Between Type Of The Accident And Type of Ships Involved In the Accident

Type of Accident	Count % within accident t ype	Unknown	Cargo ships	Tanker, liquid bulk	Passenger ships and boats	Others	Total
Unknown	Count	8	7	2	0	1	18
	% within accident t ype	44.4%	38.9%	11.1%	0.0%	5.6%	100.0%
Collision	Count	41	155	35	95	55	381
	% within accident type	10.8%	40.7%	9.2%	24.9%	14.4%	100.0%
Grounding/ Stranding	Count	8	99	25	14	11	165
	% within accident type	9.7%	60.0%	15.2%	8.5%	6.7%	100.0%
Fire	Count	6	20	4	16	16	62
	% within accident type	9.7%	32.3%	6.5%	25.8%	25.8%	100.0%
Contact	Count	29	66	12	19	8	134
	% within accident type	21.6%	49.3%	9.0%	14.2%	6.0%	100.0%
Breakdown	Count	3	17	3	5	6	34
	% within accident type	8.8%	50.0%	8.8%	14.7%	17.6%	100.0%
Others	Count	9	19	4	3	28	63
	% within accident type	14.3%	30.2%	6.3%	4.8%	44.4%	100.0%
Total	Count	112	383	85	152	125	857
	% within accident type	13.1%	44.7%	9.9%	17.7%	14.6%	100.0%

Table 8.Symmetric Measures Between Type Of The Accident And Type of Ships Involved In the Accident

Nominal by Nominal	Value	Approx. Sig
Phi	0.402	0.000
Cramer's V	0.201	0.000
N of Valid Cases	857	

The value of Cramer's V is 0.201 as shown in Table 8. Therefore, there is is a moderate level of statistical relationship between type of the accident and type of ships involved in the accident as shown in Table 9.

4.2.4. Regression Analysis &Unique Root Test

It is used regression analysiscovering the period 1982-2003 (N=21) for the accidents occurred in The Strait of İstanbul by using EVIEWS 5.0. Estimated accident rate in the Strait of İstanbul (Y) was considered as dependent variable for the linear regression model (Ece, 2005). Considered as dependent variable (Y) and potential independent variables (X_i) were given in Table 9.

Table 9. The Variables of Regression Analysis

Y = Ratio of Accidents estimated occurred in the Strait of İstanbul
X_1 = Maximum current velocity at the accident location (cm/sec/)
X_2 = Total number of days of wind blow (prevailing wind NNE)
X_3 = Average wind speed (meter/sec) (prevailing wind NNE)
X_4 = The number of average stormy days (wind speed>=17.2 m/sn.)
X_5 = The number of average strong stormy days (wind speed 10.8-17.1 meter/sec.)
X_6 = The number of average foggy days
X_7 = The number of average snowy days
X_8 = The number of average cloudy days (0-10)
X_9 = The number of average cloudyly days (bult. 8.1-10.0)
X_{10} = Average tonnage of the ships (GRT)
X_{11} = Total number of wind blow (prevailing wind SW)
X_{12} = Average wind speed (meter/sec. (SW)
X_{13} = Total number of wind blow (meter/sec.) (SSW)

It has been used The Least Squares Estimation in the study. The regression equation is given as follows (Dickey and Fuller, 1981).

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{11}X_{11+} + \beta_{12}X_{12} + \beta_{13}X_{13+}\varepsilon_i \quad (2)$$

where the values β_0. β_1. β_2. …….. .β_{13} are called the regressions coefficients.

It has been used the Augmented Dickey-Fuller (ADF) test which is unit root test to test stationarity in the data. The following equations are used for ADF Test statistics (Çekerel, 2005).

$$\Delta y_t = \mu + \gamma y_{t-1} + \sum_{J=1}^{k} \alpha_J \Delta y_{t-j} + e_t \quad (3)$$

$$\Delta y_t = \mu + \delta_t + \gamma y_{t-1} + \sum_{J=1}^{k} \alpha_J \Delta y_{t-j} + e_t \quad (4)$$

Y_t : The variableused for the ADF Test at t time, μ : Average of the series, Δy_{t-j}: Difference operator, δ_t : Trend ofLineer time and e_t : Error term.

The regression equation (2) has been estimated in the study. It is assumed that ratio of accidents estimated occurred in the Strait of İstanbul in 1982-2003 as dependent variables and other variables as independent variables as shown in Table 10(Ece, 2005).

All variables are at the level of stationary as shown in Table 10. Hence. the equation (2) has been estimated by using The Least Squares Method. The Least Squares Method was applied to the estimated accident rate (dependent variable) and independent variables such as waterway characteristics as like current velocity, ship tonnages (GRT) and meterorological conditions for the Strait of İstanbul. The resulting linear regression model has been applied for data (1982-2003) (Ece, 2005).

Table 10.The Results of Unit Root (ADF) Test

Variables	ADF	Critical value	Lag Length	Probability
Y				
X_1	-4.881	-3.832	2	0.0011
X_2	-4.617	-3.809	0	0.0018
X_3	-4.067	-3.788	0	0.0054
X_4	-5.005	-3.788	0	0.0007
X_5	-8.373	-3.809	0	0.0000
X_6	-5.102	-3.832	1	0.0007
X_7	-5.893	-3.788	0	0.0001
X_8	-4.377	-3.887	3	0.0038
X_9	-3.169	-3.788	0	0.0366
X_{10}	-3.896	-3.788	0	0.0079
X_{11}	-3.929	-3.788	0	0.0074
X_{12}	-3.437	-3.788	0	0.0211
X_{13}	-4.809	-3.832	1	0.0013

$$Y = -13.65296 + 0.004942\,X_1 - 0.002380\,X_2 - 1.763056\,X_3 - 0.387087\,X_4 - 0.585795\,X_5 + 0.016573\,X_6 + 0.014126\,X_7$$
$$(0.726335)\ (0.001679)\ (0.000351)\ (0.163392)\ (0.030382)\ (0.090135)\ (0.001893)\ (0.003796)$$

$$+ 4.736643\,X_8 - 0.003684\,X_9 + 0.360814\,X_{10} + 0.005281\,X_{11} + 0.302605\,X_{12} + 1.175667\,X_{13}$$
$$(0.314160)\ (0.001439)\ (0.045299)\ (0.002060)\ (0.127618)\ (0.078551)$$

The results of regression were reported in the Table 11.

Table 11.The Result of Regression Analysis

Variables	Coefficient	Standart Error	t-Statistics	Probability
C	-13.65296	0.726335	-18.79706	0.0000
X_1	0.004942	0.001679	2.943306	0.0216
X_2	-0.002380	0.000351	-6.779653	0.0003
X_3	-1.763056	0.163392	-10.79037	0.0000
X_4	-0.387087	0.030382	-12.74071	0.0000
X_5	-0.585795	0.090135	-6.499074	0.0003
X_6	0.016573	0.001893	8.754637	0.0001
X_7	0.014126	0.003796	3.720964	0.0074
X_8	4.736643	0.314160	15.07715	0.0000
X_9	-0.003684	0.001439	-2.560621	0.0375
X_{10}	0.360814	0.045299	7.965090	0.0001
X_{11}	0.005281	0.002060	2.563503	0.0374
X_{12}	0.302605	0.127618	2.371173	0.0495
X_{13}	1.175667	0.078551	14.96695	0.0000
R-squared	0.996891	F-statistics		172.6814
Adjusted R-squared	0.991118	Prob (F-statistic)		0.0000
Durbin-Watson (DW) stat	2.390393			

R-squared ($R^{2)}$ = 0.997 F-statistics = 172.6814
Prob (F-statistics = 0.0000)
Adjusted R-squared ($\overline{R}^2$)= 0.991
Durbin-Watson stat (DW) = 2.390393

The coeffient of determination (R^2) has been used to measure the amount of variation in the dependent variable. High value of R^2 (0.997) indicates that the model fits the data well because the amount of total variance explained by the independent variables in the model as shown in Table 11 (Ece, 2005).

As the result of the estimation; the variables which increase the ratio of accidents estimated occurred in the Strait of İstanbul (Y) are maximum current velocity at the accident place (X_1); the number of average foggy days (X_6); the number of average snowy days (X_7); the number of average cloudy days (X_8); average tonnage of the ships (X_{10}); total number of wind blow (prevailing wind SW) (X_{11}); average wind speed (SW) (X_{12})andtotal number of wind blow (SSW) (X_{13}) (Ece, 2005)

On the other hand; The variables which decrease the If DW statistic is around 2 there is no autocorrelation. According to DW statistics (2.390) there is no autocorrelation in the equation as shown in Table 11 (Ece, 2005). It means that successive values will not tend to be close to each other.

5% level and the regression equation have a higly significant F-value according to the results of the model.

Improvement of navigation aids, encouraging the use of pilots on board, diversification of navigation equipments, minimizing human errors and establishment of pipelines for transport of dangerous goods will contribute to provide safety of navigation and environmment of the Strait of İstanbul.

Ratio of accidents estimated occurred in the Strait of İstanbul (Y) are total number of days of wind blow (prevailing wind NNE) (X_2). average wind speed (prevailing wind NNE) (X_3). the number of average stormy days (X_4). the number of average strong stormy days (X_5) and the number of average cloudyly days (X_9) (Ece, 2005).

4.2.5. t Tests For Independent variables (Significance Test)

It has been used t-tests (significance test) which is a type of inferential statistic to determine if there is a significant difference between the means of two groups (Uriel, 2003). The F-test for linear regression tests whether any of the independent variables in a multiple linear regression model are significant (http://facweb.cs.depaul.edu; (Ece, 2005).

$H_0 : \beta_i = 0$ if level of significance $<\alpha = 0.05$, H_1 is accepted
$H_1 : \beta_i \neq 0$ Otherwiswe H_0 is accepted

All independent variables given in Table 11 are significant at the below 5% level .

4.2.6. Hypotheses About β's and F Test For Overall Significance Test

There are several types of hypotheses about the β's (the partial slopes or coefficients) in a multiple regression model. F statistic is a value you between two populations are significantly different by using regression analysis (Uriel, 2003; (Ece, 2005).

H_0: $\beta_1 = \beta_2 = \ldots\ldots \beta_p = 0$ if level of significance $<\alpha = 0.05$
H1 is accepted.
H_1: at least of of the $\beta_j \neq 0$ otherwise H_0 is accepted

The regression equation have a higly significant F-value according to the results of the model as shown in Table 11.

4.2.7. Durbin Watson Test

Durbin Watson Test (statistic) has been used to test for the presence of first-order autocorrelation in the residuals of the regression equation. Durbin Watson Test equation is given as follows (Johnston and Dinardo, 1997; (Ece, 2005).

$$\Delta = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t{}^2}$$

e = y - Xb (error vector)

If DW statistic is around 2 there is no autocorrelation. According to DW statistics (2.390) there is no autocorrelation in the equation as shown in Table 11 (Ece, 2005). It means that successive values will not tend to be close to each other.

5. CONCLUSION

The Strait of İstanbul is one of the most narrow, congested and risky waterways in the world from the point of view navigational constraints, geographical features and several meteorological factors. of the Strait of İstanbul. The increasing of the number of the ships and expecially tankers passing through The Strait of İstanbul have become a serious threat for human life, safety of navigation, historical and cultural heritage and environment. The Strait of İstanbul faced 857 ship accidents during the "right-side up" scheme period 1982-2018.

In the study accident analysis has been performed for the accidents occured in The Strait of İstanbul by using the statistical methods such as frequency distribution, Chi Square Test, Cramer's V Test in 1982-2018 and regression analysis, t and F tests for significance of regression model and Durbin Watson Test for testing autocorrelation in residuals from a regression analysis between the years 1982 and 2003. This paper's findings consist of the following:

The most common type of accident is collision and respectively grounding in The Strait of İstanbul; the cargo ships were the most involved in the accident and respectively passenger shipss. The most accident has been occured in the hours 20:00-24 and respectively 08:00-12:00, 12:00-16:00 and 24:00-04:00. Human error is the main reason of the accidents. There is a moderate level of statistical relationship between type of the accident and the type of ships involved ın the accident.

According to the results of regression analysis; the variables which increase estimated accident rate occurred in the Strait of İstanbul are maximum current velocity at the accident place, the number of average foggy days, the number of average snowy days, the number of average cloudy days, average tonnage of the ships, total number of wind blow, average wind speed (SW), andtotal number of wind blow (SSW). High value R-squared value (R^2=0.997) indicates that the model fits the data well because the amount of total variance explained by the independent variables in the model. According to the result of t Test, all independent variables given in the study are significant at the below 5% level and the regression equation have a higly significant F-value according to the results of the model.

Improvement of navigation aids, encouraging the use of pilots on board, diversification of navigation equipments, minimizing human errors and establishment of pipelines for transport of dangerous goods will contribute to provide safety of navigation and environmment of the Strait of İstanbul.

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Research Article

TRAINING SITUATIONAL AWARENESS AND DECISION MAKING FOR PREVENTING COLLISION AT SEA: A THEORETICAL BACKGROUND

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ABSTRACT
Maritime accidents are one of the main factors that disrupt maritime transportation. Among these accidents, collision situations, due to their frequency and consequences, possess a great threat to the safety of navigation. The majority of these accidents are directly related to the operations within the ship and human errors. In this study, we explore the importance and the training needs for situational awareness and decision making for preventing collisions at sea through a literature review. Studies suggest that seafarers on board who are responsible for keeping navigational watch can both be the causer and preventer for collisions. Recommendations of the studies in the field point to the need for specialized training to improve situational awareness and decision making. Training seafarers' expectations and goals for collision situations are proposed to achieve this improvement. Especially the usage of the training scenarios including unexpected situations to increase familiarity and readiness levels are referred frequently.

Keywords: *Situational Awareness, Decision Making, Collision at Sea, Maritime Education and Training*

1. INTRODUCTION

Navigation safety is one of the top priorities of maritime transportation. Therefore, leading organizations such as the International Maritime Organization (IMO) are constantly focusing on activities that will enhance and protect the safety of navigation. Even though the decrease in maritime accidents, with the help of new technologies, stricter rules, and evolving policies, shows us that the overall change in maritime transport is towards a more positive and proactive position, accidents continue to occur. Accidents like collision, grounding, stranding, and breakdowns involving large ships result in major losses to human lives and create economic and environmental burdens (EMSA, 2018). Since casualties are mostly related with collision incidents that occur between vessels, for this study, we mainly focus on navigation safety through the collision situations.

It is important to understand the reasons behind the accidents, especially when accidents occur where something fails, and effective preventive measures can be taken (Hollnagel, 2002). The equation to maritime accidents and navigation safety consists many factors which one of them being the human factor (Rothblum, 2000). According to European Maritime and Safety Agency, human error represents 58% of accidental events occurred within the period of 2011-2017 (EMSA, 2018). Many studies also acknowledge the human element or human error as the main driving factor in accidents (Rothblum, 2000; Pourzanjani, 2001; Darbra & Casal, 2004; Toffoli, Lefevre, Bitner-Gregersen & Monbaliu, 2005; Antao ve Soares, 2006; Hetherington, Flin & Mearns, 2006; Eliopoulou & Papanikolaou, 2007; Ziarati & Ziarati, 2007; Martins & Maturana, 2010; Chauvin Lardjane, Morel & Clostermann, 2013; Batalden & Sydnes 2014; Uğurlu, Köse & Yıldırım 2015; Yıldırım, Başar & Uğurlu, 2017). Considering these statements, the consensus in the literature is to implement various procedures to reduce human error to improve maritime safety.

