J. Black Sea/Mediterranean Environment
Vol. 16(2): 217-239 (2010)

An analytic hierarchy process approach to the analysis of ship length factor in the Strait of Istanbul

Analitik hiyerarşi süreci yaklaşımı ile İstanbul Boğazı'nda gemi boyu faktörünün incelenmesi

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Abstract

The Strait of Istanbul is an 'S'-shaped narrow channel of difficult nature with heavy, complex and irregular currents, and sharp turns. Due to these characteristics, the Strait is considered to be one of the most critical waterways in the world. The density of maritime traffic has increased from an annual count of 4500 ships in 1936, when the Montreux Convention was signed to regulate navigation in the Straits, to a current average of 54,000 vessels per year. This increase in traffic density has led to the rise in the number of maritime casualties.

In order to cope with this problem, Maritime Traffic Regulations in the Turkish Straits were established in 1994 and revised in 1998. In these regulations, the concept of a large vessel came to the fore and is defined in the definitions and abbreviations: Article 2. When considering the increase in length of vessels passing through the Strait of Istanbul, the question, 'What is a large vessel?' becomes important. This paper investigates what a large vessel is in terms of its length factor in the Strait of Istanbul. In this study, experts from VTS, pilot captains of the Strait of Istanbul and experienced captains are consulted.

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The AHP method is utilized to identify the quantitative importance of each efficient and some future works are suggested as a result of the findings.

Key words: Maritime traffic management criteria, decision making, AHP method, the Strait of Istanbul.

Introduction

The Strait of Istanbul, which is one of the world's densest regions in terms of maritime traffic, has for centuries assumed the duty of being a door serving the international shipping market. Since it links the Black Sea to the Mediterranean, it is of great strategic importance, not just for trade, but for political aspects as well.

The Strait of Istanbul is 18 miles (31 km.) in length and 700 meters at the narrowest points in width, there are numerous bends including one that require 12 course alterations for passing vessels. Some of these alterations are very sharp, in some instances more than 80 degrees (İstikbal 2006). Additionally, headlands which limit extended sight for a proper lookout, its narrowness, sharp turns, day-to-day changing currents and an unpredictable climate make it difficult and dangerous to navigate through the Strait of Istanbul. Not surprisingly, all these factors can quite easily cause vessels to collide or run aground.

In the year 1936 in which the Montreux Convention was signed and brought into effect, the number of vessels passed through the Strait of Istanbul was 4,700 (Akten 2003). However the present number of transit vessels increased to 54,396 (Republic of Turkey Prime Ministry Undersecretariat for Maritime Affairs 2003) per year. Due to the technological developments in the shipping industry and the opening of the Main Danube Canal which has linked the Rhine to the Danube, there has been a considerable increase in transit traffic (Ulusçu et al. 2008). The traffic in the Strait of Istanbul is about four times heavier than the maritime traffic in the Panama Canal (Akten 2003). The number of vessels passing through the Strait of Istanbul between 1982 and 2008 are presented in Table 1.

Table 1. Number of vessels passing through the Strait of Istanbul (Birpınar et al. 2009).

Year	Number of transit vessels	Year	Number of transit vessels
1982	12,983	1996	49,952
1983	12,767	1997	50,952
1984	11,006	1998	49,304
1985	14,271	1999	47,906
1986	12,103	2000	48,079
1987	11,557	2001	42,637
1988	12,092	2002	47,283
1989	11,805	2003	46,939
1990	11,445	2004	54,564
1991	12,085	2005	54,797
1993	20,260	2006	54,880
1994	18,720	2007	56,606
1995	46,954	2008	54,396

It must be noticed that the increase in traffic and vessel sizes have raised the likelihood and severity of accidents (Ulusçu et al. 2008). In order to ensure the safety of navigation, Maritime Traffic Regulations for the Turkish Straits and Marmara Region were adopted in 1994. Four years later, the rules were reviewed and Maritime Traffic Regulations in the Turkish Straits were accepted. The regulations include extensive provisions for safe navigation in the Straits.

One of the changes in the new regulations is the definition of large ships. In the second article of definitions and abbreviations, the description of a large ship is stated as follows:

'Big ship: ships that have a total length of 200 m or more' (Maritime Traffic Regulations in the Turkish Straits 1998).

Some provisions of the regulations state the rules that large ships must comply with. For instance; when the current speed is more than four miles/hour, large ships cannot enter the Straits as they cannot provide the necessary manoeuvring speed in reverse currents. Also, ships that have a length greater than 150 m are defined as ships that have difficulty in navigating in the traffic separation lane.

As seen from the above statements about the ship length, there is a length-interval at which the danger becomes apparent, but cannot be expressed for the ships navigating through the Straits.

Risk always exists for ships navigating through the Strait of Istanbul. This study tries to find the size interval at which there is increased danger based on the length of the vessel.

