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MARITIME TRAFFIC ANALYSIS OF THE IZMIT BAY BY IWRAP

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Abstract. Izmit Bay has a growing trade volume which result with increase in the vessel traffic and establishment of new ports. According to recent statistics, the amount of handled cargo is approximately 61 million tonnes. Due to its crucial geographical position, it is the most significant and the biggest natural bay in Turkey. Therefore, vessel condition, environmental factors and other navigational issues that influence risk has an important role in the region. A compulsory pilotage service is provided and VTS services about to commence. Heavy ferry traffic encounters with transit traffic, run from one side to other of the bay which create immense danger for cargo vessels. A suspension bridge construction commenced and will be completed soon to shorten travelling distance around the bay. Bridge construction and legs of the bridge narrowed the marine traffic lane at the entrance of the bay. Navigators have to struggle with the risks based on their own experience. Hence, VTS services intended to improve navigation safety and regulate maritime traffic. There are few major marine accidents in the past despite of increasing dense maritime traffic. Nevertheless, there are not many academic study focus on maritime traffic, navigational risk and risk mitigating counter measure in the region. In this study, probabilities of marine accidents that would influence safe of navigation in Izmit Bay are investigated by utilizing IALA Waterways Risk Assessment Program (IWRAP). IWRAP is a quantitative risk assessment model developed by IALA to quantify ship based risk by utilizing AIS data. Result of the study provide an understanding for dangerous parts of the bay in terms of collision and grounding probabilities.

Key words: Izmit Bay, maritime traffic, marine accident, IWRAP

1 INTRODUCTION

At present, 87, 6% percent of Turkey's foreign trade is carried out by maritime transportation. Hereby the commercial maritime transportation and ports consequently gained importance. In 2010, the total cargo handled in Turkish ports was about 115 million tonnes with an increase of 83% compared to 2003 and significant amount of the total cargo handled was import – export goods. Moreover, total amount of container transportation has increased up to 128% between 2003 and 2010 while the total amount in 2003 was 2.5 million TEU and 5.7 million TEU in 2010 (Erdoğan, 2011). Together with the 40 port management facilities and handling 62 million tons of cargo according to 2013 data, Izmit Bay has a significant share in these statistics.

Izmit Bay has a significant potential in terms of logistics sector due to its geographical position and also the city Kocaeli is the leading industrial centre in Turkey. The bay is geographically located between Istanbul and Kocaeli, it is also the east part of the Marmara Sea. The city of Kocaeli has a fairly significant role in Turkey's export and import because of the large hinterland in east and west directions which covers Kocaeli, Adapazarı and Istanbul. It is comprising various types of industries such as petroleum industry, automotive industry, clothing industry, pharmaceutical industry, chemical industry, cement industry, food industry and iron – steel industries etc (Bayraktutan & Özbilgin, 2013)

According to Eurostat statistics in 2011, Izmit is the 11th largest port in EU along with 55 million tonnes of total goods handled in gross weight (Lund, 2013). In 2012 and 2013, the port has handled 61.4 and 61 million tonnes of cargo respectively which corresponds %15,86 of total cargo handled in Turkish ports per year according to statistics of Turkish Chamber of Shipping (Deniz Ticareti 2013 İstatistikleri, 2014).

Izmit bay has a significant role in maritime trade of Turkey with 40 port facilities for various type of cargo such as LPG, chemical tanker, container, 50 ship yards, 8 fishing vessel shelter and 6 marina. Each year more than 10 thousand ship call the bay and 180 thousand ship movement with dense crossing local traffic, creates high risky in terms of navigational safety (Yurtören, Aydoğdu , Seta, & Atasoy, 2014). Hence due to the importance of Izmit Bay, in this research IWRAP Mk2 has been utilized to analyse the maritime traffic in the Izmit Bay for the commencement of Vessel Traffic Service (VTS) in the area. In 2014, the first Ports and Waterways Safety Assessment (PAWSA) workshop was held in Izmit and this IWRAP research is intended to be a crosscheck of PAWSA results.

In the literature, there are numerous number of academic studies regarding Golcuk earthquake and environmental pollution in Izmıt Bay. For instance Reilinger et al. (1999) conducted a study to predict ground motions arising from aftershock seismic activity with using GPS monitoring and elastic half-space model (Reilinger, et al., 2000). Barka (1999) tried to find out the Characteristics and background of Golcuk Eatrhquake and made an estimation about ground motions after the earthquake (Barka, 1999).

Deger et al. analysed the ground motions and its effects then detected the slimming plates of earth crust (Ozbakır, Ozeren, Ergintav, & Karabulut, 2014). On the other hand, Pekey et al. (2004) conducted a study about ecological risk assessment in Izmit Bay (Pekey, Karataş, Ayberk, Tolun, & Bakoğlu, 2004).

While it's possible to extend the list of such studies, there is just one study in the literature regarding maritime traffic of Izmit Bay. Yurtoren el al. (2014) conducted a study to analyse maritime traffic by using Automatic Identification System (AIS) data via Environmental Stress (ES) model (Yurtören, Aydoğdu , Seta, & Atasoy, 2014). There is no any other study available in the literature about Izmit Bay concerning maritime traffic, ship accidents or navigational safety issues. In this study, we aimed to determine the yearly probability of collision and grounding by using IWRAP (IALA Waterways Risk Assessment Program) via AIS data which has taken from Directorate General of Coastal Safety in 2014. And then analyse the bottleneck of maritime traffic to provide an insight to maritime authority, VTS and suggest counter measures for enhancement of the maritime traffic.

2 AIS (AUTOMATIC IDENTIFICATION SYSTEM) AND IWRAP

Risk analysis in maritime traffic is a necessity due to the extremely high risks involved. Determining and taking precautions of two main accident type which are grounding and collision has a fatal importance for ensuring safety at seas.