Focusing on seafarers on board of ships to achieve the desired safety levels seems to be a valid method since 70% of accidental events have shipboard operations as the contributing factor (EMSA, 2018). For collision accidents the human element on board ships describes a specific workgroup known as deck officers or officers of the watch. A deck officer is a seafarer usually assigned with the duty of watchkeeping on a ship's bridge. The officer of the watch has the responsibility of safe navigation and needs to ensure that the ship complies with International Regulations for Preventing Collisions at Sea (COLREGS). They are considered the first and the last measure in preventing collisions at sea. That's why the competency of this personnel remarkably important in collision situations. As Nikitakos et al. (2017) state, there is a direct relationship between the effective, safe and environmentally sensitive functioning of maritime transport and qualified seafarers. It is evident that the continuous development of seafarer capabilities and competencies are required. Therefore, to stride towards a safer maritime system the current performance failure of the human element should be identified, and then these shortcomings should be supported by appropriate learning theories and designs.

2. THE HUMAN ELEMENT IN MARITIME

The concept of the human element or human factor is widely used in psychology, organizational behavior, ergonomics, human-computer interaction, safety science, human resource management, health sciences, sociology, anthropology, and many other fields. The energy and aviation industry as well as the military, where the safety and security are at the forefront, pioneered the studies on the human element. Similar to these fields, maritime transport is very sensitive to human errors and depends greatly on human performance. However, the concept of the human factor/element is a broad subject that contains many topics within itself. IMO (International Maritime Organization) defines the human element as the entire spectrum of human activities performed by ships' crews, shore-based management, regulatory bodies and others (IMO, 2019). Therefore, it is obvious that the "error" in the term "human element" should be defined more clearly.

The Human Factor Analysis and Classification System (HFACS), developed by Shappell and Wiegmann (2001), based on Reason's (1997) model, defines human factor at four levels. These; are "unsafe acts", "precondition for unsafe acts", "unsafe supervision" and "organizational influences" (Shappell and Wiegmann 2001). The Human Factor Analysis and Classification System can easily be adapted for defining human errors in maritime transportation. There are already many examples of scientific research conducted within this framework to analyze maritime accidents. Most of these studies indicate the main causes of accidents as unsafe acts and preconditions triggering those acts. In addition to that, perceptual errors, decision errors and skill-based errors under the unsafe acts found to be the prominent elements in accidents (Pourzanjani, 2001; Çelik & Çebi, 2009; Chauvin et al., 2013; Batalden & Sydnes 2014; Yıldırım et al. 2017). This finding basically translates to a deficiency in the non-technical skills of individuals, namely situational awareness and decision making. Many other studies not utilizing HFACS also suggest similar findings as such; the situational awareness being one of the most dominant factors in the formation of human error in maritime (Baker and McCafferty, 2005; Barnett, Gatfield & Pekcan, 2006; Ziarati and Ziarati, 2007; Smith and Jamieson, 2012; Sandhåland, Oltedal & Eid, 2015; Øvergård, Sorensen, Nazir & Martinsen, 2015; Cordon, Mestre& Walliser, 2017; Barnett & Pekcan, 2017). Recalling the case of shipboard operations being the contributing factor, we argue that implementing processes to improve situation awareness of officers of the watch can reduce perceptual and decision errors which in return will improve the safety of navigation.

2.1. Situational Awareness

Situation awareness is defined as the perception, comprehension, and projection of the elements in the environment within a specific time and space (Endsley,

1995). Perceiving the elements, comprehending their meaning, and projecting their future status is considered as a three stepped hierarchical structure in Endsley's (1995) SA model. According to this model, situation awareness is linked with system factors (complexity, automation, workload, etc.) and individual factors (expectations, abilities, training, experience, etc.).

For an officer of the watch on ship's bridge keeping a navigational watch this can be structured as (Chauvin, Clostermann & Hoc, 2008);

- Level 1 SA: location, heading, and speed of own ship and other vessels, distance at the closest point of approach with the targets.
- Level 2 SA: meaning the elements perceived in level 1, meaning the situation: a safe crossing or a dangerous crossing situation, head-on situation.
- Level 3 SA: Possible future actions of the target ship, projection of the situation in the near future: crossing from the bow, possible collision or safe passage.

A possible error in Level 1 SA would be the entirely missing an information (failing to notice an echo on the radar) or misreading information. Since attention and working memory capacities are limited these faults could be considered typical errors in situation awareness. An error in this level affects both SA level 2 and SA level 3. At SA level 2 conditions like stress, information overload or limited experience can prevent an officer to comprehend situation straight. Error on this level greatly hinders an individual's ability to predict upcoming events (Sandhåland et al., 2015).

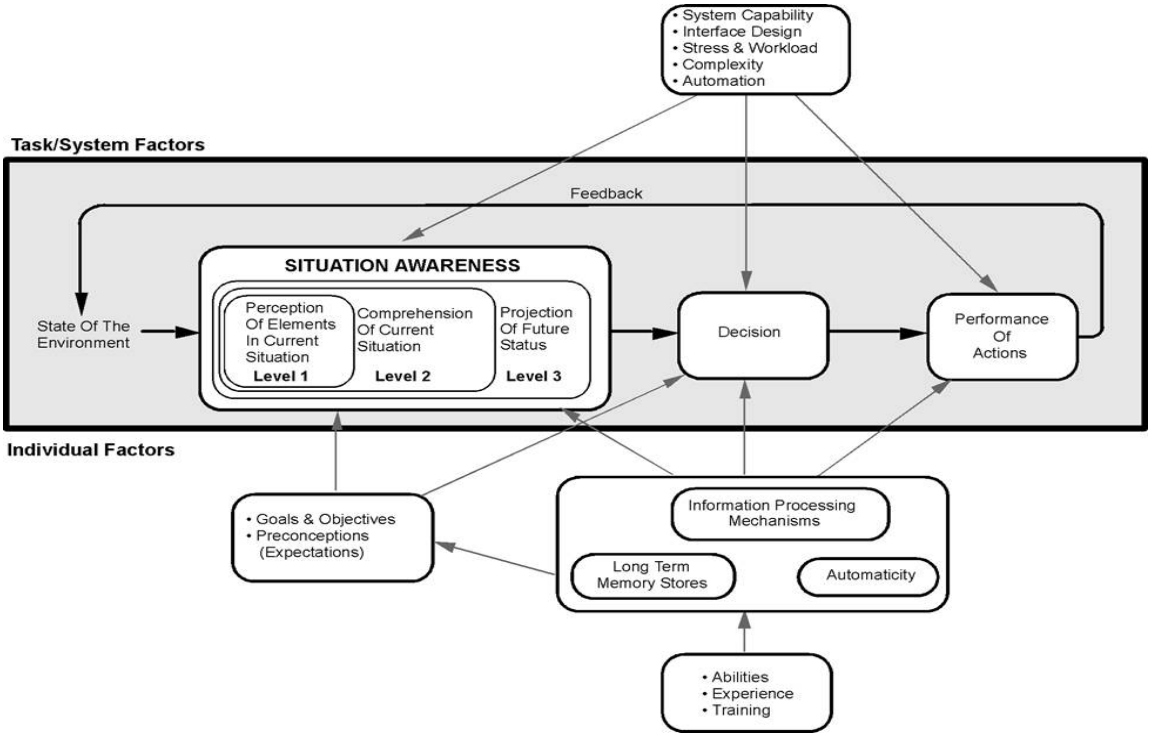

Fig. 1. Situation Awareness Model, Source: Endsley, 1995

The term situation awareness by the terminology describes the state of knowledge, but not the process used to achieve that state. An individual's process to achieve that state (acquiring or maintaining SA) is defined as situation assessment (Endsley, 2017). In both of these, patterns stored in individuals' memory are used to create a mental model. Mental models direct how one solves a problem and makes a decision. It is stated that decision making is heavily influenced by the situation awareness in a way that situation awareness is a prerequisite for quick and good decisions (Endsley, 2017; Lipshitz, Klein, Orasanu & Salas, 2001). Ultimately, decision making combined with the technical skills of the operator creates the performance. Considering the collision and emergency situations it is particularly important that the deck officer has the ability to assess the situation continuously to reach a quick and good decision to avoid any accident (Sandhåland, 2015).

2.2. Decision Making

We see various approaches have been adopted in decision-making researches in order to understand the decision-making processes of the operators. Between those two of the decision theories stand out in the literature. Rational decision-making approach states that the traditional problem solving is usually done from one stage to another using a set of rules such as defining the problem, generating an action, evaluating the action, and

implementing the action. In rational decision-making, it is suggested that the decision-maker makes a comparison of a set of known and defined options, evaluating the possible outcomes for each option and selecting the appropriate one (Kobus, Proctor & Holste, 2001). However, it has been found that this approach does not fully explain decisions made under stress, time pressure and with limited resources (Bohanec et al., 2009; Klein, 1997). This is because in dynamic situations the problems are more ill-defined rather than being structured and having well-defined goals (Klein, 2008).

Naturalistic decision-making studies have arisen due to an increase of indications that people do not make the ideal decision contrary to expectations in difficult conditions (Gore, Banks, Millward & Kyriakidou, 2006; Klein, 2008). Naturalistic decision-making is an approach that aims to explain how decision-makers make decisions under difficult circumstances in real life (Klein, 2008). Klein's recognition-primed decision (RPD) model states that people do not carry out a formal comparison between options and the experts in the area can generate a single and satisfying action by using their experience (Klein, 1997; Klein, 2008). According to the RPD model, experts can make quick and proper decisions by using environmental cues and matching the patterns (Klein, 1997; Klein, 2008). In the RPD model, the recognition of the situation through situation assessment is the priority when carrying out the decision (Brytant, Webb & McCann, 2003; Klein, 2008). Alternatives to the solution are not compared one-to-one to choose the best action. For example; in a man overboard situation a captain instead of analyzing the best course of action methodologically, will aim to select the fastest and most plausible action from his "mental database" through a situation assessment that will enable him to take man overboard back to the ship.

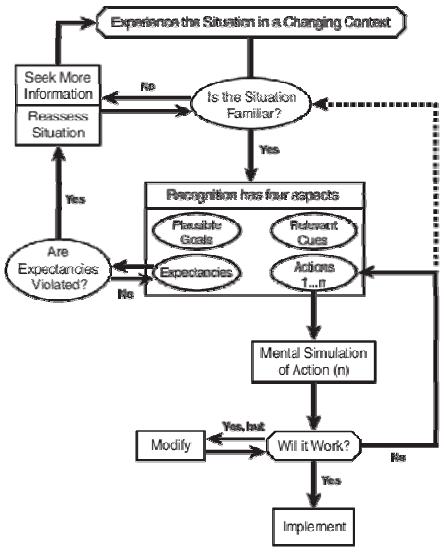

Fig. 2. Recognition Primed Decision Model
Source: Klein et al., 1993

RPD model defines four elements as the keystone to recognition. These are perceptual cues, goals, expectations, and actions (Klein, 2008). These elements are also the key factors in situational awareness according to Endsley's (2017) model. Since situation awareness is a prerequisite for quick and good decisions, the assumption is: situation assessment conducted by the operator enables him to build and maintain situational awareness and therefore recognition of the situation can be assessed, and the right decision can be made. Therefore, lack of situational awareness is what essentially creates the faulty decision making resulting in poor performances. However, in this context, SA errors should not be confused with decision errors. Poor situation awareness might create such an environment that officers can think that they made the right decision based on their perceptions (Sandhåland, 2015). Likewise, lack of situational awareness cannot account for all performance shortcomings of the operator. Yet it is essential to evaluate situational awareness together with the decision making.

3. TRAINING SITUATION AWARENESS AND DECISION MAKING FOR EMERGENCY COLLISION SITUATIONS

Interactions between vessels in maritime traffic is a dynamic process, in which complexity can steadily or instantaneously change (Brčko, 2014). In this kind of operational setting, watchkeepers might not have enough time to generate a series of actions, make an analytical assessment and choose the best decision (Kobus et al., 2001). The act of collision avoidance at sea is basically a test of situational awareness (perceiving incoming ships, comprehending the situation and predicting the outcome), decision making (turn to port/starboard, stay on course) and technical skills (adjust course). A deck officer on navigational watch must act decisively during stressful and high-risk situations. Considering these, the RPD model interlinked with the situational awareness model can be used to explain operational decisions taken by the officers of the watch in collision avoidance settings. This is also supported with the fact that several studies on the deck officer's decision making and situational awareness on the ship's bridge focus on natural decision making, recognition primed decision and Endsley's situational awareness models (Chauvin & Lardiane, 2008; Chauvin et al., 2009; Chauvin, 2011; Harvey, Zheng & Stanton, 2013; Øvergård et al., 2015; Sitka, 2016; Imbsweiler et al, 2018).

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (the STCW Convention), went through revisions in June 2010. Revised STCW Convention and Code adopted at the Manila Conference are called "The Manila Amendments" (IMO, 2019). The Manila amendments make emphasis on the needs for training of non-technical skills for good seamanship with the introduction of modern training methodology including distance learning and web-based learning. Situational awareness, decision making, leadership, and teamwork are mentioned as the non-technical skills in the amendments. The STCW Convention states that the way for future seafarers to be able to handle critical situations, their training must be tailored to enable them to "effectively obtain and maintain situational awareness and apply decision-making techniques in order to conduct situation assessment, generate, identify and consider options, select a course of action and evaluate

the outcome" (IMO, 2010: STCW Code Table A-II/1) This standard set alone should suffice for creating specialized trainings for non-technical skills. With this in mind, considering the previously mentioned theories for creating training on situational awareness and decision making seems to be the way to reduce most of the collision accidents.

A large part of maritime education is done with formal education and seminar-style instruction in the classroom. Through the education given in the classrooms, individuals learn the theories, concepts, and rules of the related subjects and gain knowledge about the functioning of the systems. However, the design of this training generally does not provide an environment for individuals to develop the abilities or skills for certain subjects. That is why education given in the classrooms is supported by high reality applications like simulators. Individuals with theoretical knowledge about the subject then have the opportunity to develop and improve their skills through realistic exercises. In addition to these, most of the maritime students undergo through an open sea training which supports both theoretical and practical skills of individuals with experience. However, there are certain disadvantages arising from the methods used within the framework of this training model. The duration of the individual training given in the simulator is limited due to the time required for each practice as well as the number of trainers and students. Therefore, it is a common practice to form bridge teams for simulator trainings which further limit the development of individual decision-making capabilities. This also limits students' ability to become familiar with the unusual events and emergency situations. Training onboard ships suffer from a different problem. There is a possibility that individuals, unlike in the simulator training, may not face with conditions that include negativities or unexpected situations. This is expected since we want the safe operation of the ships at all times. In the end this condition prepares students for the routine operation of the ship rather than for emergencies or unusual conditions. Several studies put forward a theoretical framework and various recommendations for this subject.