Methodology

Analytic Hierarchy Process (AHP), since its invention, has been a tool at the hands of decision-makers and researchers; and is one of the most widely used multiple criteria decision-making tools (Vaidya and Kumar 2006). It is designed to cope with both the rational and the intuitive to select the best from a number of alternatives evaluated with respect to several criteria. In this process, the decision maker carries out simple pairwise comparison judgments which are then used to develop overall priorities for ranking the alternatives (Saaty and Vargas 2001).

The form of matrix of the pair-wise comparisons is as follows:

$$A = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & A_3 & A_n \end{array} \\ \begin{pmatrix} w_1/w_1 & w_1/w_2 & w_1/w_3 \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & w_2/w_3 \cdots & w_2/w_n \\ w_3/w_1 & w_3/w_2 & w_3/w_3 \cdots & w_3/w_n \\ \vdots & \vdots & \vdots & \vdots \\ w_n/w_1 & w_n/w_2 & w_n/w_3 \cdots & w_n/w_n \end{pmatrix} \end{array} \quad (1)$$

The comparisons are made using a scale that indicates the importance of one element over another element with respect to a given attribute. Table 2 shows the scale ranges from 1 for 'least valued than' to 9 for 'definitely more important than.

Table 2. Saaty's 1-9 Scale for the pair wise comparison (Saaty and Vargas 2001).

Linguistic term	Preference number
Equally important/preferred	1
Weakly more important/preferred	3
Strongly more important/preferred	5
Very strong important/preferred	7
Absolutely more important/preferred	9
Intermediate values	2,4,6,8

In the basic structure of Analytic Hierarchy presented in Figure 1, the goal is specified at the top, all the objectives or criteria are listed below the goal and all alternatives are presented at the last level.

Some key and basic steps involved in this methodology are;

Step 1. Determine the problem.

Step 2. Structure the decision hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.

Step 3. Compare each element in the related level and establish priorities.

Step 4. Perform calculations to find the normalized values for each criteria / alternative. Calculate the maximum Eigen value, CI (Consistency Index) and CR (Consistency Ratio).

Step 5. If the maximum Eigen value, CR and CI are satisfactory, then the decision is made based on the normalized values. If not, the procedure is repeated until the values lie in the desired range.

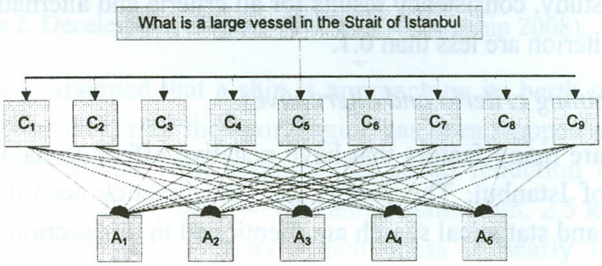

Figure 1. Basic structure of AHP.

Calculating the consistency

The consistency analysis is a part of the AHP method. It is applied in order to assure a certain quality level of decision. The measure of inconsistency can be used to successively improve the consistency of judgements (Saaty and Vargas 2001). The formula 2 and 3 is generated to determine the convenience of the numerical judgment. In this respect, we calculated the CR confirming Saaty, which is defined as a ratio between the consistency of a given evaluation matrix (consistency index CI) and the consistency of a random matrix. The consistency ratio (CR) is not less than 0.10, we study the problem and revise the judgements (Saaty and Vargas 2001).

$$CI = \frac{\lambda - n}{n - 1} \quad (2)$$

$$CR = \frac{CI}{RI} \leq 0.1 \quad (3)$$

Where *RI* is the average index of randomly generated weights and *n* is number of criteria or alternatives. Table 3 shows the average random consistent indicator RI of 1-10 judging matrix.

Table 3. The average random consistent indicator RI of 1-10 judging matrix (Saaty and Vargas 2001).

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

In this study, consistency results for all criteria and alternatives based on each criterion are less than 0.1.

Determining criteria and alternatives

There are many factors that have negative effect on navigation in the Strait of Istanbul. The factors put into practice according to expert advice and statistical search are mentioned in this section.

Firstly, 50 m- 100 m (A_1), 101 m- 150 m (A_2), 151 m- 200 m (A_3), 201 m- 250 m (A_4), 251 m- 300 m (A_5) ship length intervals are selected as the alternatives of the problem.

After determining the alternatives, criteria affecting casualties is categorized. There are 9 criteria such as: ship speed (C_1), loading condition of ships (C_2), wind effect (C_3), current effect (C_4), narrowness of the area (C_5), restricted visibility (C_6), the effect of pilot existence on board (C_7), local traffic (C_8) and turning circle of ship(C_9).