Before AIS was developed, ship tracks were plotted via radar images. Those images were used to determine traffic flow and traffic density in a specific area. This method is no longer used in conjunction with technological advances. Developing Automatic Identification System (AIS) was a milestone in risk analysis of maritime traffic.

AIS is the most reliable system to provide ship position and ship dynamic data with the current technology that use in maritime (Yurtören, Aydoğdu , Seta, & Atasoy, 2014). All ships over 300 gross tonnes which are navigating in international waters, all ships over 500 gross tonnes which are navigating inland waters and all passenger ships regardless of their tonnage must carry AIS in accordance with the regulations (IMO, 2014).

AIS is a system that came in to force as a result of IMO's (International Maritime Organization) performance advices in 1997. AIS is a transponder system working on VHF band. This system includes three types of information which are static, dynamic and voyage related information of the ship. IMO and MMSI (Maritime Mobile Service Identity) numbers, ship's call sign and name, type of the ship, length and beam, location of position fixing antenna such as GPS/DGPS static information. Time of signal transmit in UTC, course over ground, speed over ground, heading, navigational status (Not under command, constrained by draught, etc) are dynamic information. Ship's draught, type of cargo, destination port and ETA to destination port, number of persons on board, route plan-waypoints (optional) are voyage related information. (Mokhtari, Wall, Brooks, & Wang, 2007). The system automatically transmits those information to shore and other ships around. IMO's AIS resolutions are intended for ensuring safe navigation, environmental protection and integrating ships to Vessel Traffic Service Systems (VTSS) (Yurtören, Aydoğdu, Seta, & Atasoy, 2014).

The AIS was used in many risk assessment studies since it has first been utilized because of its usefull and reliable information. For instance Commander Brian J. Tetreault (United States Coast Guard) conducted a study about enhancing maritime safety and security by enhancing Maritime Domain Awareness (MDA) by using AIS tracking (Tetreault, 2005). Kurt D. Schwehr and Philip A. McGillivary analysed the contribution of AIS to oil-spill tracking and pollution monitoring (Schwehr & McGillivary, 2007). Moreover, Ingo Harre conducted a study about AIS, described the genesis of the systems, their operational and technical aspects, discussed the standard and extended applications and also its potential (Harre, 2000). In 2009, Heather M. Perez et al. analysed Texas State waters in terms of marine vessels emission estimation by using Automatic Identification System (AIS) (Perez, Chang, Billings, & Kosub, 2009). Along with the usefull and reliable data, it was inevitable to use AIS data on maritime traffic analyses.

The IALA working group was tasked to develop a generic port and waterway risk assessment model capable of being adapted for use in any specific port or waterway. In January 2002, Minimum Safe Distance" (MSD) tool was represented but there were some missing parts of this tool because the tool was not capable of calculating the collision and grounding probabilities in a specific waterway. In 2004 IWRAP Mk1 was developed as a result of these needs. IWRAP Mk I had been tested on the Straights of Bosporus, Tampa Bay, and parts of the St. Lawrence River but the results were not realistic and much higher than actual accident statistics in those Bays. In 2008 IALA developed and validated IWRAP Mk2 which was based on BaSSy ToolBox (GRISK). IWRAP Mk2 is capable of taking into account the risk reduction effect of Aids to Navigation and gives satisfactory results (IALA, 2009).

IWRAP is a quantitative safety assessment model which enables user to conceive yearly collision and grounding frequencies of a selected waterway. IWRAP software is recommended by International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) and approved by IMO.

IWRAP utilize AIS data to calculate yearly collision and grounding frequencies. While calculating these, IWRAP uses mathematical equations and Bayesian Belief Network (BBN).

At present the main approach used for static collision probability assessment is rooted in the researches carried in the 1970s by Fujii et al. (Fujii, Yamanouchi, & Mizuki, 1974) and MacDuff (MacDuff, 1974). According to this researchs, the probability of a collision is defined as follows:

$$N_o = N_G \times P_C \tag{1}$$

In the equation, N_o stands for "Frequency of Collision", N_G is the number of candidates that are geometrically on a collision course and P_C is "Causation factor" which means the probability of falling to avoid a collision while on a collision course.

2.1 Crossing Collision

Determining the collision canditates (N_G) while crossing is calculated via formula given below (Friis-Hensen, 2008):

$$N_G^{crossing} = \sum_{i,j} \frac{Q_i^{(1)} Q_j^{(2)}}{V_i^{(1)} V_j^{(2)}} D_{ij} V_{ij} \frac{1}{\sin\theta} \quad for\ 10^0 < |\theta| < 170^0 \tag{2}$$

$Q_i^{(1)}$ is number of movements of ship class *i* in the selected period of waterway 1.

$Q_j^{(2)}$ is number of movements of ship class *j* in the selected period of waterway 2.

The ship in waterway 1 is approaching the ship in waterway 2 with the relative speed of $V_{ij.}$

$$V_{ij} = \sqrt{\left(V_i^{(1)}\right)^2 + \left(V_j^{(2)}\right)^2 - 2V_i^{(1)} V_j^{(2)} \cos\theta} \tag{3}$$

$V_i^{(1)}$ = Velocity of ship class *i* in waterway 1
$V_j^{(2)}$ = Velocity of ship class *j* in waterway 2
θ = The crossing angle between two waterways

D_{ij} is the geometrical collision diameter shown in (4):