According to Chauvin & Lardjane (2008), it is possible to increase the familiarity and readiness levels of seafarers for emergency situations by improving their mental models and pattern recognition abilities. Sandhåland et al. (2015) support this claim with a similar finding. They revealed that insufficient training was the most common contributing cause in their research for failure to comprehend the situations which result from poor mental models. These mental models can be improved by the use of scenarios involving unusual and complex maritime traffic situations in training. This will enable more effective implementation of the COLREGs and reduce human errors in collision situations (Demirel & Bayer, 2015a). Various scientific studies also support these views; emphasizing the specialized training for decision-making to support deck officers' collision prevention performances. According to Pekcan et al. (2005); decision-making exercises will improve deck officers' ability to analyze complex situations (Pekcan, Gatfield & Barnett, 2005). Good decision-making is not only influenced by experience, age, and education, but also by specialized training. Recognizing complex patterns (pattern matching) would enable watchkeepers to find appropriate options to solve various problems more easily (Chauvin et al., 2009). This means training the expectations and anticipations of the students will provide a learning to observe the traffic situation, even if one is not directly involved in. According to Brčko et al. (2014), these statements mainly emphasize the importance of training of deck officers' expectations and goals. Accordingly, the deck officers' observations of maritime traffic and their ability to react quickly with the situation assessment in a distress are proportional to the expectations and familiarization of these individuals. Sitka (2016) in their study examining the decision-making of deck officers concludes that the use of cognitive teaching tools as early as possible in the education process would support the development of decision-making skills of maritime students. Chauvin et al. (2008) states that new educational tools such as decision-making practices/exercises are worth using in maritime education. In their study, these researchers described decision-making exercises as low-reality processed simulations of situations that might actually occur (in the field). Chauvin et al. (2008) recommends; presenting a dilemma to students to decide and giving them a few minutes to determine their actions. In this way, it the participants will gain experience on important clues, incorrect evaluations and the types of uncertainties encountered. Demirel and Bayer (2015b) suggest that a training based on possible and unusual scenarios would help to understand COLREG better with the help of an information-based tool such as e-courses. Chauvin & Lardjane (2008) similarly emphasized the importance of identification of relevant patterns and clues to prevent collision at sea and the mental models they will use to achieve satisfactory decisions. Chauvin et al. (2009), stated that in French maritime schools, the simulators were used to provide trainees with experience for difficult situations. However, they stated that the emergency scenarios processed in the simulator could not be repeated to ensure that the students were able to respond accurately and quickly. They emphasized that pattern matching, and correct action selection are gained by repetitions of these practices. At this point, the researchers recommended that decision-making exercises should be used to introduce maritime students to specific difficult situations.

4. CONCLUSION

In general, the primary role of deck officers is to maintain the safe course of ships on a pre-designated route. In this context, the officer of the watch (OOW) is usually the ultimate decision-maker in avoiding collision situations during the navigational watch. In order to avoid collisions quickly and accurately officer of the watch must not only possess near-perfect knowledge of International Regulations for Preventing Collisions at Sea (COLREGs) but also requires adequate skills to implements COLREG rules. This means a deck officer may fail to avoid collision due to insufficient navigational knowledge, observation capability or lack of situational awareness, even though he is fully aware of the rules defined in the COLREG. Additionally, complex traffic conditions where it is difficult to interpret the rules can cause perception and decision errors. Also, in tight emergency situations, an action that

first seemed to be reasonable may lead to then unforeseen distresses. When these conditions are evaluated, it is crucial to set the expectations and goals of the situation accurately and quickly in order to prevent situations from going beyond recovery. The way to achieve these lies within the specialized situational awareness trainings and decision-making practices. In addition to informing students with theoretical aspects of situational awareness and decision making, we should aim for shaping their mental models and improving their pattern and situation recognition capabilities. This can be achieved with practices and exercises, using either already available simulators or creating new tools to help them set their goals, expectations and possible actions right in collision situations.

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FREIGHT TRANSPORT MODE CHOICE WITH STATED PREFERENCE METHOD: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT
Modeling transport choice is one of the most important components of transportation analysis since it determines the parties to be involved, the resources to be used and the impact made on the environment. Many different techniques have been used to analyze choice modelling. As a principle, all choice modelling techniques suppose that goods/services can be defined in terms of their characteristics or attributes and the levels. In the stated preference methods, decision makers evaluate and decide on the multi-attribute and mutually exclusive alternatives they prefer. The aim of this study is to analyze the studies that use the stated preference method in transport mode choice in terms of transportation modes, study area, decision-makers, decision variables and general findings. The research points of this study is the identification of the most appropriate, scientifically (objectively) derived variables for use in the stated preference experiment of freight route/mode choice. This study carries out globally in terms of different variables provide novelty as it complements the limited number of studies most of which have involved only certain limited geographical areas. For this purpose, a systematic literature review method has been conducted for freight mode choice using "stated preference method". A systematic literature review from relevant academic studies has indicated such transportation choice variables through as transport time, transport cost, transport mode, flexibility, frequency, reliability, risk of delay/punctuality, risk of loss and damage and service quality. To analyze the freight transport choice, discrete choice experiments which are one of the stated preference techniques have been the most preferred methods. According to literature review, most effective variables in choosing freight transport mode are transport cost, transport time and reliability. This study is important in terms of providing an insight to academicians, practitioners and policy makers by analyzing attributes, types of stated preference models, theories, analysis methods and findings of academic articles about freight mode selection with stated preference methods. Additionally, it has been found that the features involved as effective variables in the preferred freight route / mode selection experiments indicated are most strongly confirmed by applying more mechanical, more easily and less subjective applied approaches to the literature review.

Keywords: *Freight Forwarders, Freight Transportation, Mode Choice, Shippers, Stated Preference*

1. INTRODUCTION

The transportation system is an organization that designs, plans, organizes and describes the movement of goods by considering the technical constraints in which the goods are transported from the point of origin to the destination by using loading units such as motor vehicles and pallet-containers (Khooban et al., 2011). Freight transportation is as "the movement of goods from one area to another" (National Academies of Sciences, Engineering, and Medicine, 2011). Another definition highlights as a main part of supply chain and all logistics systems (Ranaiefar and Regan, 2011). Intermodal transport in the field of logistics and transportation is growing rapidly as a new transportation market and has begun to form the basis of transportation policies of many countries, especially the European Union, United States and Far East countries (Deveci, 2010). Freight transport selection or decision making on carrier or mode to use from the view point of transportation service users has been an important research area in the literature (Denktaş Şakar, 2010). Mode selection and decision variables are two closely related issues (Köfteci, 2008: 43).

The primary freight transportation modes are road, rail, sea, air and pipeline (National Academies of Sciences, Engineering, and Medicine, 2011). Railway is the second low cost type of transportation preferred for large volume and long distance transportation. This type of transport, which is adopted and preferred as environmentally friendly, is particularly preferred for the transport of low value goods. The most convenient mode of transport for door-to-door transport is by road. It is the most widely used mode due to its wide range of transportation networks. Pipeline is a type of transport used for the movement of energy sources such as crude oil, natural gas and gasoline, where the risk of loss, damage and flexibility is low. The airline, which has the most advantageous position in terms of transportation time, is the most expensive mode of transportation compared to all types of transport. Despite its high reliability, it is not a flexible transport type. Seaway is the lowest cost transportation mode in terms of price. However, it is disadvantageous in terms of long transport times and low flexibility (Gourdin, 2006; Akay, 2016).

After the describing of the cargo and destination, exporter determines selection criteria in terms of transport mode and carrier and later they analyze and choose company for transportation. The exporters' decisions can be divided into "mode selection" and "carrier selection" (Tuna and Akarsu, 1999). The choice of transport mode is the outcome of the relationship between the attributes of the transport service and the nature of the product being transported and also the relationship between the buyer and the seller of the product (Gray and Kim, 2001; 37). It is very important to determine the mode of transportation that will provide services with minimum cost and maximum service quality for a certain route in freight forwarding (Krapfel ve Mentzer, 1982, Köfteci, 2008). According to McKinnon (1989), transport mode choices in freight transport are related to service (speed, reliability, cost etc.), traffic (length of haul, dimensions, value etc.) and consignor (size of firm, investment priorities etc.).

According to Golias and Yannis (1998), parameters affecting the choice of freight transportation are performance parameters (transportation time, reliability, frequency and capacity limits), cost parameters (price and credit contracts), service quality (loss and damage rate and management, communication, customer distribution and transportation services and planning flexibility) and general parameters (government interventions, company structure and organization and existing transport facilities).

Mode choice decision variables in literature are generally transport cost (Gilmour, 1976; Burdg and Daley, 1985; Pederson and Gray, 1998; Jovicic, 1988; Bolis and Maggi, 1998; Shingal and Fowkes, 2002; Garcia-Menendez et al., 2004; Patterson et al., 2006; Feo et al., 2016; Duan et al., 2017 etc.), transport time (Saleh and Das, 1973; Coyle et al., 1996; Jovicic, 1988; Bolis and Maggi, 1998; Shingal and Fowkes, 2002; Gubbins, 2003; Patterson et al., 2006; Feo et al., 2016; Duan et al., 2017 etc.), services (Krapfel and Mentzer, 1982; Matear and Gray, 1993; Murphy and Hall, 1995; Shingal and Fowkes, 2002 etc.), flexibility (Jovicic, 1988; Bolis and Maggi, 1998; Duan et al., 2017 etc.), frequency (Jovicic, 1988; Bolis and Maggi, 1998; Shingal and Fowkes, 2002; Feo et al., 2016; Duan et al., 2017 etc.), reliability (Shingal and Fowkes, 2002; Patterson et al., 2006; Duan et al., 2017 etc.), security (Bardi, 1973; Jovicic, 1988; Noda, 2004; Patterson et al., 2006; Duan et al., 2017 etc.) etc.) and route (Hayuth, 1987; Cullinane and Toy, 2000; Banomyong and Beresford, 2001 etc.) related factors. Transport cost refers to the charge for door-to-door transport. Reliability is the ability to comply with the promised delivery date. Flexibility can be defined as the ability to adapt to changing customer needs and conditions. The transport time is the duration of the entire transport process (door-to-door). Security is the possibility of preventing the loss of quality and damage of goods (Vannieuwenhuyse et al., 2003: 128).

2. STATED PREFERENCE

Many different techniques have been used to analyze choice modelling. As a principle, all choice modelling techniques suppose that goods/services can be defined in terms of their characteristics or attributes and the levels that these take. The focus is on the values given to these qualities (Competition Commission, 2010). Stated preference method is a theoretical method. It provides many advantages if designed correctly. For this purpose, the questionnaires representing the stated preference experiment should be in detail in accordance with the subject under investigation. Factors affecting the demand should be evaluated at the beginning. The differences between the proposed alternatives should not be small. There should be significant differences between them (Fowkes and Tweddle, 1988).

Choice modelling techniques with stated preference can be classified into five categories, which reflect differences in analysis methods, theoretical assumptions and procedures of experimental design (Adamowicz and Boxall, 2001, Bateman et al., 2002, Kjaer, 2005): "Contingent ranking", "discrete choice or stated choice experiments", "paired comparisons", "contingent rating", and "best-worst scaling" (BWS) (Finn and Louviere, 1992 and Flynn et al., 2007). In "discrete choice experiments" (DCEs), participants choose one of

two or more alternatives offered. In a "contingent ranking" exercise, participants should rank all proposed alternative options by their preference. In a "contingent rating" experiment, participants are presented one alternative at every turn and are asked to rate each on a semantic or numerical scale (for example low preference - high preference, 1-10). In "pairwise comparison" exercises, participants are asked to choose their preferred alternative from two options. The selected alternative is also expected to be explained numerically or semantically (Competition Commission, 2010). In "the best-worst scale" (BWS) approach, participants are asked to specify two preferred endpoints, given a single set of qualifications, which is considered to be the best and worst feature (Wittenberg et al., 2016).

Stated choice experiments are based on behavioral theories. There are "Social Judgement Theory" (Brunswick 1952; Hammond 1955), "Lancaster's consumer theory" (Lancaster, 1966), "Information Integration Theory" (IIT) (Anderson 1970), "Hierarchical Information Integration" (HII) Theory (Louviere, 1984) and "Random Utility Theory" (Thurstone 1927; McFadden 1974; Manski 1977; Shingal, 2002).

The researchers who have an advantage for using stated preference method to analyze mode selection have controlled over the qualifications and manipulated selection sets. The researchers have also analyzed how choices may change when if the composition or size of the selection changes (Witlox and Vandaele, 2005). The stated preference modelling technique has also mentioned some limitations. Firstly, selection experience has been difficult to perform and survey design has been serious to achievement. Secondly, stated preference models are based on hypothesis that decision making under semi-laboratory circumstances is interested in the real world. In this case, the selection or selection specified may not compromised very closely to the essential preferences or the selection (Daniels, 2002).

3. METHODOLOGY

The method used in this study, Systematic Search Procedure has been developed by Kitchenham (2004) and later adapted by Bacca (2014), which divides the process into planning, conducting the review, and report the review. This procedure requires several sub-stages, *"it starts with a set of search words and the scientific thesaurus, a search semantic structure, search script adapted to each database, a specific process of selection of studies and a list with the search results as a variable resulting from this procedure"* (Torres-Carrion et al., 2018).

In literature, there are a lot of studies in urban and travel transportation using stated preference method for the transport mode selection; Hartgen (1974), Hensher (1994), Alpizar and Carlsson (2001), Koppelman and Bhat (2006), Van der Waerden, et al. (2007), Catalano et al. (2008), Pavlyuk and Gromule (2010), Richter and Keuchel (2012), Bando et al. (2015), Anciaes et al. (2018), Wu et al. (2019). This study has focused freight transportation mode selection with stated preference method.

In this study, a general framework has been drawn by analyzing the attributes, types of stated preference models, theories, analysis methods and findings of academic articles about freight mode selection with stated preference methods.

The databases used in this literature review, conducted in October 2019, are Scopus, Web of Science, ScienceDirect and Taylor & Francis. The review has covered the "titles, "keywords" and "abstracts" (Table 1).

Table 1. Search terms used and amount records received from databases.

Search terms (Transport OR freight OR multimodal OR intermodal OR multimodal) AND "stated preference"
Limit to Journal (maritime OR shipping OR logistics OR transport OR transportation)
and not Public OR tourism OR traveler OR city OR urban OR passenger

The search strategies presented by the specific search strings have been formulated according to the search logic of each database, but containing the same terminology. Only the journals containing such words phrases as maritime, shipping, logistics, transport and transportation words are examined. Journal names, number of articles and impact factor are given in Table 2.

Table 2. Detailed information about journals in which the articles in the search results

Journal name	**No of Articles**	**Impact Factor in 2018**
Transport Reviews	1	.648
Transportation Research Part E: Logistics and Transportation Review	3	.253
Transportation Research Part A: Policy and Practice: An International Journal	2	.693
Transportation	1	.457
Transport Policy: Journal of the World Conference on Transport Research Society (WCTRS)	2	.190
International Journal of Sustainable Transportation	1	.586
Research in Transportation Business & Management	1	.065
Transportation Planning and Technology	2	.893
Journal of Transport Economics and Policy	1	.857
Transportation Research Board	1	.695
Maritime Policy Management	3	.4
Transportation Research Procedia	3	
Total	**21**	

The review has comprised research articles only and shippers and freight forwarders as decision makers. . The freight forwarders and shippers' selection allows to set light to market segment, which makes up more than fifty of the transport decisions (Bergantino and Bolis,

2008). After the rigorous screening and eligibility evaluation of titles, abstracts, and keywords, finally 21 studies are identified as eligible for the final synthesis; 9 of 21 studies have chosen shipper as decision makers, freight forwarders have been chosen as decision makers in 9 of 21 studies and studies have chosen both freight forwarders and shippers as decision makers.

4. ANALYSIS

Having identified 21 studies as eligible for the final synthesis, decision makers, research area, stated performance methods variables (modes of transport, attributes and number of alternatives) are given in detail in Table 3. As a result of literature review, the most used attributes considered in stated preference methods are "transport time", "transport cost", "frequency", "reliability", "risk of delay/punctuality", "risk of loss and damage", "flexibility" and "service quality" (Table 4).

Choice modelling techniques with stated preference can be classified into five categories; "contingent ranking", "discrete choice or stated choice experiments", "paired comparisons", "contingent rating" and "best-worst scaling" (BWS). 10 of 21 studies have used discrete choice experiments as stated preference techniques (Patterson et al. (2016), Daniels and Marcucci (2007), Arunotayanun and Polak (2011), Feo et al. (2011), Arencibia et al. (2015), Feo-Valero et al. (2016), Nugroho et al. (2016), Duan et al. (2017), Larranaga et al. (2017) and Vega et al. (2018). Shingal and Fowkes (2002), Witlox and Candaele (2005), Beuthe and Bouffioux (2006), Li and Hemsher (2012) and Simecek abd Dufek (2016) have used contingent ranking techniques to analyze transport mode choice. Vermeiren and Macharis (2016) have used paired comparisons techniques for choice modelling. The other studies in sample (Bergantino and Bolis, 2008; Norojono and Young, 2012; Bergantino et al., 2013; Regmi and Hanaoka, 2015 and Kim et al., 2017) have used contingent rating. To analyze the transportation mode selection variables with
stated preference method, studies have generally used logit models such as mixed logit model, Tobit mixed logit model, nested logit model, mixed nested logit model.