Ship speed

If a vessel is obliged to stop engine or reduce speed in case of a failure or dangerous situation in the Strait of Istanbul, the increase in ship length becomes important. Figure 2 shows deceleration diagram for different size of ships.

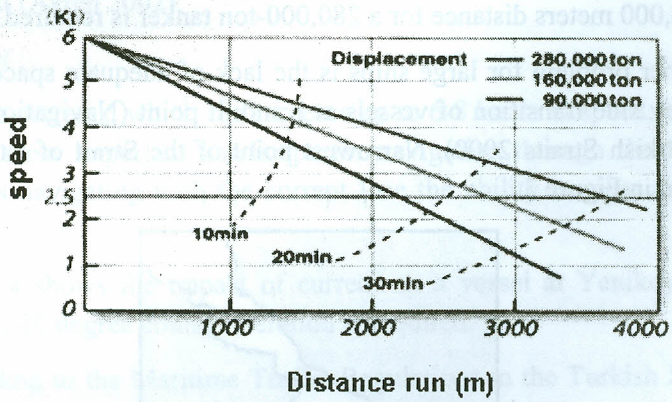

Figure 2. Deceleration diagram (The best seamanship 2008).

In Figure 2, it is assumed that a ship is approaching its berth using a deceleration maneuver, after the main engine has been stopped and the ship is making 6 knots. Time required for speed reduction is also shown as a function of displaced weight and distance run. 2.5 knots is the critical speed at which rudder effectiveness is nearly lost. A 160,000-ton tanker requires approximately 22 minutes or its speed to decelerate to 2.5 knots; while a 280,000-ton tanker takes approximately 30 minutes (The best seamanship 2008).

As seen from the diagram as the size of ship increases, the time required to reduce speed also increases.

Narrowness of the area

The Strait of Istanbul is risky in terms of geographical features; the narrowest part of the Strait is situated between Anadolu Hisarı and Rumeli Hisarı with 698 m (Birpınar 2008). Narrowness of the area is a problem in terms of ship length factor for vessels navigating through the Strait.

The distance required to stop gets longer as the vessel increases in size. Approximate distance covered by the time ship speed is reduced from 6 knots to 2.5 knots can be obtained from Figure 2 (The best seamanship 2008). 2,800 meters distance for a 160,000-ton tanker; and 4,000 meters distance for a 280,000-ton tanker is required.

Another problem for large ships is the lack of adequate space during side by side transition of vessels at Kandilli point (Navigation Safety of Turkish Straits 2000). Narrowest point of the Strait of Istanbul is shown in Figure 3.

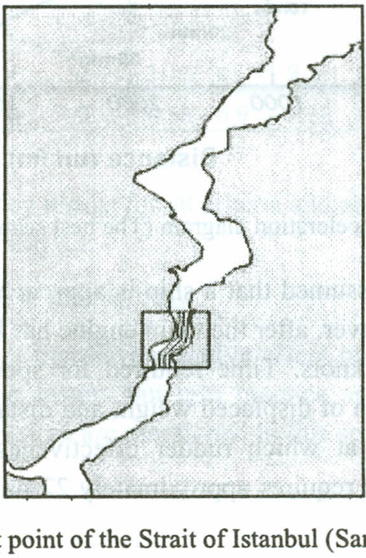

Figure 3. Narrowest point of the Strait of Istanbul (Sarıöz and Narlı 2003).

Loading Condition of ship

Loading condition of ship is important in terms of maneuvering ability. Turning ability and maneuvering abilities of large vessels deteriorate in full-load condition relative to ballast condition (The best seamanship 2008).

Dominant winds in the region

The wind effect on the superstructure above water limits the maneuvering performance of ships. The larger the ship, the wider the wind-exposed area is. Large ships are more vulnerable to danger because of increasing force affecting the maneuverability.

Moreover, the 6-7 knot north easterly winds are able to increase the current strength to 7- 8 knots in the narrow parts of the Strait of Istanbul. Surface current may change direction under strong southwest and northern winds and makes maneuvering and steaming of the ships difficult (Akten 2002).

Current

Surface currents, which can increase up to 6-8 knots in speed, are one of the most important handicaps for navigation through the Straits. Vessels navigating with the current lose the ability to steer (Istikbal 2006).

Figure 4 shows the impact of current on a vessel at Yenikoy point where a 80 degree course alteration is required.

According to the Maritime Traffic Regulations in the Turkish Straits, when the surface current speed cxceeds 4 knots, then large vessels which cannot provide safe manoeuvring speed will not enter the strait and must wait until the current speed is 4 knots or less. If the current speed is 6-7 knots or more, then large vessels will not enter the Straits (Maritime Traffic Regulations in the Turkish Straits 1998).