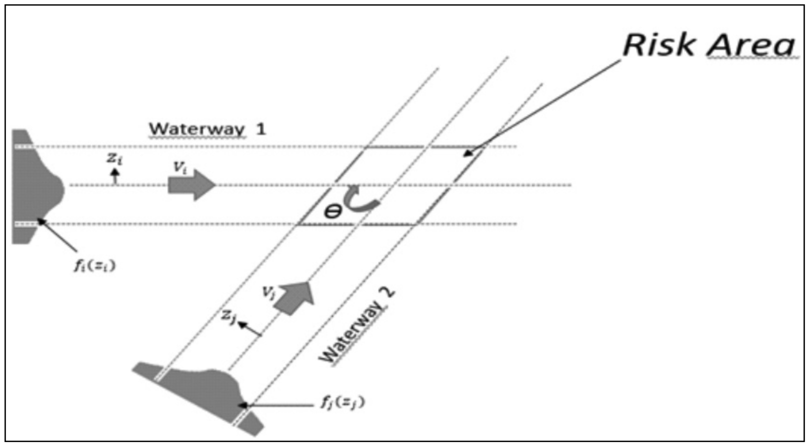

Figure 1 Crossing Waterways Risk Area

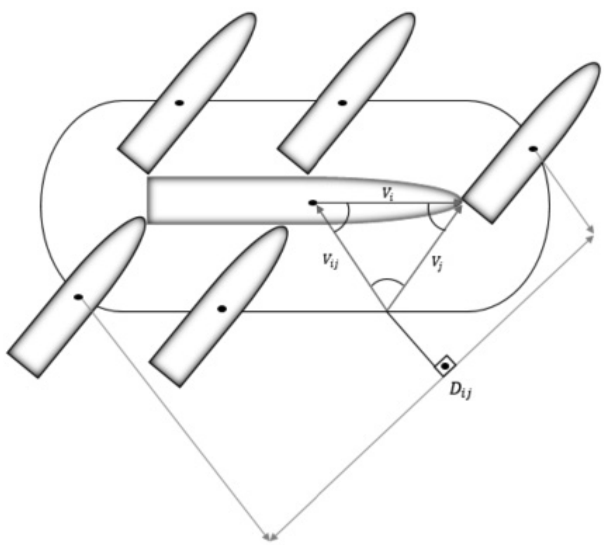

Figure 2 Geometrical Collision Diameter D_{ij}

$$D_{ij} = \frac{L_i^{(1)}V_j^{(2)} + L_j^{(2)}V_i^{(1)}}{V_{ij}} sin\theta + B_j^{(2)} \left\{1 - \left(sin\theta \frac{V_i^{(1)}}{V_{ij}}\right)^2\right\}^{1/2}$$

$$+ B_i^{(1)} \left\{1 - \left(sin\theta \frac{V_j^{(2)}}{V_{ij}}\right)^2\right\}^{1/2} \quad (4)$$

$L_i^{(1)}$ = Length of vessel class *i* in waterway 1
$L_j^{(2)}$= Length of vessel class *j* in waterway 2
B_i = Breadth of vessel class *i* in waterway 1
B_j = Breadth of vessel class *j* in waterway 2

2.2 Head on Collision

The number of head on collision candidates is calculated below (Friis-Hensen, 2008):

$$N_G^{head-on} = Lw \sum_{i,j} P_{G_{i,j}}^{head-on} \frac{V_{i,j}}{V_i^{(1)}V_j^{(2)}} \left(Q_i^{(1)} Q_j^{(2)}\right) \quad (5)$$

L_w = Length of the waterway

$$P_{G_{i,j}}^{head-on} = \Phi\left(\frac{B_{i,j} - \mu_{i,j}}{\sigma_{i,j}}\right) - \Phi\left(-\frac{B_{i,j} + \mu_{i,j}}{\sigma_{i,j}}\right) \quad (6)$$

Φ = Standard normal distribution function.
$P_{Gi,j}$ = Probability of two ships colliding each other in a head on situation
$\mu_{ij} = \mu_i + \mu_j$ is the mean sailing distance between two ships passing the waterway.
$\sigma_{ij} = (\sigma_i + \sigma_j)^{1/2}$ is the standart deviation from the joint distribution.

$B_{ij} = \frac{Bi + Bj}{2}$ is the average vessel breadth.

2.3 Overtaking Collision

The relative speed between two vessels in overtaking situation is given below:

$$V_{ij} = V_i^{(1)} - V_j^{(2)} \quad (7)$$

$$P_{G_{i,j\,(overtaking)}} = P\left[y_i^{(1)} - y_j^{(1)} < \frac{B_i^{(1)} + B_j^{(1)}}{2}\right] -$$

$$- P\left[y_i^{(1)} - y_j^{(2)} < -\frac{B_i^{(1)} + B_j^{(1)}}{2}\right] \quad (8)$$

For normally distributed traffic $\mu_{ij} = \mu_i - \mu_j$ number of overtaking collision candidates is calculated as if they are head – on collision (Friis-Hensen, 2008).

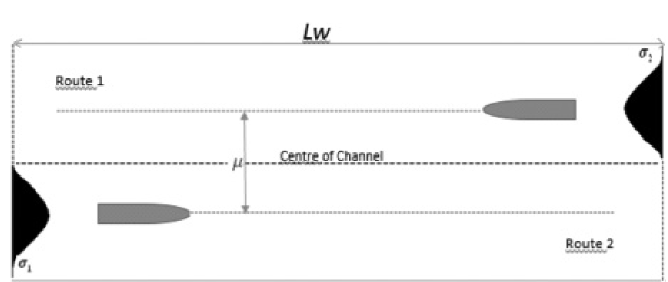

Figure 3 Parallel Waterways

2.4 Merging and Bending Collisions

A merging collision is a type of crossing collision but ship tracks have the probability of 0.5 to intersect. A bend collision occurs when the vessel do not turn at a bend of a waterway and come come across with another vessel at a collision course. The probability of bending collision is only 0.01 (Friis-Hensen, 2008).