Studies using the stated preference method in the selection of mode of transportation are generally based on the "Random Utility Theory" and "Hierarchical Information Integration (HII) Theory". Studies which based on "Random Utility Theory" are Witlox and Candaele (2005), Beuthe and Bouffioux (2006), Daniels and Marcucci (2007), Bergantino and Bolis (2008), Arunotayanun and Polak (2011), Feo et al. (2011), Li and Hemsher (2012), Arencibia et al. (2015), Regmi and Hanaoka (2015), Nugroho et al. (2016), Simecek abd Dufek (2016), Duan et al. (2017), Kim et al. (2017), Larranaga et al. (2017) and Vega et al. (2018). Patterson et al. (2006), Norojono and Young (2012) and Bergantino et al. (2013) have predicated on "Hierarchical Information Integration (HII) Theory".

The articles are given in chronological order according to the type of decision makers which are only shippers, only freight forwarders and both shippers and freight forwarders.

4.1. Studies Involving Shippers Only

Studies in which shippers have been selected as decision makers; Danielis and Marcucci (2007), Arunotayanun and Polak (2011), Li and Hensher (2012), Arencibia et al. (2015), Feo-Valero et al. (2016), Vermeiren and Macharis (2016), Duan et al. (2017), Kim et al. (2017) and Vega et al. (2018).

According to Danielis and Marcucci (2007), the quality of loss and damage is the most affected; it is followed by cost, transport/transit time and late arrivals. In the area of acceptability, cost appears to be the most relevant feature; this is followed by loss and damage, transport/transit time, flexibility, frequency and late arrivals. The minimum requirements for transport services are quite stringent, particularly with regard to late arrivals, losses and damages and costs. There seems to be some flexibility with respect to transport/travel time. These results should be of interest to both intermodal service providers and policy makers.

Arunotayanun and Polak (2011) have based "stated preference method" to investigate taste heterogeneity influencing 186 shippers' mode choice behavior in Java, Indonesia. They have focused various commodity groups; leather, food, electronic and textile. Shippers of food are sensitive to both time and cost (by large truck) and shippers of textile are sensitive only to transport/travel time (by large truck). Shippers of food and leather pay attention to more frequent shipments so they have preferred small truck for transportation. According to results of this study, variables related to cargo, value and frequency are coherently significant.

Li & Hensher (2012) has identified a theoretical framework that brings about integration risk manners into modelling of freight behavior and places particular emphasis on convent variable of travel/transport time. They have used stated preference technique with random utility maximization for 35 shippers in Switzerland. Transport modes are road, piggyback, and combined transport. Shippers and transporters are liable to take risks when making risky choice about travel/transport time, but transporters are more risky than shippers.

Arencibia et al. (2015) have analyzed freight transport demand in a context of model choice. They have implemented stated preference survey through 93 shippers between Spain and continental Europe. The actions with the greatest effect on deviation of traffic to modes of alternative are those that influence the transportation cost.

Feo-Valero et al. (2016) have analyzed attribute cut-offs through a stated preference experiment in Aragon and Valencia with 94 shippers. The attributes have been transit time, door-to-door transport cost, frequency, delay and notice for contracting with two alternative modes (road and rail) using 12 alternatives scenarios. The results of the transport cost variable show that decision-makers strongly penalize the raises above the cut in transport costs. Regarding delays, the insignificance of coefficients when introducing quality cuts indicates that decision makers do not consider this variable in the modal selection process. For the frequency variable, the results obtained indicate the presence of extremely polarized positions; this highlights the traditional specifications weaknesses that averages extreme positions and leads to erroneous subjective values. Ignoring the presence of segments

Table 3. Literature Review on the Freight Transport Mode Selection through Stated Preference Method

Authors	**Decision Maker**	**Area**	**Modes of Transport**	**Attributes Considered in Stated Preference**		**Number of Alternatives**
Shinghal and Fowkes (2002)	32 Freight Forwarders	Delhi to Bombay corridor, India	Road Intermodal container Rail	Time Services Cost	Reliability Frequency	21
Witlox and Vandaele (2005)	88 Freight Forwarders and Shippers	Antwerp and Ghent Port Areas in Belgium	Road Rail Inland Short sea shipping Inter and multimodal	Cost Time Loss and damage	Frequency Reliability Flexibility	25
Beuthe and Bouffioux (2006)	113 Freight Forwarders	Belgium	Road Rail Inland navigation	Frequency Time Reliability	Flexibility Loss Cost	25
Patterson et al. (2006)	392 Freight Forwarders	Ontario and Quebec	Road Rail	Cost Reliability	Risk Time	18
Danielis and Marcucci (2007)	99 Shippers	Italy	Road Intermodal	Transport cost Door-To-door transit time Late arrivals	Loss and damage Flexibility Frequency	3
Bergantino and Bolis (2008)	16 Freight Forwarders		Road Maritime Ro-Ro	Price Time	Reliability Frequency	4
Arunotayanun and Polak (2011)	186 Shippers	Java, Indonesia	Road Rail	Cost Time	Service quality Flexibility	3
Feo et al. (2011)	45 Freight Forwarders	Spain	Road Maritime	Transit time Transport cost	Reliability Frequency	9
Li and Hensher (2012)	35 Shippers	Switzerland	Road	Transport price Damage	Time Punctuality	2
Norojono and Young (2012)	186 Freight Forwarders	Java, Indonesia	Rail Road	Transport cost Delivery time	Quality Flexibility	16

Table 3. Literature Review on the Freight Transport Mode Selection through Stated Preference Method (continued)

Authors	**Decision Maker**	**Area**	**Modes of Transport**	**Attributes Considered in Stated Preference**		**Number of Alternatives**
Bergantino et al. (2013)	92 Freight Forwarders	Sicily	Road Road with transshipment Road–sea(Ro-Ro)	Cost Time Punctuality	Risk of loss/damage Frequency	16
Arencibia et al. (2015)	93 Shippers	Madrid	Road-sea-road Road-rail-road Road-air-road	Cost Transit time	Punctuality Service frequency	18
Regmi and Hanaoka (2015)	10 Freight Forwarders	Laos and Thailand	Road Rail	Time Cost	Reliability Co2	3
Feo-Valero et al. (2016)	94 Shippers	Aragon and Valencia	Road Rail	Transport cost Transit time Frequency	Delays Notice for contracting	12
Nugroho et al. (2016)	161 Shippers and Freight Forwarders	Java, Indonesia	Road Rail	Cost Time	Frequency	4
Simecek and Dufek (2016)	51 Freight Forwarders	Slovakia	Road Rail	Cost Per One Shipment	Transport Time Reliability	4
Vermeiren and Macharis (2016)	32 Shippers	Rhine(Antwerp)-Scheldt (Rotterdam) delta	Rail Barge	Total cost CO2 emission	Frequency	16
Duan et al. (2017)	83 Shippers	Southwest area of China	Rail	Transport cost Transport time Service frequency	Service reliability Service safety	4
Kim et al. (2017)	190 Shippers	New Zealand	Road Rail Coastal	Size of shipment Cost	Reliability Distance – Time	18
Larranaga et al. (2017)	50 Shippers and Freight Forwarders	Rio Grande Do Sul	Road Intermodal Rail Intermodal Waterway	Transport cost Transport time	On-time delivery percentage Percentage of deliveries delayed	3
Vega et al. (2018)	49 Shippers	Ireland	Landbridge UK Direct	Cost Transit Time Probability Of Delays	Delays Duration Service Frequency	12

Table 4. Literature Review on the Most Often Used Attributes/Variables in the Transport Mode Selection through Stated Preference Method

Variables	Shinghal & Fowkes (2002)	Witlox and Vandaele (2005)	Beuthe & Bouffioux (2006)	Patterson et al.,(2006)	Danielis & Marcucci (2007)	Bergantino & Bolis (2008)	Arunotayanun & Polak (2011)	Feo et al. (2011)	Li & Hensher (2012)	Norojono & Young (2012)	Bergantino et al. (2013)	Arencibia et al. (2015)	Regmi & Hanaoka (2015)	Feo-Valero et al. (2016)	Nugroho et al. (2016)	Simecek & Dufek (2016)	Vermeiren & Macharis (2016)	Duan et al. (2017)	Kim et al. (2017)	Larranaga et al. (2017)	Vega et al. (2018)
Transport cost	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Transport time	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Frequency	✓	✓	✓		✓	✓		✓			✓	✓		✓	✓		✓	✓	✓		✓
Flexibility		✓	✓		✓		✓												✓		
Reliability	✓	✓	✓	✓		✓		✓					✓			✓		✓			
Risk of loss and damage		✓	✓	✓	✓				✓		✓										
Risk of delay / Punctuality					✓				✓	✓	✓	✓	✓	✓						✓	✓
Service quality	✓						✓			✓											

with polarized values and / or segments of the population may lead to erroneous results in terms of actual rail possibilities for withdrawing the quota from the road.

Vermeiren and Macharis (2016) have investigated the preferences of 32 shippers for intermodal land transportation and port choice in Rhine-Scheldt delta. They have used total cost, CO2 emission and frequency as variables for rail or barge transportation choice with stated preference method. The most striking results of this study are that the shippers have not interchanged their preferences when the names of the applicable maritime gateways are indicated. Shippers in the Delta have no particular choices preference for Antwerp or Rotterdam. Costs are the best solution for shippers. Maritime route, the trade flow direction, and type of mode haven't affected the choice behavior.

Duan et al. (2017) used 4 options in stated preference with logit model and latent class model. Road, rail and waterway have been used as transport mode alternatives. Transport cost, transport time, frequency, reliability and safety are used as transport choice variables. The finding of this study shows that quality attributes are more preferred than price attributes by railway shippers. A literature review through relevant academic studies has indicated the following transportation choice variables such as transport time, transport cost, transport mode, flexibility and frequency.

Kim et al. (2017) have used stated preference technique for 190 shippers in New Zealand. Transport modes are road, rail and coastal. Their attributes are size of shipment, cost, and reliability and time. According to the findings, policy makers can design more favorable strategies and policies for various segments of the population to provide intermodal transport and captivate the largest latent class. Additionally, the stated preference method specifies that the potential development in modal shift, which can be procured by implementing various policy options, varies with both shipment size and distance of transport. Furthermore, in order to support sustainable freight transport, a policy would be to raise the reliability of both the maritime freight transport and rail services.

Vega et al. (2018) have used stated preference method for maritime freight transport mode choice from Ireland to continental Europe with 49 shippers as decision makers. The attributes considered in stated preference have been transport cost, transit time, probability of delays, delays duration and service quality with two alternatives modes. Changes in costs are more effective in moving from the UK land bridge route to the direct continental option. In addition, there is a greater sensitivity to the deterioration in the cost of UK land bridge transport, directly from the further developments in the cost competitiveness of direct continental services. For this reason, transport policy aims to increase the use of direct routes as a mechanism to decrease dependence on the UK land bridge. Transport policy should also focus on enhancing the transit time - service, delays and frequency of the direct alternative. Similarly, any increase in the cost of road bridge roads will further affect the possibility of using a direct road from any policy aimed at decreasing the direct terrestrial road alternative costs.

4.2. Studies Involving Freight Forwarder Only

Studies in which freight forwarders have been selected as decision makers; Shinghal and Fowkes (2002), Beuthe and Bouffioux (2006), Patterson et al. (2006), Bergantino and Bolis (2008), Feo et al. (2011), Norojono and Young (2012), Bergantino et al. (2013), Regmi and Hanaoka (2015) and Simecek and Dufek (2016).

Shinghal and Fowkes (2002) have carried out an empricial survey on the significatives of mode choice for freight in India. Road and rail have been used as modes of transport in 32 companies on the Delhi to Bombay corridor. Time, services, cost, reliability and frequency are used as mode selection variables. Service frequency is an significant attribute to determine mode choice. Reliability valuation is generally lower than expected. Time value is quite similar across different product segments. Given prevailing costs, the results offer that intermodal services can be viable for high value and finished goods.

According to Beuthe and Bouffioux (2006)'s study, different qualitative factors play an essential and differentiated roles in the transport solution choice and their relative importance and values vary according to the firm and transport categories, as well as their willingness to change modes.

The findings of Patterson et al. (2006)'s study has developed first model for the Quebec City Windsor Corridor in 2005. These shipments were made by rail. The results of the study show that freight forwarders are very insecure about using railways to transport their shipments, and the increasing share of rail transport faces increasing challenges.

Bergantino and Bolis (2008) have constructed freight forwarders' preferences toward the maritime ro-ro transportation with attributes related to cost, reliability, frequency and time. The result of this study emphasizes the relative significance of frequency and reliability for decision of freight forwarders mode selection and modal shifts to maritime services.

Feo et al. (2011) aim to promote to the effective freight transport policy design through empirical analysis. Stated preference method has been used for mode choice between short sea transport and door-to-door road transport on the Motorway of the south-west European Sea in 2006 with 45 freight forwarders from five Spanish states (Barcelona, Zaragoza, Valencia, Murcia and Madrid). According to findings of this study, *"the percentage change in the probability of choosing the maritime intermodal alternative has been calculated when faced with variations in both own cost, transit time, reliability and frequency as well as that of the road alternative"*. Decision makers are more susceptible to changes in the service levels offered by the alternative mode in the case of reliability, as in transport costs, than in maritime mode. In the meantime, the possibility of choosing the intermodal maritime alternative is more sensitive tondevelopments in its transportation time than possible changes in the transition time in alternative mode. Cost policies have the greatest impact on the possibility of choosing the maritime alternative.

Norojono and Young (2012) have described the development of a discrete mode selection model applicable to a data collection approach and analysis of

transport company decision making. It focuses on railway and road selection in Java, Indonesia. The model demonstrates that reliability, responsiveness snd safety are the main characteristics that influence rail / road freight mode selection. In order to improve these dimensions, transport policies should raise the railway transportation attractiveness.

According to Bergantino et al. (2013), road transportation is preferred by freight forwarders who attach substantial to the risk of loss/damage. However, it was not preferred by freight forwarders who care about punctuality. Larger companies pay less attention to time but paid more attention to the risk of loss and damage if shipments are not frequent. Service reliability and cargo type significantly affect the choice of freight forwarders.

Stated preference survey includes questions about time, cost, reliability/punctuality, and CO2 emissions for transport by rail and road, and whether or not the freight forwarders would change to choose a mode. The flexibility and scenario analysis shows the variety modes considered. Finally, the changes in the possibility of the maritime intermodal alternative choosing has been estimated when faced with variations in both own cost, frequency, transit time and reliability as well as that of the road alternative (Regmi and Hanaoka, 2015).

Simecek and Dufek (2016) have conducted a survey through freight forwarders on freight preference in Slovakia. For each of the responsive tasks, mode, cost, travel time and reliability have passed the experiment of adaptive state preference where alternatives are characteristics. 51 freight forwarders have participated in the survey. It has been found that rail or road is not significantly preferred, but freight forwarders are resistant to changing the routine freight mode. Generally, the particular constant of the current mode of use has been found positive and almost thirty times greater than the value of time. This is a complex situation for the standard transport model shifts because it cannot be assigned to the alternative specific fixed specific transport mode equation. Moreover, the actual data on freight transport in Slovakia have different levels of accuracy. Very accurate and detailed information (commodity and values in origin-arrival pairs) is available for rail transport. On the other hand, there is a lack of information about land transport. This challenge allows to create a two-way split model for road and rail freight transport.

4.3. Studies Involving Both Shippers and Freight Forwarders

Studies in which both shippers and freight forwarders are involved as decision makers; Witlox and Vandaele (2005), Nugroho et al. (2016) and Larranaga et al. (2017).

The modes of transport considered have been rail, road, short sea transport, inland navigation and all combinations of inland and multimode. A total of 88 freight forwarder managers have participated. The study has 25 transport alternatives, each defined as six quality characteristics (cost, time, loss and damage, frequency, reliability, flexibility), and each with five levels. The stated preference experiment show that 11 alternatives are chosen over the status quo position. The respondents declare that they are ready to change modes of transport if alternatives are applicable (Witlox and Vandale, 2005).

Nugroho et al. (2016) have aimed to identify critical mode choice factors from shippers and freight forwarder's perspectives with stated preference method in Java, Indonesia. They have used cost, time and frequency as attributes considering in stated preference using road and rail transportation. Cost and time variables have negative affect to mode choice while reliability has affected positively the mode choice. According to the results of this study, fuel subsidies reduction for road transport and giving encouragements to decrease rail freight rates would ensure the most significant incentives to modal shift from road to rail transport.

Larranaga et al. (2007)'s study is concerned with the demand analysis for maritime freight transport services from Ireland to continental Europe. The purpose of the study is to procure empirical evidence on the determinants of route choice between the two alternatives: to the continent via the UK land bridge and directly to Europe without UK passage. They argue that investments to improve the reliability of intermodal alternatives are more effective than cost reductions in promoting intermodality. Policies and investments to promote multimodality should give priority to increased reliability of intermodal alternatives and combined policies of reliability and cost reduction.

5. CONCLUSION

Modeling transport choice is one of the most important components of transportation analysis. This paper presents and discusses the articles using stated preference method which is based on theoretical scenarios to route / mode choice literature in Scopus, Web of Science, ScienceDirect and Taylor & Francis databases and journals containing such terms as maritime, shipping, logistics, transport and transportation words. Mode selection and decision variables are two closely related issues. Many different techniques have been used to analyze choice modelling. In stated preference methods, decision makers evaluate and decide multi-attribute and mutually exclusive alternatives they prefer. In this study, a systematic literature review has been conducted for freight mode selection using stated preference method. The adoption of stated preference techniques in freight route/mode choice studies is in need of defining of the main modal attributes that affect these decisions. The research points of this study is the identification of the most appropriate, scientifically (objectively) derived variables for use in the stated preference experiment of freight route/mode choice. These variables will reflect, and emerge from, the dominant categories such as attributes, types of stated preference methods, basal theories, analyzing methods and general findings identified through the systematic literature review of a sample database of literature. This study carries out globally in terms of different variables provides novelty as it complements the limited number of studies most of which have involved only certain limited geographical areas.

There are many studies using stated preference method in academic literature. The aim of this study is to provide a general perspective for academicians, practitioners and policy makers by examining the

current academic studies. Thus, this study is important in terms of providing an insight to academicians for future studies by analyzing attributes, types of stated preference models, theories, analysis methods and findings of academic articles about freight mode selection with stated preference methods. From the point of view of policy makers and practitioners, this study suggest several things. First, transport cost should be the main concern of shippers and freight forwarders, since in all cases the cost factor is the most important. Secondly, transport time and reliability play a significant role in decision making, but their specific weights vary with the transports' characteristics and from one industry to another. This means that efforts and investments to promote specific modes should focus on markets where particular qualifications may be more valuable.

There are a lot of decision makers such as shippers, freight forwarders, shipping lines or carriers in the freight mode selection. This paper has used shippers and freight forwarders as decision makers. The freight forwarders and shippers' selection allows to set light to market segment, which makes up more than fifty of the transport decisions.

According to the systematic literature review, "transport time", "transport cost", "frequency", "reliability", "risk of delay/punctuality", "risk of loss and damage", "flexibility" and "service quality" use as the attributes considering the stated preference mostly. When the findings of the studies have been examined, it is concluded that the most effective variables in choosing freight transport mode are transport cost, transport time and reliability. To analyze the freight transport choice, discrete choice experiments which are one of the stated preference techniques have been the most preferred methods. Studies have generally based on Random Utility Theory developed by Thurstone (1927). Most of the studies in literature have been carried out with shippers and freight forwarders in Belgium and Indonesia.

A systematic literature review ensures a scientific basis and more logical for the justification of overall impact categories on freight mode choice decisions, as opposed to the more usual, ad hoc selection of attributes to be tested. Another result of this analysis is that the features that are the most effective variables in stated preference experiments of freight route/mode choice are most strongly confirmed by applying of the more mechanical, more easily approaches and less subjective to literature review.

In further research, studies using more than one mode could generally be scanned. Studies focusing only on one mode in future studies may also be included in the literature review. Besides, future studies could use any other mode selection methods other than the stated preference method used in this study. In further studies, articles may also be examined in terms of all decision makers. Furthermore, the future studies could expand the databases and journals only a few of which have been involved in this study.

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Review Article

INVESTIGATION OF THE USABILITY OF RENEWABLE ENERGY IN MARITIME TRANSPORTATION

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ABSTRACT
One of the most important actors of maritime transport is cargo ships where cargo is transported. Nowadays, the expansion of the maritime trade volume with increasing acceleration, the increase in the size and quantity of ships in the world's merchant navy fleet cause transportation costs to decrease per ton while to bring some negative effects such as air pollution. The major cause of ship-source air pollution is the conventional fuel used in propulsion systems. As of 2006, serious steps are being taken in the context of air pollution prevention measures that have been on the agenda in the sector on a global scale. In this study, recent academic literature conducted on this subject reviewed in recent years, renewable energy and other fuel types that can be used in efficiency equivalent to conventional fuel were evaluated. As a result of this thematic review, although the ship projects carried out with renewable energy in the project phase are exciting, the most powerful alternative in the short term seems liquefied natural gas (LNG) which is not accepted as renewable but found to be successful in terms of emissions. It can be used in ships with tonnage nearby coastal voyages, while in the offshore vessels which constitute the main emission problem; renewable energy is evaluated within the scope of additional measures that increase efficiency in the short term. In addition, as a fuel alternative, hydrogen is a candidate for future ship fuel in the medium and long term.

Keywords: *Renewable Energy, Greenhouse Gas, Maritime, Ship, LNG*

1. INTRODUCTION

Since maritime transportation is a more convenient transportation method in terms of cost and efficiency than other transportation modes, therefore, it is the most used mode of transportation and its place in the sustainable global economy is very valuable. In the maritime sector, the usual expectation of stakeholders is that transport must be cheaper, faster and more sustainable. However, international maritime transport is a global system in which safe, fast and green transport efforts are interconnected in different ways without a central decision-making mechanism. In spite of the rapid development of technology such as satellite monitoring systems, incinerators, economizers, scrubbers, sewage and ballast water treatment units etc., this situation causes many serious problems such as marine pollution due to ship pollution, shipborne transport of biodiversity degrading species, fluctuation in fuel prices, changes in international trade routes, cyber-attacks, data theft and geopolitical stresses (IUMI, 2018). Another of these problems is "ship-based air pollution which is our research topic.

On a global basis, maritime trade volume has increased 2.5 times in the last 40 years, population density has increased by about 90% and energy consumption has increased by about 170% (Lindstad et al., 2015). This difference in acceleration results in the global warming and air pollution of harmful gases released into the atmosphere from the chimneys of the global maritime trade fleet, consisting of around 100,000 ships of various sizes. As a precautionary measure, reducing the volume of maritime trade is not an attractive option, and the idea of abandoning the conventional fuel used in the main power units of the ship, propulsion system during the execution of the transport business, has led to controversy around the world. The aim of this study is to find out which systems produce less pollution for maritime transportation such as solar energy, wind power, hydrogen, biofuels and liquefied petroleum gas.

2. VIEW OF INTERNATIONAL ORGANIZATIONS

IMO (International Maritime Organization), which is a member of the United Nations, directs the sector with approximately 98% of the global fleet in the areas of safety, security, pollution prevention, marine law, shipbuilding industry and technology. IMO's mission can be summarized as safe and secure life on board, pollution prevention and efficient transport (IMO, 2018). Regarding the emission problem mentioned in the above paragraph, IMO aims to become an international authority in the global maritime trade and industry.

One of the current issues that IMO has discussed and guided the sector in environmental pollution prevention committees is the use of low-emission alternative energy sources, including renewable energy types, in ship propulsion systems. In the area of maritime transport, the use of renewable energy sources in ship propulsion / propulsion systems, greenhouse gas emissions, which have become a serious problem for humanity, and global warming problems are one of the prescribed ways to solve these problems, although a clear solution strategy for ship-based air pollution is not yet developed (Bouman et al., 2017).

Although maritime transport is more economical per unit ton and more efficient at long distance than other modes; GHG (Green House Gas) emissions from ships account for 2.2 percent of the total emissions, with an increase in international cargo volumes, which is expected to increase by about 50 percent to 250 percent by 2050 (IMO, 2018). According to another scenario, Cames et al., are expecting emission rate to increase to 17 percent in 2050. In the same study, it is stated that the technical and operational measures to be taken regarding energy efficiency will contribute to the decrease of the increase acceleration of the amount of greenhouse gas emissions (Cames et al., 2015). IMO aims to reduce emissions by 20% by 2020 and by 50% by 2050 through measures taken globally (Hughes, 2016).

Therefore, IMO wants to contribute to global preventive activities by using an effective action plan such as focusing on greenhouse gas emissions from international maritime transport (IMO, 2018). The Maritime Environment Protection Committe (MEPC), a sub-committee of the IMO, first developed a Data Collection System for Fuel Oil Consumption of Ships that would provide the necessary discussion environment for a transparent and inclusive policy. Within the scope of the system, vessels of 5,000 gross tonnage or more, which are responsible for 85% of carbon dioxide emissions, are required to report their annual reports on fuel to the local authorities. The Environmental Ship Index (ESI), which includes consumption and transport parameters, is used in this reporting. The data collected according to ESI are sent to the common Ship Fuel Consumption Database. Information such as the index and the technical data of the ship, the process covered, the fuel expenditure, the transported cargo and the Energy Efficiency Design Index (EEDI), if regularly calculated by ships, are recorded in the "Energy Efficiency Management Plan (EEMP), which is required to be present on the ships. The relevant IMO MEPC 22A regulation entered into force on 1 March 2018 and became compulsory for all vessels of 5,000 gross tonnage and above. In addition, the IMO MEPC 73 committee meeting minutes requires that the "fuel oil" sulfur ratio used as a fuel in ships be below 0.50% by January 01, 2020, except for the emission control zones as seen in Table 1 (Hughes, 2016; IMO, 2018d). The establishment of emission-controlled zones under the umbrella of IMO-MEPC and the gradual implementation of the sanctions have attracted the experts, academics and investors of the sector.

Large vessels such as Post-Panamax and oversized tankers-container ships will install scrubbers on their funnels at the cost of $1-5 million. Small vessels will have to switch to the bunker called low sulfur gas oil with doubling the cost from "fuel oil high sulfur". The new rule will directly affect the carriers (ship owner and charterer) while indirectly to the shipper and the loaders. For example, since the "Bunker Adjustment Factor" has a positive impact on freight rate, then it will affect the customer through the freight rate. Since the new rules will bring new problems, only a permanent solution can contribute to sustainability. The issue can be summarized from a commercial point of view like this. However, since environmental pollution is the source of

the problem, maritime states (IMO members) have rules for the benefit of the society from an environmental point of view, even if they are against them commercially.

Table 1: Sulfur emission (SOx) upper limit values of ships according to navigation area (IMO, 2019).

SECA (SULPHUR EMISSION CONTROL AREA)	
Before 1 July 2010	%1.50 m/m
Between 1 July 2010 and 1 January 2015	%1.00 m/m
1 January 2015	%0.10 m/m
OTHER AREAS OUTSIDE OF SECA	
Before 1 January 2012	%4.50 m/m
Between 1 January 2012 and 1 January 2020	%3.50 m/m
From 1 January 2020	*%0.50 m/m*

3. AIM AND SCOPE OF THE RESEARCH

The research topic of this study is to investigate the feasibility of fuel types and energy sources, which may be an alternative to conventional fuel, as discussed in the solution of ship-based air pollution, in ship propulsion systems. In addition, it is aimed to evaluate the approaches of academic studies on conventional fuels and alternatives in terms of technical and economic aspects and thus to make a sectoral prediction. In addition, this issue is currently being discussed and the fact that it is not found in the literature sufficiently shows the importance of the research.

4. METHODOLOGY

The data of the study was obtained from "Science Direct" and "Scopus" international databases with the keywords of "Ship", "Renewable Energy", "Maritime", "Greenhouse Gas", "LNG. The search covers the period between 2005 and 2019, when the MARPOL 73/78 Annex VI on "Prevention of Air Pollution from Ships" came into force. 526 studies listed as a result of the search, upon preliminary assessment, specifically, technical and operational strategies developed to prevent greenhouse gas emissions, as well as 43 scientific studies on renewable energy sources to replace fossil fuels and additionally, greenhouse gas studies published by the International Maritime Organization (IMO) GHG Studies. Within the scope of this study, academic studies related to alternative energy sources that can be used in ships are grouped into hydrogen, solar energy, wind energy, biofuels and LNG (not renewable) according to the type of energy that they directly or indirectly emphasize. Other studies that are subject to emission reduction are tried to be excluded from the scope of the research.

Table 2: Classification of literature covered by the alternative energy sources

Alternative Energy Source	Studies
Hydrogen	(Cabrera, Lund and Carta, 2018), (Faber et al, 2009), (Michalski et al., 2018), (Freese, 2017), (Connolly et al., 2014), (Matulić, 2019), (Cames et al., 2015), (Lindstad, 2014), (Tronstad, 2017), (IPCC, 2006), (El-Gohary, 2013), (Clean North Sea Shipping Project, 2014), (Faber et al., 2009), (Tanç et al., 2018), (Breyer et al., 2017)
Wind Power	(Cabrera et al., 2018), (Jain and Jain, 2017), (Algarín, 2017), (Rehmatulla, 2017), (Haas et al., 2019), (Faber et al, 2009), (Bouman et al., 2017), (Haifeng Wang et al., 2013), (Michalski et al., 2018), (Freese, 2017), (Technical, 2012), (Zhang et al., 2014), (Rehmatulla et al., 2017), (Mander, 2017), (Connolly et al., 2014)
Alternative Energy Source	Studies
Solar	(Cabrera et al., 2018), (Jain and Jain, 2017), (Algarín et al., 2017), (Rehmatulla et al., 2017), (Ertay et al., 2013), (Burke and Stephens, 2018), (Haas et al., 2019), (Faber et al., 2009), (Blazquez et al., 2018), (Bouman et al., 2017), (Pata, 2018), (Wang et al., 2013), (Technical, 2012), (IMarEST and Colfax, 2015a), (Algarín et al., 2017), (Hua et al., 2019), (Xu, 2017), (García-Olivares et al., 2018)
Bio-fuels	(Tronstad et al., 2017), (Jain and Jain, 2017), (IPCC, 2006), (Rehmatulla et al., 2017), (Chong et al., 2018), (Ertay et al., 2013), (Algarín et al., 2017), (Connolly et al., 2014), (Kinto et al., 2017), (IMO, 2015), (Freese, 2017), (García-Olivares et al., (Burke and Stephens, 2018), (Cabrera et al., 2018), (Calleya, 2014), (Wan, 2018), (Rahim et al., 2016), (Psaraftis, 2016)

Research questions (RQ):

1. Is it possible to replace the conventional fuel currently used in the propulsion system with a renewable energy source?
2. Is there enough infrastructure to use renewable energy in maritime transportation?
3. Does renewable energy see sufficient interest and value in maritime transport?