2.5 Causation Factor

Causation probability can be estimated in two ways, these are the scenario approach and synthesis approach. Scenario approach is used if the probability is calculated on the basis of available accident data. The advantages of scenario approach are its simplicity and related robustness. In synthesis approach, specified error situations are supposed to occur in the vessel. They may cause an accident if they take place before or at the same time with the critical situation. Probability of those error situations are found by application of a Bayesian Belief network or by the use of a fault tree (Kujala, Hanninen, Arola, & Ylitalo, 2009).

The Causation Factor P_c is a factor which accident candidates has to be multiplied with to find estimated frequency of maritime accidents. The causation factor can be estimated via two methods which are scenario-based approach and Bayesian Belief Network (BBN) respectively (Trucco, Cagno, Ruggeri, & Grande, 2008).

$$P_C = \frac{N_C}{N_T} \tag{9}$$

N_C = Number of maritime accidents calculated for a selected period (eg. 5 years)
N_T = Number of maritime traffic in the selected period.

The study carried out by *Kwang İl Kim* and others shows that the causation factors in Mokpo waterway in the period of 2006 – 2010 are 8.4×10^{-5}, 8.1×10^{-5}, 7.1×10^{-5}, 9.3×10^{-5}, 1.7×10^{-5} respectively and total average causation factor in this selected period is found 6.4×10^{-5} (Kim, Park, & Jeong, 2011).

According to Kocaeli Port Authority Reports, there have been two collision accidents in Izmit Bay in the five year period 2009 to 2013 and in the same period, total ship moves was about 900.000.

According to formula, the collision causation factor for Izmit bay is found to be $2/900.000 = 2{,}22 \times 10^{-6}$

3 APPLICATION OF IWRAP TO IZMIT BAY

In order to analyse maritime traffic and the accident probabilities in Izmit Bay, the IALA Waterways Risk Assessment Program (IWRAP) tool has been utilized. The data of all vessels were collected via AIS. 3 months of AIS data has been obtained from General Directive of Coastal Safety Authority. Due to the size of the area and the number of ships and ship movements, three days of AIS data which correspond to 1.3 million data has been utilized in the study.

3.1 Research Area

Izmit Bay is geographically located between Istanbul and Kocaeli, it is also the eastern part of the Marmara Sea (Figure 4).

3.2 Investigation of Maritime Traffic

Yearly total number of ships visiting Izmit Bay is given with the Table 1.

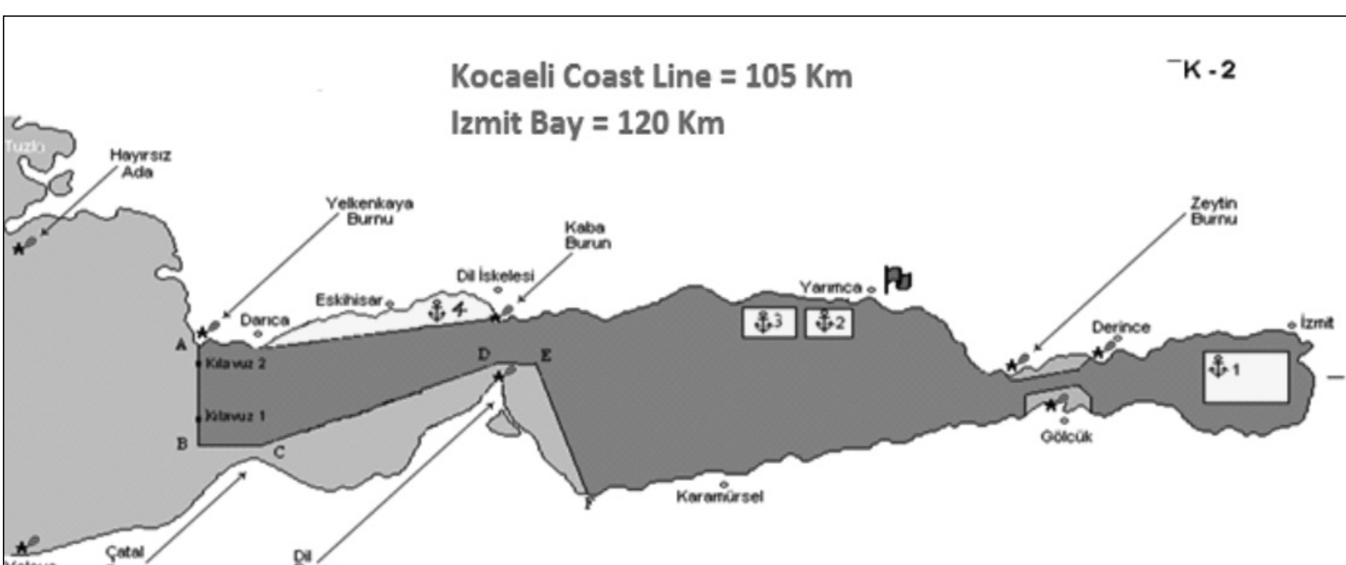

Figure 4 Izmit Bay

Table 1 Annual Ship Counts of Kocaeli Ports (Kocaeli Harbour Master, 2014)

Kocaeli Harbour Master Annual Ship Counts of Kocaeli Ports						
2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
13.237	12.457	11.575	11.133	10.573	10.644	10.627