4. Can liquefied natural gas (LNG) be used as an alternative energy in ship propulsion systems?

5. FINDINGS

There are potential barriers to achieving the goals set by the IMO. Rehmatulla and Smith (2015) investigated barriers to maritime transport in the energy sector and in low carbon strategies. Energy Efficiency Design Index (EEDI) parameters, regulations contained in the IMO International Convention for the Prevention of Pollution from Ships (MARPOL), the regulations of the IMO Convention on Marine Nitrogen and Sulfur Compounds were in the scope of their carbon-pricing scenarios. They justify that alternative fuels cannot be considered realistic until 2025. Their thought was the contribution of alternative energy sources to emission of greenhouse gas targets as 17% (Rehmatulla et al., 2017). IMarEST and Colfax predicted that alternative energy sources will reduce greenhouse gas generation by 75% in public areas in 2015 (IMarEST and Colfax, 2015). Calleya indicated that very few ships have LNG, biofuel and solar technology (Calleya, 2014).

Mander (2017) investigated the advantages and disadvantages of "wind energy and slow steaming" methods, which means wind energy to generate thrust, which is a more sustainable and reasonable solution rather than discontinuous solutions.

Biofuels, which have been discussed in the sector for a long time, reduce the emission of 50% -90% compared to the low sulfur marine gas oil (Connolly et al., 2014; Kinto et al., 2017). However, since the complexity of the mass production, storage and distribution processes of advanced biofuel projects increase costs, it is necessary to establish a supply chain with solid foundations (Burke and Stephens, 2018; Psaraftis, 2016; Rahim et al., 2016; Rehmatulla and Smith, 2015). New generation biofuel costs are much higher than fossil fuels. This means that if production and logistics costs are not substantially reduced, political incentives and support will be needed to ensure business continuity (Blazquez et al., 2018).

Hydrogen-containing fuel cells are an effective means of generating electricity with low carbon emissions (Lindstad, 2014). However, the hydrogen stock and the low volumetric energy density seem to be the disadvantages of fuel cells. It also requires additional infrastructure and system setup (Tronstad et al., 2017). It is stated in another study that greenhouse gas emissions would not occur when the energy stored in hydrogen fuel cells is converted into kinetic energy (Haas et al., 2019), but it is necessary to consider greenhouse gas emissions that occur in supply chain processes that occur until hydrogen supply. The methods of hydrogen generation differ. Methods such as renewable electrolysis, renewable natural gas or biomass gasification pave the way for different scenarios (Matulić et al., 2019).

The electric drive systems designed using hydrogen have a system in which the stored electrical energy is transferred to the electric motor. Greenhouse gas emissions depend on the source of stored energy. Therefore, the development of the infrastructure necessary to minimize the greenhouse gas emissions generated during the supply process of hydrogen may increase the flexibility of the industry. A study involving economic evaluations of electrical power plant system could not be found in the literature. However, the rapidly decreasing cost of batteries, electricity or fuel costs used for charging can accelerate the usage of fuel cells. (Matulić et al., 2019; Tanç et al., 2018).

In addition to changing the type of fuel, fuel expenditure can be optimized by improving the existing technology on the ship and/or by integrating renewable energy sources into the propulsion system. Energy efficiency can be increased while reducing the oscillation rate (Faber et al., 2009; IMO, 2018e).

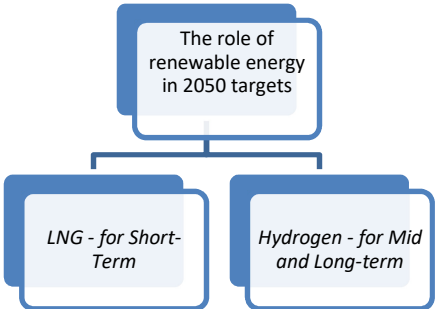

Fig. 1: Short and medium-long term solutions in the literature

As one of the renewable energy types, wind energy is preferred of both conventional sails and propulsion systems in modern designs. These designs include fletner rotors, kite system, soft sails, wing sails and wind turbines. In propulsion systems installed by these devices, wind energy often does not serve as the main propulsion component of a typical ship. However, in bad weather conditions where the intensity of the wind is high, the ship can reach the desired speed by saving fuel without using maximum power. A vessel operated entirely from wind energy can have a maximum carrying capacity of 3000 tons 10,000 tons in size for use on certain coastal voyages (Ertay et al., 2013; Jain and Jain, 2017). This quantity constitutes a small part of total carried freight.

Solar energy is used in propulsion systems of ships thanks to its ability to be stored in fuel cells. Due to the appropriate area boundary on the ship, it cannot be used as a main propulsion in strong and offshore vessels (Adams et al., 2018; Burke and Stephens, 2018; García-Olivares et al., 2018; Mander, 2017; Rehmatulla et al., 2017). Instead, hybrid sails can be used with other alternative fuel types such as LNG to save fuel (Jain and Jain, 2017). As the solar panels on the deck are subject to corrosion, the cost of installation, operation and storage should be taken into account, as shown in Fig. 2 (Bouman et al., 2017).

IMO's strategy includes vision, composition and guidance principles, short, medium- and long-term measures, their impact on possible processes and situations, barriers and supportive measures, followed actions, revised and developed strategies, periodic evaluation of these strategies (IMO, 2018f). The aim of this strategy is to take urgent steps to combat climate change and its impacts, as appropriate, to determine the actions to be taken by the international maritime transport sector, to address the impacts on states and to ensure the continuous development of international maritime transport and global maritime trade. Emphasis has been placed on identifying actions and measures to

help achieve the stated objectives, including incentives for research, development and monitoring of greenhouse gas emissions from maritime transport (Chen et al., 2019; Haifeng et al., 2013).

Options for reducing carbon emissions for ships can be summarized as; ship design is categorized into alternative fuel options, including renewable energy, flue gas improvement, improving fuel efficiency with ship design, improving fuel efficiency with machine selection, low-mileage, fuel improvements, improving conventional fuel quality, and renewable energy. Options to reduce carbon emissions in practice are; slow steaming, water emulsion in fuel, conventional fuel distillation, use of liquefied natural gas, diesel fuel particle filtration, use of high sulfur-containing exhaust gas scrubbers (Faber et al., 2009; IMO, 2018g; Lindstad et al., 2015).

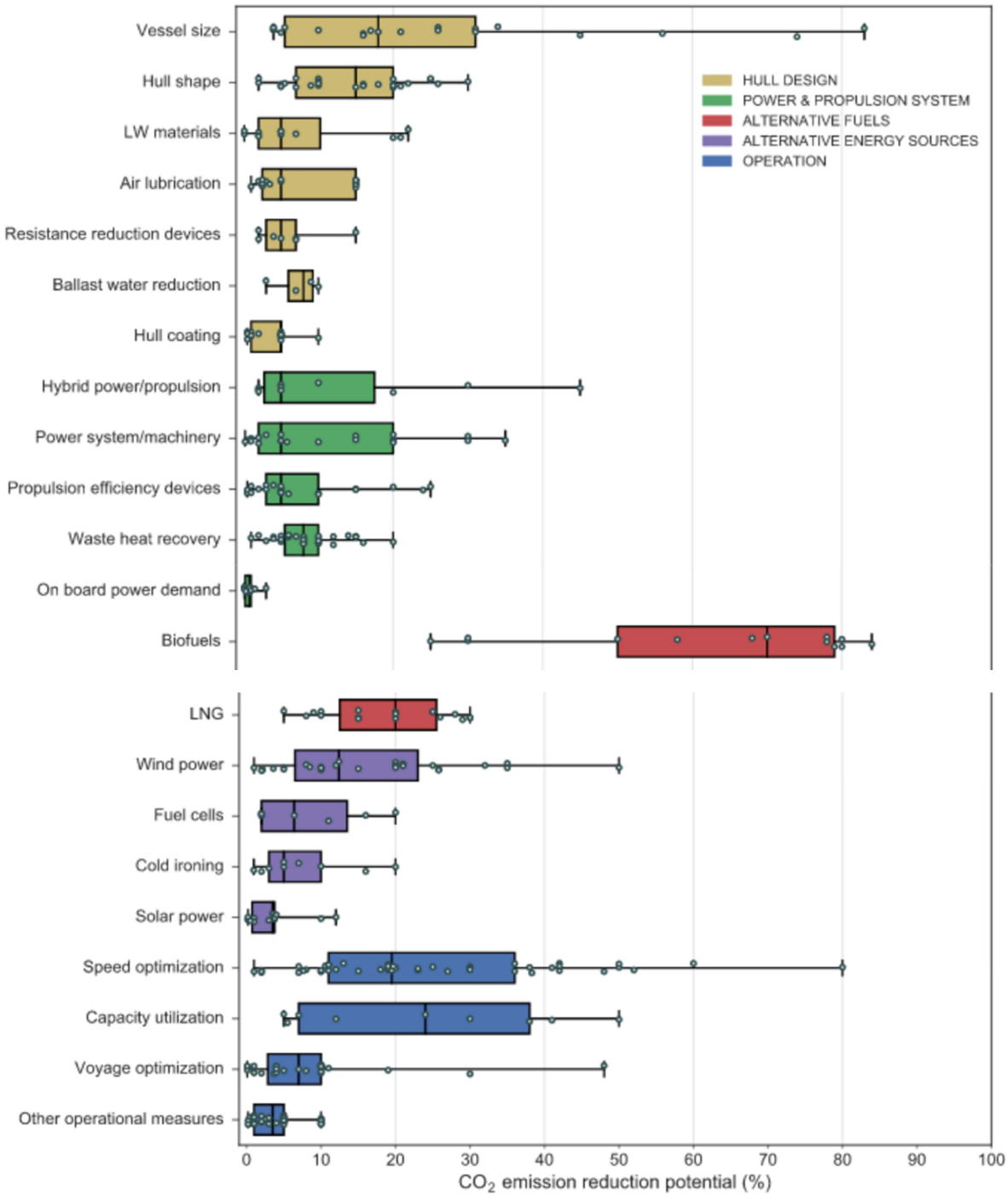

Fig. 2: CO_2 emission reduction potential from individual measures classified into 5 main categories of measures (Bouman, 2017).

Theoretically, although biofuels can reset renewable hydrogen and solar and wind energy greenhouse gas emissions, it is stated that alternative energy sources do not receive sufficient attention in the sector for technical,

economic and operational reasons (Wan et al., 2018). When studies on alternative energy sources in the literature are examined, "wind energy", "fuel cell", cold ironing "(using coastal connection instead of auxiliary machines in the port) and the reduction of greenhouse gas emissions of solar energy are 8-22%, 3-10%, 4-10%, 2%, 4% respectively (Bouman et al., 2017; Pekşen and Meter, 2014).

Super tankers, bulk cargo vessels such as post-Panamax type and oceangoing container vessels such as ultra large container ships (ULCS) most likely cause ship-induced greenhouse gas emissions (Freese, 2017). The steps taken to reduce greenhouse gas causes the oceangoing ships with powerful machines to take part in preventive activities until their economic life is completed (Zhang et al., 2014).

Based on these explanations and scientific studies, it can be inferred that current global maritime trade fleet which categorized in line with Fig. 2, current methods to reduce greenhouse gas emissions from the maritime trade fleet and to achieve targeted global warming values should mainly involve large tonnage offshore vessels. Although these measures are also short-term, long-term measures are possible with renewable energy as a fuel alternative regarding our RQ 1.

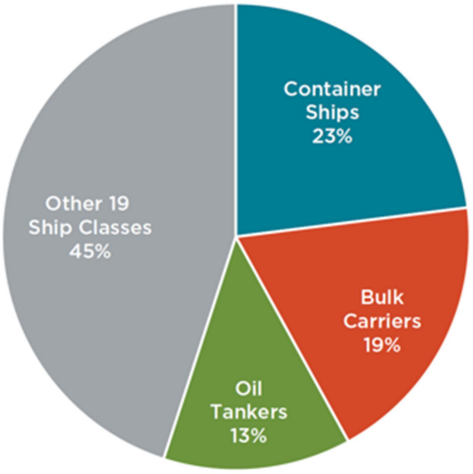

Fig. 3: Carbon emission values by ship types (Freese, 2017).

Our second research question regarding RQ 2 is that, considering the current literature and current conditions, the global energy supply network is intended for the transportation of fossil fuels and that the storage and distribution systems of renewable energy are not in a position to meet the potential demand in case of complete abandonment of fossil fuels. Comprehensive academic studies and simulation applications are needed. It is proposed that natural gas, which is not considered as a renewable energy source since its resources are limited, is considered as the most appropriate solution in terms of both emission value and efficiency in the short and medium term (Mosácula et al., 2019; Pierru et al., 2019). However, in the end, hydrogen can be used in combination with internal combustion diesel engines by spraying directly into the cylinder (Bouman et al., 2017; Morsy El-Gohary, 2013).

Regarding our third research question (RQ 3), it is seen that the projects realized by using completely renewable energy are generally used in small tonnage passenger ships. (Eyring et al., 2005; IMO, 2009; H. Lindstad et al., 2015; Mofor et al., 2015; El-Gohary, 2013; Wärtsilä, 2009) The obtained power is around 50 kW 300 kW and usability in large tonnage cargo ships is not appropriate. One of the most important reasons for this issue is that the limited surface of the ship deck is not suitable for installation of solar panels, masts and sailing equipment due to loading and unloading operations. Additionally, the limitations in storage electricity is a difficult problem to overcome. With the technological developments, it is expected that the battery costs will decrease (Breyer et al., 2017; Tanç et al., 2018). Considering this from an environmental point of view, in addition to technical and operational measures, the use of low-emission fossil fuels should be continued in ships that are currently being operated as a solution proposal for ship propulsion systems. In addition, as much as the free deck areas of the ship allow hydrogen from solar energy to be stored and integrated into the fuel system.

As regards our fourth research question (RQ 4), as shown in Fig. 5, liquefied natural gas (LNG) is used in today's ships at a rate that cannot be ignored (DNV, 2015; Deniz and Zincir, 2016). According to the 2015 report of the DNV-GL class organization, 63 vessels, including primary and secondary fuels, utilize LNG. High sulfur fuel oil and diesel are used in diesel engines. The alternative of these conventional fuels is that they can be easily adapted to the same internal combustion system, which will provide an economic advantage. LNG seems to be the first alternative today and in the near future as it meets this requirement and seems to be able to cope with the traditionally distilled fuel prices. As shown in Fig. 5, LNG has very low emission rates in the process from the storage tank (bunker tank) on the ship to the propeller, while the hydrogen obtained from the biodiesel and methane has high emission values. However, hydrogen derived from water is remarkable with relatively low oscillation values, although the energy capacity is relatively low.

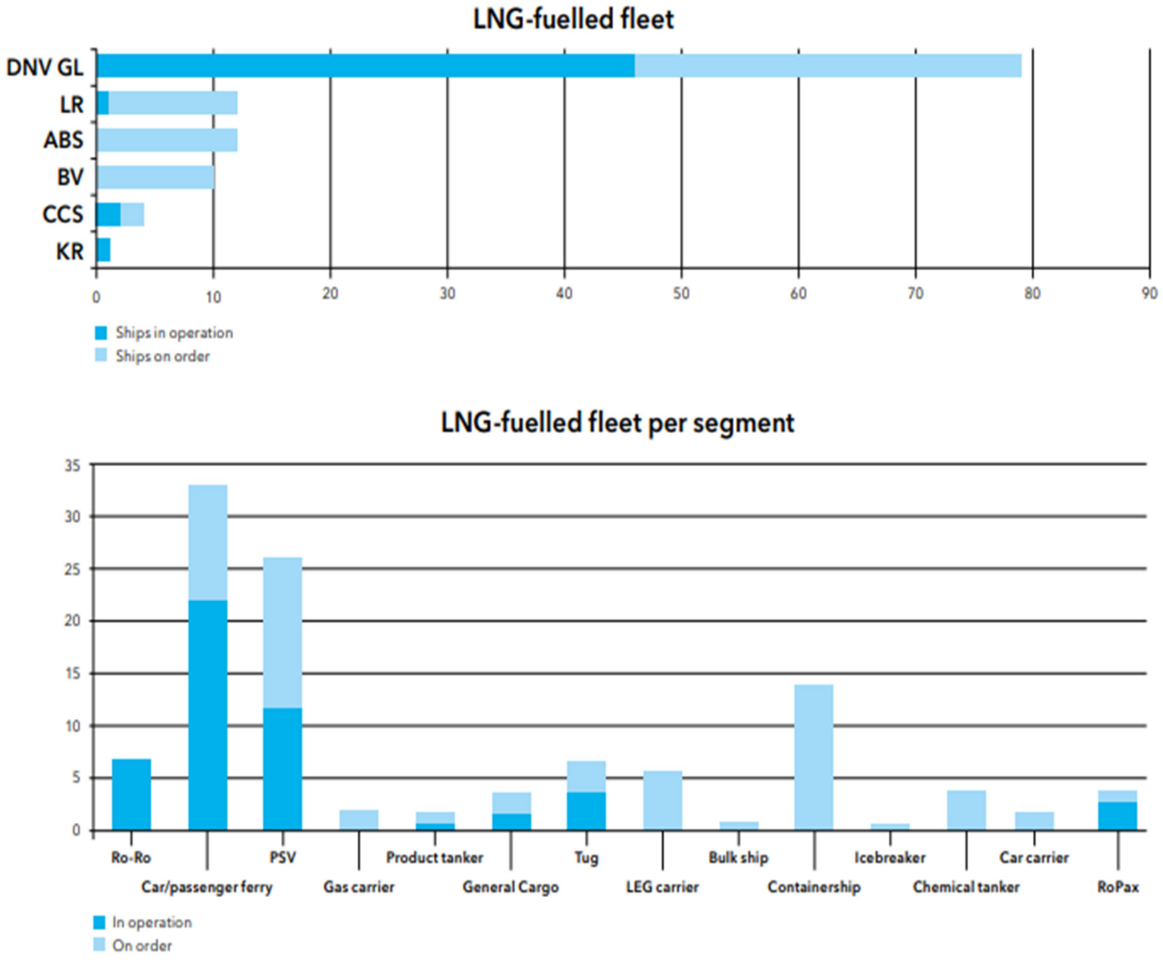

Fig. 4: LNG fueled fleet. Distribution of fleets with LNG propulsion (by class and segment) (DNV, 2015).

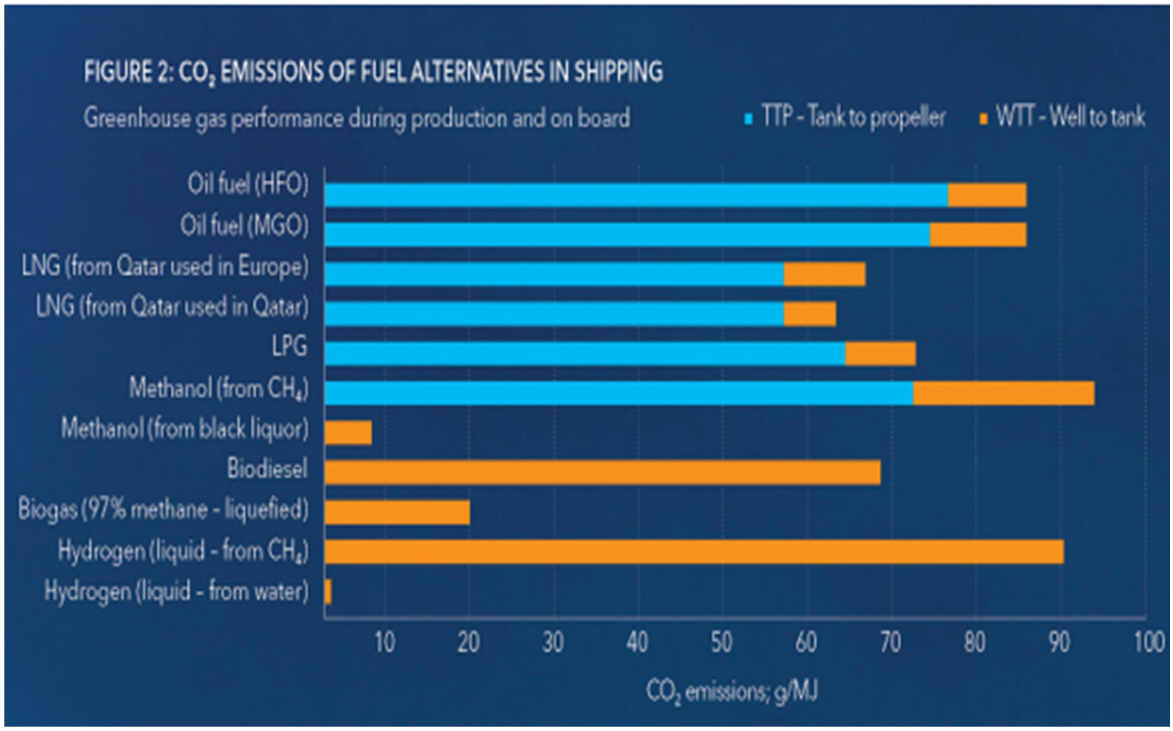

Fig. 5: Carbon emission values of fuel alternatives (DNV-GL, 2019).

6. CONCLUSION

In order to prevent airborne pollution caused by the ship, it seems there is not one energy source that reasonable sufficient. Several solutions need to be addressed together. The main reasons underlying this situation are the lack of homogeneity such as the limitation of solution alternatives, the inadequacy of each solution alternative, economic, political and operational barriers, differences in emission rates according to ship type and size, fuel type, and the characteristic structure of the marine routes used. While the alternative energy sources are given as one of the solutions in the data set examined, they are generally shown as additional measures to reduce emissions.

The increase in maritime trade indirectly increases greenhouse gas emissions. The important point here is not to narrow the global trade volume and to cause a crisis in price policies in order to reduce greenhouse gas emissions. Therefore, sector stakeholders will need to take initiative to achieve the optimum solution. One of the agenda items of the United Nations' IMO is to promote the use of alternative energy sources and to develop projects to prevent greenhouse gas emissions and indirect global warming. Therefore, smart, environmental and green-friendly innovations in the ship industry, operation and operation level, which are compatible with today's technology, should be realized.

Considering the current economic dimension of greenhouse gas emissions, it can be said that a system based on renewable energy sources will be cheap, solution-oriented and sufficient in the future (Kinto et al., 2017; Michalski et al., 2018; Pata, 2018; Xu et al., 2017).

Nevertheless, it is argued that electricity prices are likely to increase due to the increasing demand and disruptions in the supply chain, that the sector may lose its attractiveness and that the sector needs solution proposals in combination with fossil fuels (Blazquez et al., 2018).

Ship-induced greenhouse gas emissions mostly arise from super tankers, oceangoing large bulk cargo and post-panamax container vessels (Freese, 2017). The steps taken to reduce the greenhouse gas consist of partial preventive activities of the distant ships with powerful machines until their economic life is completed (Zhang et al., 2014). Therefore, the focal point of solution strategies should be the vessels offshore. Furthermore, the cost of technical solutions, the support of the sector to technical solutions, and the significant concerns in the use of performance-based indicators to reduce carbon dioxide emissions should be examined.

The obvious advantage and limitation of navigating by abandoning machine power is the necessity of additional operational measures due to the need for ships to accelerate as a result of improved market conditions and increased cargo traffic. The consolidation of renewable energy types in maritime transport seems to be possible with future hybrid systems, especially for oversized vessels. In this case, the most powerful fuel alternative in the short term is liquefied natural gas (LNG), which is not considered renewable, whereas in the medium and long term, hydrogen-containing fuel cells will be the actors of the new era.

The naval projects carried out with renewable energy in the project phase are exciting in today's literature. However, in order to achieve more realistic results, especially for capsize bulk carriers; super tankers and container ships, instead of searching for solutions with a single fuel alternative instead of heavy fuel, energy alternatives, efficiency with the aim of increasing the inclusion of projects will be more appropriate. Additionally, following the completion of the economic life of conventional vessels requiring relatively low power on shore navigation, the design of all new vessels to be constructed using solar and wind energy, especially the fuel cell containing hydrogen as the energy source, will contribute to the achievement of 2050 emission targets.

NOTE: This review article is a comprehensive version of the conference paper that presented previously in "8th national Logistics and Supply Chain Congress" titled "Energy Alternatives and Current Approaches for Ship Power Plants".

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LITERATURE REVIEW ON SUSTAINABILITY IN MULTIMODAL TRANSPORTATION

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ABSTRACT

There has been significant growth in research on sustainability issues and intermodal transport in freight distribution since the 1990s. However, when it comes to sustainability literature in multimodal transport it seems that there are very few publications. The aim of the study is to analyze the studies that examine sustainability in multimodal transport, which is the most sustainable transportation system. Therefore, the three key phrases, "multimodal transport sustainability", "intermodal transport sustainability", and "combined transport sustainability" have been scanned in seven separate databases and the studies obtained have been analyzed by content analysis method. The analysis reveals that railway transportation has prominently been used in the intermodal combinations, which seems to have contributed to gaining sustainability. It is also observed through the analysis that most of the studies have used case study method to analyze the sustainability of multimodal transport activities. Still another point revealed is that the social dimension of sustainability seems to have scarcely been analyzed in the sustainable intermodal transportation literature.

Keywords: *Multimodal Transportation, Sustainability, Content Analysis*

1. INTRODUCTION

The term of sustainability born was in 1987 in the Brundtland Report as a policy concept (Kuhlman and Farrington, 2010). Sustainability has three main dimensions as environmental, social and economic (Tanzil and Beloff, 2006); however, in time, it has started to be used to refer to practices that are more environment related (Heinberg and Lerch, 2010). In addition to that, in recent years, "sustainability" concept has attracted the attention from the media, the industry and the research community because of the concerns related to global warming and this has made the concept more popular (Hakam and Solvang, 2013). Until today, one of the biggest challenges for businesses that are trying to adapt to the information age by using many methods, tools, approaches and policies, especially with the advent of the information age, has been to adapt to sustainability approaches (Nazlı, 2006). Basically, "sustainability" concept can be defined as the management of resources with a view to continue for current generation and the generations to come (Kuş, 2012). The most common and most cited definition of sustainability was made in the Bruntland Report in 1987 by the World Commission on Environment and Development, which is "*Meeting the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987).

In 2010, "sustainability" was announced as megatrend by Lubin and Esty. McDonagh and Prothero (2014), recognized that at world's current consumption levels the planet cannot sustain so more or its carrying capacity for humanity ad infinitum. So, the importance of sustainability issues has increased highly in the last two decades. The etymological root of the "sustainability" term is based on the word "sustenere" (sustain) in Latin. Conceptually, it is based on forestry, fisheries and soil science and was first used in these branches of science. At the end of the 18th century, the German miner Carlowitz used it as the mining industry's masts to mean that timber plantations would be utilized in a way that would increase the productivity and sustainability (Aksoy, 2013). After that, the concept of sustainability has been associated with the renewable sources like agriculture ecology and fishery, in other words, the productivity related areas (Bozlağan, 2005). It has been described as "ability to maintain productivity despite obstacles" (Aksoy, 2013).

Sustainability concept has three dimensions which are; environmental, financial and social dimensions that are also referred as the triple bottom line of sustainability (Sislian *et al.,* 2016) or called three dimensions of sustainable development (Tanzil and Beloff, 2006). That triple bottom line is defined as 3P in several papers, standing for People, Planet and Profit. Similar to the triple bottom line of sustainability, the three dimensions of sustainable development are specified as economic growth, social progress, and stewardship of the environment (Tanzil and Beloff, 2006). Likewise, Litman (2014) also has summarized "sustainability" dimensions as economic, environmental and social. Litman has also added some sub-dimensions to those three main dimensions. The three main dimensions and their sub-dimensions are given in Table 1. Litman claims that a system must contain all those sub-dimensions to be sustainable (Kolak, 2015).

Table 1. Sustainability System Dimensions and Sub-Dimensions

Economic	**Social**	**Environmental**
Economic Productivity	Equity/ Fairness	Climate change prevention
Economic Development	Human safety, security and health	Air, noise and water pollution prevention
Resources Efficiency	Community development	Non-renewable resources conservation
Affordability	Cultural heritage preservation	Open-space conservation
Operational efficiency		Biodiversity preservation

Source: Kolak, 2015.

The economic dimension of sustainability deals with the economic conditions of businesses, their stakeholders, and their impacts on economic systems at local, national and global levels (GRI, 2013). The Economic Category demonstrates the capital flow between various stakeholders and the main economic impacts of businesses on society (GRI, 2013). There are four main aspects within the economic dimension, as economic performance, market presence, indirect economic impacts and procurement practices, and each of them meets different indicators that provide information about the development and economic impacts of the organization (GRI, 2013).

The social dimension of sustainability primarily focuses on human development; in addition to that, it deals with cultural and social necessities like; permanent establishment of basic requirements such as food and shelter, security, equality, health, freedom, education and employment (Eş, 2008). The social dimension of sustainable development is primarily concerned with reducing poverty, increasing social investments for everyone and building safe and secured communities. (Torjman, 2000). When policy makers develop future scenarios, the social dimension is generally neglected. However, considering the long-standing balance between social and environmental improvements in the market economy, environmental and social dimensions should be developed equally and from the very beginning of the process (Omann and Spangenberg, 2002). There are some other topics related with social sustainability in the current literature that include corporate social responsibility (CSR) and community involvement, as well as the company's position on issues involving women, ethnic minorities, gays, lesbians, bisexuals and transgenderists and disabled individuals (Ugbaja, 2016).

The environmental dimension of sustainability includes the reduction of people's negative impacts on environment and the protection of nature and ecosystems (Eş, 2008). Similarly, Ugbaja (2016), indicates that the environmental dimension of sustainability mainly focuses on preservation of natural resources. Environmental sustainability basically emphasizes that there are renewable and non-renewable resources in our world and humans must act sensitively in the use of all resources (Eş, 2008). To evaluate the environmental sustainability performance system is highly complex (Olaffson *et al.,* 2014) but it is unquestionably a significant concept in policy making

area (Dias, 2017).

2. SUSTAINABILITY IN MULTIMODAL TRANSPORTATION

Intermodal freight transport is a term used to describe the movement of goods in the same loading unit or vehicle, following each other without any action during transfers between multiple modes of transport as road, rail or water (European Conference of Ministers of Transport, 1993). The White Paper of the European Commission, called European Transport Policy for 2010 (European Commission, 2001), recommends the given necessary emphasis to promote intermodal transport, because it reduces the traffic congestion on the roads (Macharis *et al.,* 2007). In the international economy, all supply chain partners (manufacturers, distributors, consumers and transport users) must actively participate in the supply chain process to optimize flow of materials and products (Furtado and Frayret, 2015). Transport companies and third-party logistics companies should look for ways to provide different services for various products at a minimum cost, while at the same time becoming more sustainable (Furtado and Frayret, 2015).

When pros and cons of transportation modes are analyzed, flexible, door-to door and complementary to other transportation modes, road transportations look suitable for short distances with high value added and small volume loads, rail transportation is suggested for big quantity or high weighted goods for distances between 500km to 1200km, on contrary maritime transportation is suitable for very big quantities and over 1200km. distances (Frayret, 2012).