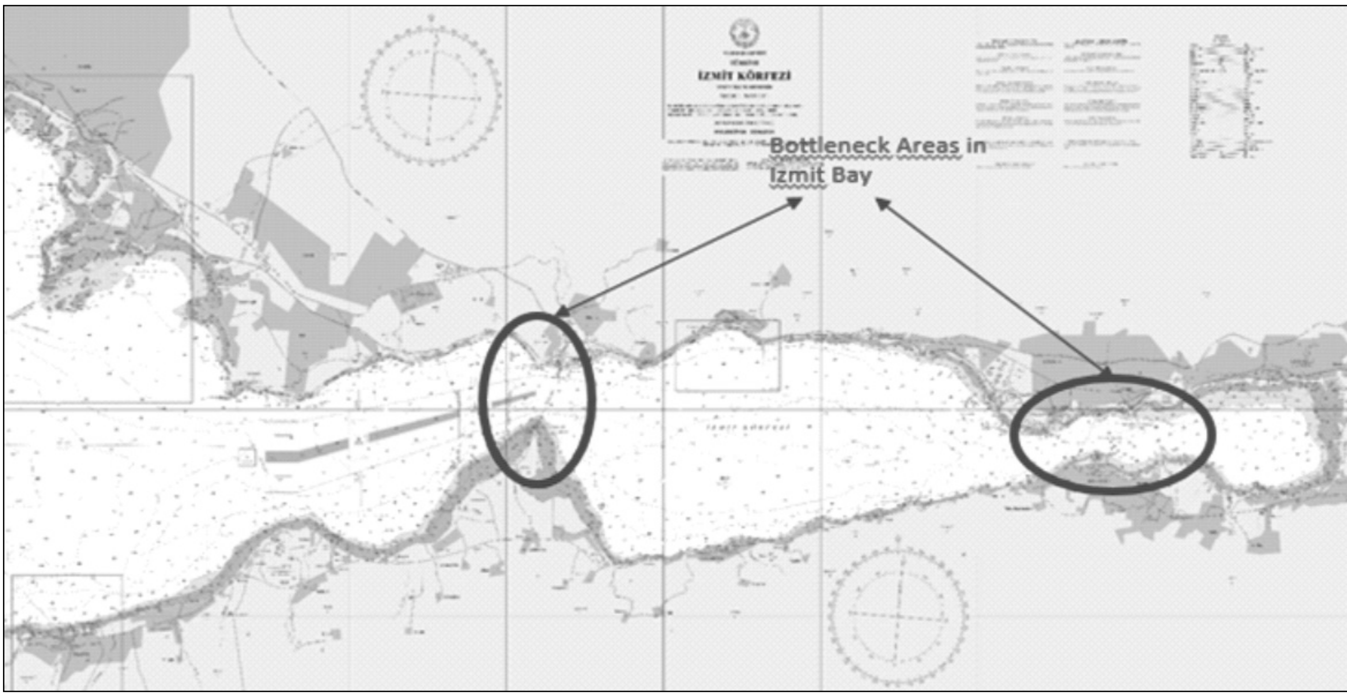

Figure 5 Izmıt Bay Bottleneck Areas

The number of annual ship movements in Izmit Bay is more than 180.000 together with the local traffic (Yurtören, Aydoğdu, Seta, & Atasoy, 2014). This huge traffic flow, creates a dense traffic in bottleneck areas especially in Kaba burun – Dil burnu and Zeytin Burnu – Derince – Gölcük.

In order to calculate the probability of collisions and groundings, navigation legs which are very similar to waypoints had to be created and then in each leg, density of traffic flow has been calculated by IWRAP.

In figure 6, created legs for scenario 20 and the density of traffic flow on each leg is shown.

After creating legs the IWRAP calculates the density of traffic flow and incident probabilities and based on this calculation, program calculates probability of collisions and groundings.

The program calculates crossing, overtaking, head on, merging and bending collisions and probability of groundings as well.

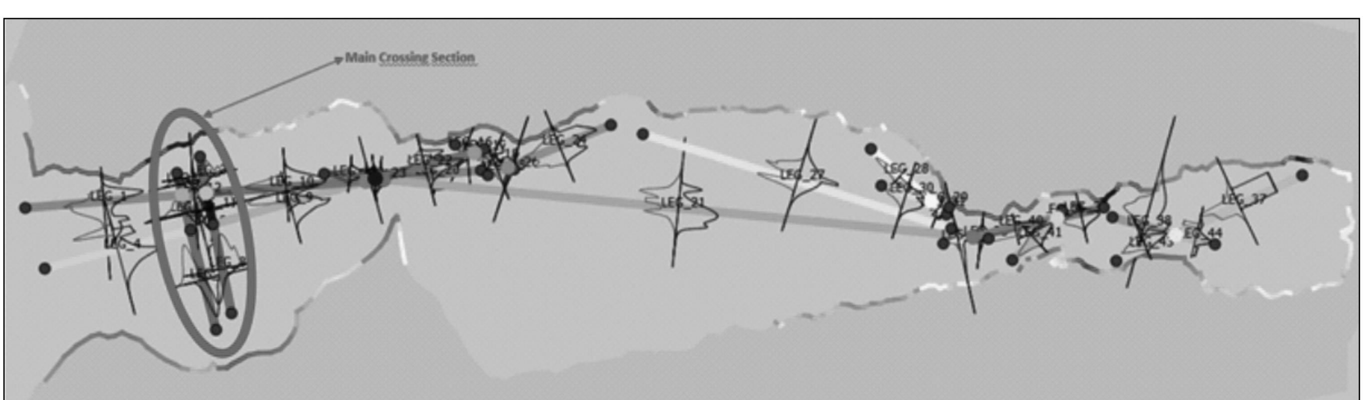

Figure 6 Main Crossing Section and Traffic Density in scenario 20

IWRAP has been utilized with 30 different leg scenarios. Mean value of this 30 scenario has been taken. Two of them has been shown in the research as an example (Figure 7 and Table 2, 3).