In the current literature, in 2007, Priemus *et al*. studied on the technological and organizational innovations in intermodal systems. They outlined the current multimodality problems of European freight transport and observed promising developments in terminals and networks in technological and organizational concept. MacHaris *et al.,* (2008) conducted a case study in Belgium and examined improvements in intermodals systems by using electric or hybrid trucks for the PPH operations. Their results demonstrate the high traditional costs of road transport, and their calculations show that their suggested system is feasible both organizationally and financially. How current trends affect the role and development of intermodal road-rail transport especially in Scandinavia has been examined by Bergqvist and Floden in 2010. They focused mainly environmental dimension of sustainability and they concluded using intermodal transport instead of road transportation, which is substantial to reduce CO2 emissions in Sweden. Behrends (2012) also conducted a case study and analyzed urban sustainability used the external costs of a single-modal road transport (Sweden between Gothenburg and Stockholm) versus potential intermodal alternative as sample and concluded that the integration of the intermodal terminal and the shippers' location in the urban structure is required to achieve desired sustainability performance of intermodal road-rail transport (IRRT). All three dimensions of sustainability have been analyzed by Furtado and Frayret in 2015. With the aim to present the freight network performance indicators to evaluate it, they demonstrated a preliminary model of intermodal resource sharing container transport network. Simha (2016), aimed to analyze freight transportation in India and conducted a case study which especially focused on economic dimension of sustainability. Qu et al. (2016), also carried out a case study that used eleven different locations in the UK and focused financial dimension of sustainability as well and they described an intermodal freight transportation model by taking GHG emission cost into account.

3. METHODOLOGY

In this study, content analysis method has been carried out to examine the studies on sustainability in the multimodal transportation concept. According to Hakam and Solvang (2013) the aim of the content analysis is to summarize existing studies by identifying patterns and issues. In line with the given definition of content analysis, the aim of this specific study is to analyze the studies that examine sustainability in the most sustainable mode of transportation which is multimodal transport. To reach this aim, an online search has been made in seven electronic databases that mainly publish maritime and transportation related studies and for which free access has been provided by Dokuz Eylül University, which are: Google Scholar, Ebscohost, Proquest, Science Direct, Scopus, Taylor & Francis and Web of Knowledge (Web of Science). The search terms "multimodal transport sustainability", "intermodal transport sustainability" and "combined transport sustainability" have been scanned for 30 years period through all databases from the period of 1987 to 2017 October. These three key phrases are shown in Table 2.

Table 2. The Search Key Phrases

Number	Corresponding Phrases
1	Multimodal Transport Sustainability
2	Intermodal Transport Sustainability
3	Combined Transport Sustainability

While conducting the scan, some criteria have been used to limit the search. Articles and conference proceedings have been included as source. There also has been a time limit in the search criteria. The literature between 1987 and 2017 has been screened, because as mentioned before, sustainability concept was born in the Brundtland Report of 1987 (Kuhlman and Farrington, 2010), so, 30 years of literature has been determined as acceptable. All scans included in the title of the studies have been carried out, with "containing all of the words" condition. Each key phrases and the relevant paper count are given in Table 3 for each database.

In sample selection process, first the studies, selected through the literature survey, have been analyzed in detail; then, irrelevant studies have been chosen according to their subject, and these studies scanned through different databases have been separated, at the end, the sample of the study has been identified as nine studies. These nine studies have been examined by means of content analysis.

Table 3. Number of Studies Available in Multimodal Sustainability Related Publications from Different Electronic Databases

Key Phrases/ Databases	**Google Scholar**	**Web of Knowledge**	**Ebscohost**	**Proquest**	**Science Direct**	**Scopus**	**Taylor & Francis**
Multimodal Transport Sustainability	1	3	2	4	2	4	1
Intermodal Transport Sustainability	4	3	7	6	3	4	3
Combined Transport Sustainability	0	0	2	0	0	0	0

Content analysis is one of the qualitative research techniques and is used widely describing a family of analytic approaches ranging from impressionistic, intuitive, interpretive analyses to systematic, strict textual analyses (Rosengren, 1981). Mayring (2000), has defined qualitative content analysis as "*an approach of empirical, methodological controlled analysis of texts within their context of communication, following content analytic rules and step-by-step models, without rash quantification*". Walcott (1994) argues that the most significant difference between qualitative and quantitative research methods is the data analysis process. The researcher conducting the qualitative analysis, aims to discover and reveal the information hidden in the data by taking the data collected from the field (Özdemir, 2010). In content analysis, the researcher primarily develops categories related to the research topic, then counts the words, sentences or pictures that fall into these categories in the data set that has been examined (Silverman, 2001). Qualitative content analysis enables researchers to understand social reality in a scientific way; searching for the underlying meaning of physical messages; it is based on the analysis of topics and themes, as well as the interpretation of data extracted from them (Kaid and Wadsworth, 1989). Although it is a single method, existing content analysis practices can be examined in three different approaches, the main differences between which are coding schemes, the origins of codes, and threats to reliability: traditional, directed, or summative (Hsieh and Shannon, 2005).

- In conventional content analysis, coding categories are derived directly from the data in the text.
- Directed content analysis begins with the findings of a theory or related research to guide a first theory.
- Summative content analysis usually involves counting and comparing keywords or content (Hsieh and Shannon, 2005).

Main differences among these three techniques are given in Table 4.

Table 4. Major Coding Differences Among Three Approaches to Content Analysis

Type of Content Analysis	**Study Starts With**	**Timing of Defining Codes or Keyword**	**Source of Codes or Keyword**
Conventional content analysis	Observation	Codes are defined during data analysis	Codes are derived from data
Directed content analysis	Theory	Codes are defined before and during data analysis	Codes are derived from theory or relevant research findings
Summative content analysis	Keywords	Keywords are identified before and during data analysis	Keywords are derived from interest of researchers or review of literature

Source**:** Hseih and Shannon, 2005.

Summative content analysis has been used in this specific study. A study that uses a summative approach begins with the definition and digitization of specific words or content in the text in order to understand the contextual use of words or content (Holsti, 1969). The purpose of this analysis is to focus on discovering the underlying meaning of words or content (Babbie, 1992).

4. FINDINGS

4.1. Total Number of Publications per Year

Annual distribution of studies in sustainability and intermodal transportation literature is given in Figure 1. According to this figure, most of the studies were published in 2016. However, when it is compared to the studies in other areas like Sustainability in Supply Chain Management, the number of studies in 'Sustainable Supply Chain Management' key phrase, is "1245" in just Google scholar database, the number of multimodal sustainability studies in current literature has been found to be very few.

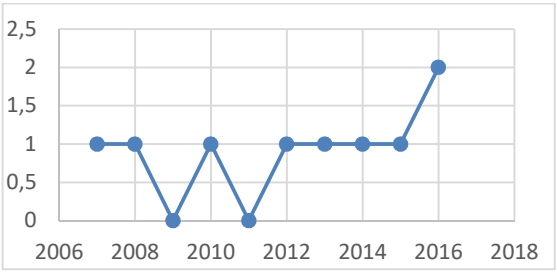

Fig. 1. Total Number of Publications per Year

4.2. Publication Types of the Studies

As for the types of academic publications, it has been concluded that four of them are conference proceedings and five are articles. However, one of the examined articles has been published as an expanded summary, not full text.

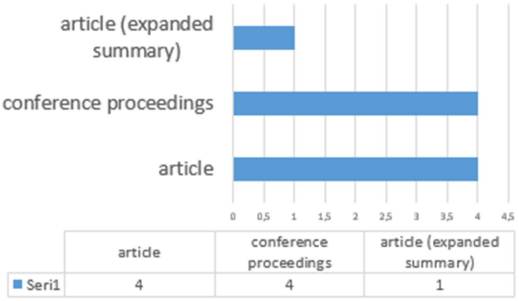

Fig. 2. Publication Types of the Studies

4.3. Journals That Have Published Intermodal Sustainability Studies

According to the content analysis results, only four common journals can be found, which are; Transportation Planning and Technology, Environmental Modelling & Software, Netw Spat Econ and Periodica Polytechnnica Transportation Engineering.

4.4. Transportation Modes Used in The Studies

When the transport modes used in the studies are examined one by one, the most used mode has been the Roadway. However, the fact that the use of railroads is close to the roadway, it has taken place among the positive results of this study in terms of sustainability. Unfortunately, only seven studies contain information on the mode of transport used, no information is given in the other two studies. The detailed information on the other transport modes is demonstrated in Figure 3.

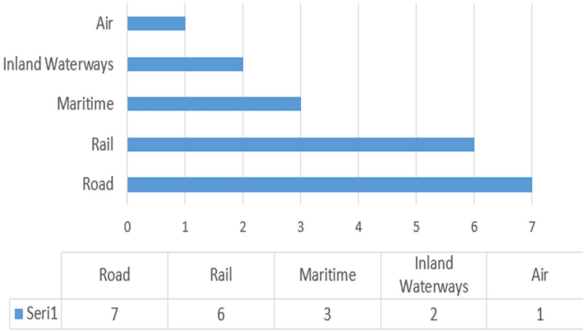

Fig. 3. Transportation Modes Used in the Studies

4.5. Transportation Mode Combinations Used in The Studies

As for the multimodal combinations of transportation modes used in the studies, road and rail transportation has become the prominent result. The other important combination obtained is road, rail and maritime transport. The detailed information on the other transport mode combinations is shown in Figure 4.

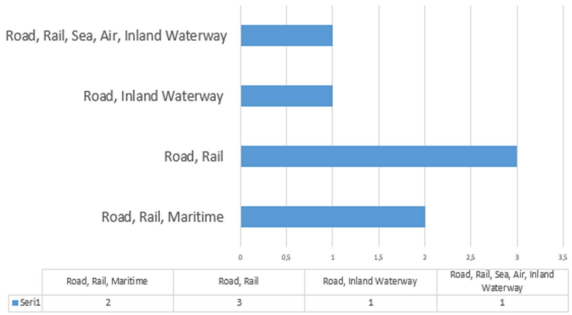

Fig. 4. Transportation Mode Combinations Used in the Studies

4.6. Sustainability Dimensions Included in the Studies

It has been determined that intermodal transport studies concentrate on environmental and economic dimensions of sustainability according to Figure 5. It is observed that the social dimension of sustainability is largely neglected.

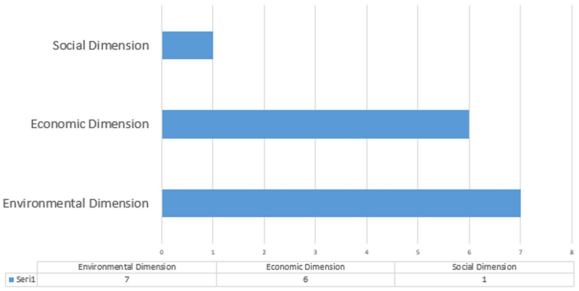

Fig. 5. Sustainability Dimensions Included in the Studies

4.7. Sustainability Dimensions Combinations Used in the Studies

In the case of sustainability combinations, it is observed that in parallel with the previous results in Figure 5, the studies jointly examine the economic and environmental sustainability dimensions. There are also a number of studies that examine just one dimension of sustainability.

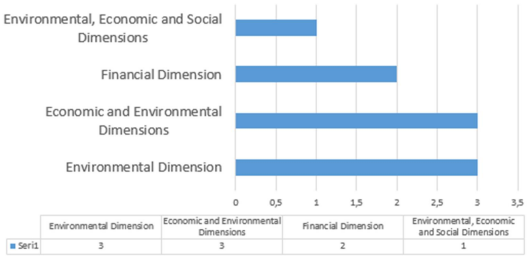

Fig. 6. Sustainability Dimensions Combinations Used in the Studies

4.8. The Main Subjects of the Studies

When the scope of the work is assessed, innovation, urban sustainability and infrastructure issues together with freight transportation draw attention as priority and specific issues as demonstrated in Figure 7.

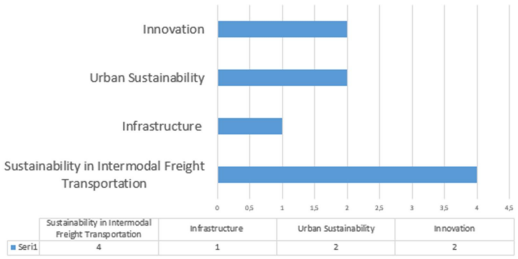

Fig. 7. The Main Subjects of the Studies

4.9. Geographical Areas Used in the Studies

According to the content analysis results, it is observed that most of the studies have used case study method to analyze the sustainability of multimodal transport activities. The main geographical areas that have been used in these studies are listed as follows; The United Kingdom, Argentina, Brazil, Sweden, Gothenburg, Stockholm, Belgium, Canadian cities; Quebec and Ontario, U.S.A, Rhode Island, Massachusetts, New Hmapshire, Pennsylvania, Vermont, Maine and New York.

4.10. The Methods Used in the Studies

As mentioned before, it is observed that most of the studies have used case study method to analyze the sustainability of multimodal transport activities. The other methods used in these studies are HIT (Heuristics Intermodal Transport) model, Agent based simulation and conceptual methods.

Fig. 8. The Methods Used in the Studies

5. CONCLUSION

The main aim of this study is to analyze the studies that examine sustainability in multimodal transportation, which is the most sustainable transport system. To the authors knowledge, there is no study reviewing sustainability approach in multimodal transportation. Therefore, the main motivation of the study is first, to examine the multimodal transportation studies in the concept of sustainability and to reveal the current shape of these studies, second, to identify the deficiencies and third to provide a road map to the researchers who wish to work in this field.

One of the main results of this study in terms of sustainability is the prominent use of railway transportation in the intermodal transport combinations. However, the geographies where the studies have been conducted such as; The United Kingdom, Sweden and New York are developed countries in terms of having railway infrastructure and transportation system. Therefore, it is thought to be useful to compare and contrast the samples of less developed and developing countries in terms of sustainable multimodal transportation. Although there are many theoretical studies in the literature (World Commission on Environment and Development, 1987, Pagell and Wu, 2009, Lozano and Huisingh, 2011, Özispa and Arabelen, 2018), about the importance of considering 3 basic dimensions of sustainability together in practice the studies mainly get interested in economic or environmental aspects of sustainability. Likewise, we have found that just one study has evaluated sustainability in terms of all three dimensions of it. Especially, the social dimension of sustainability has scarcely been analyzed in the sustainable intermodal transportation literature. Current literature claim that the social dimension of sustainability is the most neglected dimension in many sectors (Geibler *et al*, 2006; Oman and Spangenberg, 2002). Geibler *et al.,* 2006, state that due to the abstract and qualitative nature of social sustainability, the provision and measurement of social sustainability is seen as an important challenge for practitioners and they point out the necessity of measurement criteria on which consensus is reached. Likewise, for multimodal transport, which emerged as a sustainable transportation model, it is necessary to establish agreed criteria to obtain and measure social dimension of sustainability as well as economic and environmental dimensions of sustainability. Oman and Spangenberg (2002), have discussed the importance of an equal and balanced approach to environmental and social dimensions in order to ensure social sustainability. In line with this view, studies on sustainability in multimodal transport need to include all three dimensions of sustainability as the basis for and support to each other in order to meet the basic requirements of both multimodal transport and sustainability. Additionally, the case study method, the main purpose of which is to reach the "general" with the special case examined in detail (Deveci and Deveci, 2018), has been identified as the main analysis method used in the studies. It is thought that, to determine a prominent method used mainly in intermodal transportation sustainability studies is useful for literature in terms of creating a road map for future studies. Also, the lack of empirical studies in sustainable multimodal transportation literature is noticeable. So, it would be a lot better if the researchers who will work on this subject prefer conducting empirical methods.

The key phrases used in the study were searched within the name of the studies in all databases, and it is thought that it would be beneficial to make literature searches in keywords or in the whole document. The limited time span is the main limitation of the study, so, the future studies can extend the time span and key phrases used in the studies such as "sustainable multimodal transportation, etc". Furthermore, it is considered that conducting studies to investigate what social, economic and environmental sustainability criteria should be for multimodal transport will contribute to both practitioners and the current literature.

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