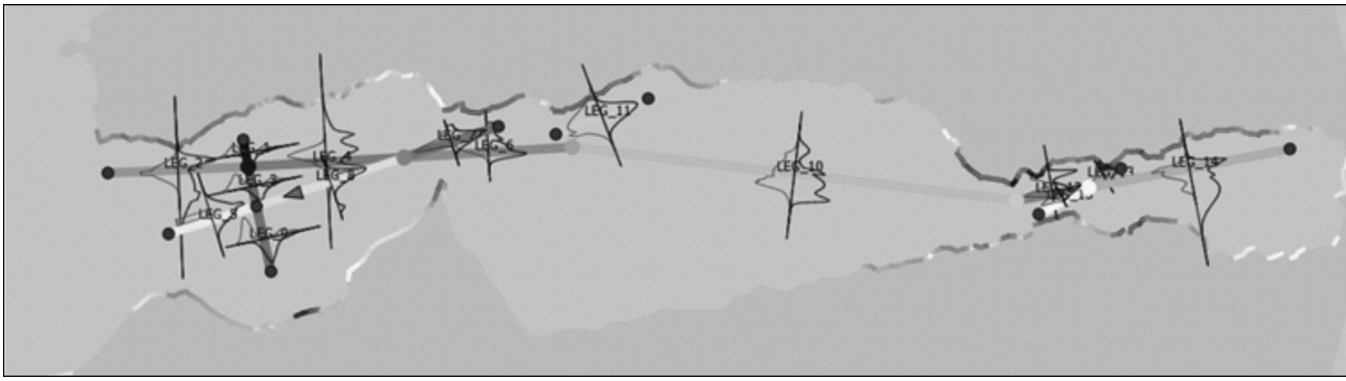

Figure 7 IWRAP Scenario 10. Distribution of Legs

Table 2 IWRAP Scenario 10 Results

	Izmit 10 Unit	
Powered Grounding	1,3965	Incidents/Year
Drifting Grounding	0,358	Incidents/Year
Total Groundings	**1,754**	**Incidents/Year**
Overtaking	0,0769	Incidents/Year
Head On	0,161	Incidents/Year
Crossing	0,041	Incidents/Year
Merging	0,0088	Incidents/Year
Bend	0,0251	Incidents/Year
Total Collisions	**0,313**	**Incidents/Year**

Table 3 IWRAP Scenario 20 Results

	Izmit 20 Unit	
Powered Grounding	1,893	Incidents/Year
Drifting Grounding	0,371	Incidents/Year
Total Groundings	**2,264**	**Incidents/Year**
Overtaking	0,0544	Incidents/Year
Head On	0,149	Incidents/Year
Crossing	0,0374	Incidents/Year
Merging	0,015	Incidents/Year
Bend	0,0036	Incidents/Year
Total Collisions	**0,2599**	**Incidents/Year**

The main ship crossing section is between Eskihisar and Topcular. Local ferry traffic and the inbound – outbound ships traffic intersect in this area. While total annual crossing collision number is 0,291 according to IWRAP scenarios in Izmit Bay, 0,166 of these collisions occur in the area between Eskihisar and Topcular.

While scenario 10 results are relatively higher than scenario 20 in terms of yearly collision numbers with 0.313 to 0.259, scenario 20 clearly indicates more groundings compared to scenario 10 with 2,264 groundings to 1,754.

To make a clear vision of total annual grounding and collision numbers, 30 different scenarios with different leg distributions are created and IWRAP utilized. Mean value of those different scenarios has been taken as a final result of IWRAP.

Created scenarios result table is shown in the graph below. IWRAP has been utilized with 1.3 million data which covers 3 days of ship movement data. The only difference between scenarios are leg distributions which is illustrated before by the example scenarios 10 and 20 (Table 4).

Table 4 Different Leg Scenarios and results table

Scenario Number	1	2	3	4	5	6	7	8	9	10
Powered Grounding	1,286	1,413	1,745	1,585	1,519	1,984	1,619	1,427	1,739	1,396
Drifting Grounding	0,312	0,462	0,421	0,364	0,343	0,298	0,386	0,302	0,398	0,358
Total Groundings	**1,598**	**1,875**	**2,166**	**1,949**	**1,862**	**2,282**	**2,005**	**1,729**	**2,137**	**1,754**
Overtaking	0,067	0,052	0,085	0,053	0,075	0,048	0,085	0,068	0,063	0,077
Head On	0,154	0,163	0,148	0,155	0,167	0,163	0,145	0,147	0,136	0,161
Crossing	0,038	0,041	0,046	0,038	0,021	0,031	0,028	0,048	0,043	0,041
Merging	0,006	0,012	0,018	0,032	0,013	0,020	0,018	0,021	0,013	0,008
Bending	0,021	0,018	0,033	0,022	0,043	0,038	0,020	0,012	0,023	0,025
Total Collisions	**0,286**	**0,286**	**0,33**	**0,3**	**0,319**	**0,3**	**0,296**	**0,296**	**0,278**	**0,313**

Scenario Number	11	12	13	14	15	16	17	18	19	20
Powered Grounding	1,562	1,894	1,256	1,764	1,347	1,614	1,473	1,198	1,374	1,893
Drifting Grounding	0,385	0,414	0,347	0,462	0,276	0,384	0,265	0,482	0,289	0,371
Total Groundings	**1,947**	**2,308**	**1,603**	**2,226**	**1,623**	**1,998**	**1,738**	**1,68**	**1,663**	**2,264**
Overtaking	0,081	0,054	0,058	0,071	0,076	0,049	0,061	0,067	0,048	0,054
Head On	0,153	0,128	0,174	0,143	0,138	0,164	0,161	0,149	0,151	0,149
Crossing	0,051	0,033	0,022	0,03	0,034	0,028	0,043	0,046	0,039	0,037
Merging	0,028	0,022	0,019	0,024	0,031	0,024	0,017	0,019	0,016	0,015
Bending	0,032	0,038	0,033	0,029	0,031	0,048	0,037	0,031	0,028	0,0036
Total Collisions	**0,345**	**0,275**	**0,306**	**0,297**	**0,31**	**0,313**	**0,319**	**0,312**	**0,282**	**0,258**

Scenario Number	21	22	23	24	25	26	27	28	29	30
Powered Grounding	1,598	1,547	1,657	1,958	2,021	1,252	1,542	1,478	1,638	1,427
Drifting Grounding	0,326	0,399	0,344	0,452	0,452	0,305	0,256	0,359	0,366	0,341
Total Groundings	**1,924**	**1,946**	**2,001**	**2,41**	**2,473**	**1,557**	**1,798**	**1,837**	**2,004**	**1,768**
Overtaking	0,064	0,086	0,081	0,057	0,054	0,063	0,052	0,028	0,056	0,086
Head On	0,121	0,137	0,182	0,166	0,142	0,155	0,157	0,138	0,152	0,175
Crossing	0,033	0,040	0,025	0,026	0,036	0,039	0,036	0,039	0,035	0,033
Merging	0,022	0,020	0,027	0,016	0,013	0,018	0,022	0,031	0,024	0,026
Bending	0,034	0,022	0,013	0,031	0,029	0,033	0,022	0,024	0,034	0,037
Total Collisions	**0,274**	**0,305**	**0,328**	**0,296**	**0,274**	**0,308**	**0,27**	**0,26**	**0,301**	**0,357**

Table 5 Total Mean Values of 30 Scenarios

Total Mean Values of 30 Scenarios	
Mean Powered Groundings	1,573
Mean Drifting Groundings	0,364
Total Mean Groundings	**1,937**
Mean Overtaking Collisions	0,0639
Mean Head On Collisions	0,1524
Mean Crossing Collisions	0,036
Mean Merging Collisions	0,0204
Mean Bending Collisions	0,0281
Total Mean Collisions	**0,3**

After scenarios created, mean value of all scenarios has been taken as final result. Mean value has been found for groundings as 1,937 and for collisions as 0,3 per year.

After completing 30 scenarios, we created a separate scenario pack with 5 different scenarios in terms of leg distribution and those scenarios include only the Eskihisar – Topcular area. As shown in the figure below, approximately 60% of the collision incidents and about 80% of groundings occur in this specific area.

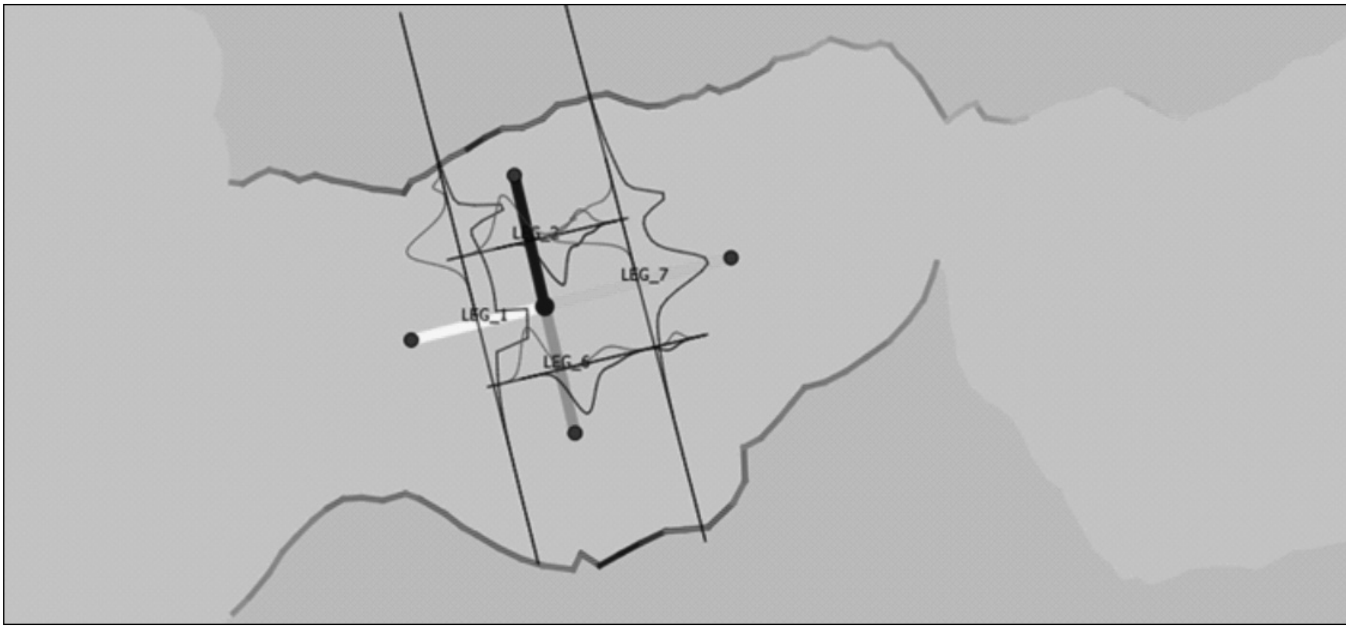

Figure 8 IWRAP Scenario 31 Eskihisar – Topcular. Distribution of Legs

Table 6 IWRAP Scenario 31 Results

	Izmit 31 Unit	
Powered Grounding	1,665	Incidents/Year
Drifting Grounding	0,069	Incidents/Year
Total Groundings	**1,734**	**Incidents/Year**
Overtaking	0,0538	Incidents/Year
Head On	0,108	Incidents/Year
Crossing	0,004	Incidents/Year
Merging	0	Incidents/Year
Bend	0	Incidents/Year
Total Collisions	**0,166**	**Incidents/Year**

In order to find mean value for Eskihisar-Topcular area, 5 scenarios with different leg distributions have been utilized. Results are below (Table 7):

Table 7 IWRAP Scenarios Eskihisar-Topcular Results

	Scenario Number				
	31	**32**	**33**	**34**	**35**
Powered Grounding	1,665	1,548	1,475	1,746	1,697
Drifting Grounding	0,069	0,073	0,056	0,064	0,076
Total Groundings	**1,734**	**1,621**	**1,531**	**1,81**	**1,773**
Overtaking	0,0538	0,0474	0,0615	0,0674	0,0463
Head On	0,108	0,097	0,136	0,112	0,101
Crossing	0,004	0,011	0,002	0,005	0,003
Total Collisions	**0,166**	**0,1554**	**0,1995**	**0,1844**	**0,1503**

Mean value of Eskihisar-Topcular area with 5 scenarios is found 0,171 collisions per year and 1,693 groundings per year.

Looking at the real accident numbers taken from Kocaeli Harbour Master reports, while collision frequencies matchs up with IWRAP results, grounding frequencies are slightly different.

Table 8 Izmit Harbour Master Accident Statistics

Izmit Harbour Master Accident Statistics (2009-2013)						
	2009	**2010**	**2011**	**2012**	**2013**	**Total**
Collision	-	1	-	-	1	2
Groundings	-	2	-	-	-	2

In ship-ship result table of IWRAP, we can see the collision candidates by its type (Figures 9, 10).

	oil	products tanl	cal	tar	ine	General cargo ship	cai	lo-Ro cargo shi	Passenger ship	Fast ferry	Support ship	Fishing ship	Pleasure boat	Other ship	Sum
Crude oil tanker															
Oil products tanker		0,0144844				0,0221617			0,0110158	0,000180912	0,00237491		2,2367e-06	0,000641788	0,0508618
Chemical tanker															
Gas tanker															
Container ship															
General cargo ship		0,0187237				0,0277489			0,00201012	0,00218848	0,00465247			0,000861228	0,0561849
Bulk carrier															
Ro-Ro cargo ship															
Passenger ship		0,00870047				0,0012991			0,134923	0,000421166	0,0343789		0,00115233	0,000503156	0,181378
Fast ferry		8,76798e-05				0,000753524			0,000178199	0,000296328	5,6989e-05			1,3153e-05	0,00138587
Support ship		0,00481893				0,00737124			0,00772157	0,000176485	0,00100491		1,3557e-05	0,00020494	0,0213116
Fishing ship															
Pleasure boat		1,58916e-07							0,000100224		2,76712e-06		1,44968e-07	8,551e-08	0,000103381
Other ship		0,000581748				0,00109855			0,000162219	5,00865e-05	0,000142461		2,69504e-07	7,63259e-05	0,00211166
Sum		0,0473971				0,060433			0,156111	0,00331346	0,0426135		0,00116854	0,00230068	0,313337

Figure 9 IWRAP Scenario 10 Detailed Schema

	oil t	Oil products tanker	cal	tar	ine	neral cargo sl	cai	carg	Passenger ship	Fast ferry	Support ship	Fishing ship	Pleasure boat	Other ship	Sum
Crude oil tanker															
Oil products tanker		0,0214466				0,0240056			0,00100074	0,000102523	0,00369161	2,3216e-05	2,1988e-07	0,00057773	0,0508483
Chemical tanker															
Gas tanker															
Container ship															
General cargo ship		0,0180771				0,02623			0,000808421	0,000510894	0,00323454	1,85322e-05		0,000610195	0,0494897
Bulk carrier															
Ro-Ro cargo ship															
Passenger ship		0,000731044				0,000694012			0,124869	0,000314503	0,0159196		0,000510184	0,0004838	0,143522
Fast ferry		3,19883e-05				0,00032391			0,000135678	0,00025144	3,44458e-05			1,89234e-05	0,000796386
Support ship		0,00411067				0,00238149			0,00477562	0,000101336	0,00149804	3,55905e-06	2,37693e-05	0,000122869	0,0130174
Fishing ship		3,50152e-05				5,23967e-05			1,78601e-06		9,69866e-06			4,61862e-06	0,000103515
Pleasure boat		2,1988e-07							9,44836e-05		1,01141e-05		3,12962e-07	5,40811e-07	0,000105671
Other ship		0,000540182				0,000911392			0,000288006	4,28627e-05	0,000193799	7,9204e-07	8,15776e-07	4,92575e-05	0,00202711
Sum		0,0449728				0,0545989			0,131973	0,00132356	0,0245919	4,60992e-05	0,000535302	0,00186793	0,25991

Figure 10 IWRAP Scenario 20 Detailed Schema

As shown in both tables, passenger ship collision probabilities are extremely high and refers to at least 40% – 50% of all possible collisions. The mean results of 30 different scenarios are the same with scenarios 10 and 20 values.

4 CONCLUSIONS

This paper gives a brief information about Izmit Bay and application of IALA Waterways Safety Assessment Program (IWRAP) to area. 1.3 million data which corresponds to 3 days of AIS data was imported to IWRAP and scenarios are repeated 30 times with creating different legs, default causation factors was used. After all 30 scenarios are completed, Eskihisar-Topcular area is found to be the highest risky are and a new 5 scenarios utilized to obtain detailed information about this area. According to IWRAP results, annual collision ratio in Izmit Bay is 0,3. Yearly grounding frequencies are found 1,937. Local traffic between Eskihisar and Topcular creates a crossing line to main inbound – outbound traffic so 50% of total collisions and 80% of total groundings in Izmit Bay occurs in this particular area. Passenger ships are the main collision candidates with approximately 50% of total collisions. IWRAP results are compared with real statistics taken from Kocaeli Port Authority and its found that results are compatible with real life situations in terms of collision frequencies. The results of this research has coincide with the results found in 2014 Izmit Bay PAWSA workshop which was utilized for identifying Vessel Traffic Service (VTS) control areas.

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