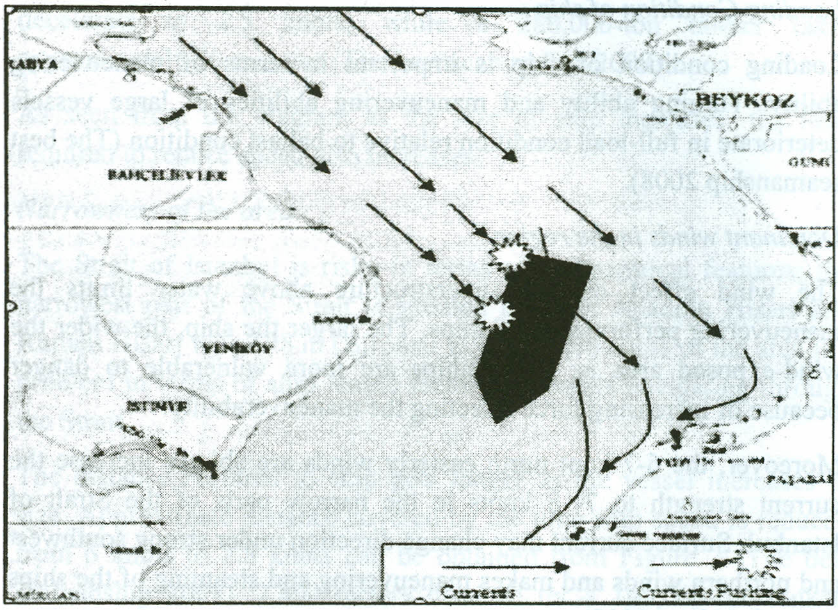

Figure 4. Current effect in the Strait of Istanbul (İstikbal 2006).

In case of a failure, the distance required to stop is getting longer as the vessel increases in size. As well as being a leading factor in accidents, currents cause an increase in danger due to the increase in vessel length.

Restricted Visibility

Another factor that greatly affects navigation in the Strait of Istanbul is restricted visibility. It is known that many casualties occur when the visibility drops to 1/2 mile or less in the strait. Low visibility causes casualties, especially in the winter (Akten 2004).

At the moment a vessel proceeding at a safe speed incurs danger; it immediately starts manoeuvring to avoid trouble. Reducing distance causes limited manoeuvring area.

A late realization of danger by reason of restricted visibility causes reduction of manoeuvring area. As the distance reduces, the increase in ship length triggers a decrease in time to escape from danger.

Existence of pilot on board

The pilot is entirely familiar with the special regulatory requirements and unique conditions that exist in his specific pilotage area. The Master of the vessel cannot be expected to be fully conversant of these regulations and conditions. The pilot is wholly familiar with all the local factors that might affect the navigation of the ship. These may include strong tidal flows, recent shoaling, ferry activity, dredging operations and other hazards (İstikbal 2006).

Existence of a pilot on board has a risk-reducing effect on transit vessels not familiar with other hazards related to ship length.

Local traffic

The density of local traffic has a negative effect on navigation in the Strait of Istanbul. Routes causing traffic density between the Anatolian side and the European side of the Strait are: conventional ferry transportation, sea buses, private passenger vessels, sports-fishing boats, yachts and military (Republic of Turkey Prime Ministry Undersecretariat for Maritime Affairs Publications, 2000).

When we consider that each floating vehicle forms a safe manoeuvring area around it, it is obvious that the size of the area is a positive function of ship length. In dense local traffic areas it is much more difficult for large vessels to maneuver.

Turning circle

Due to the winding shape of the Strait of Istanbul, big course alterations are required at Kandilli point (45 degrees), Yenikoy point (80 degrees) and Umur bankı (70 degrees) (Güngör 1999).

Figure 5 and Figure 6 shows the turning circle of a 260Kdwt VLCC and 6000 unit PCC ships in the Strait of Istanbul. The Strait is divided into 4 parts according to VTS sectors and only Sector Kandilli and Sector Kavak areas where consist of all the turning points in the Strait are studied.

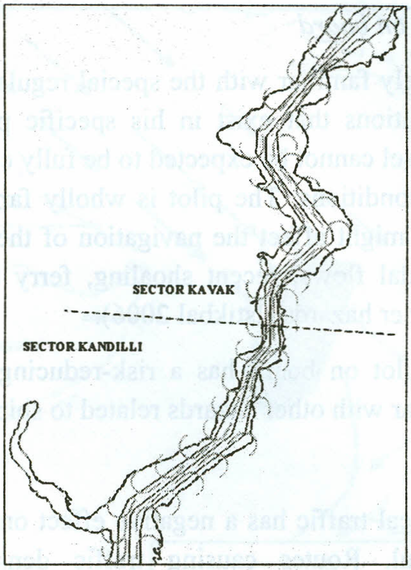

Figure 5. Turning circle tracks of a 321.95 meter- long –vessel in the Strait of Istanbul.

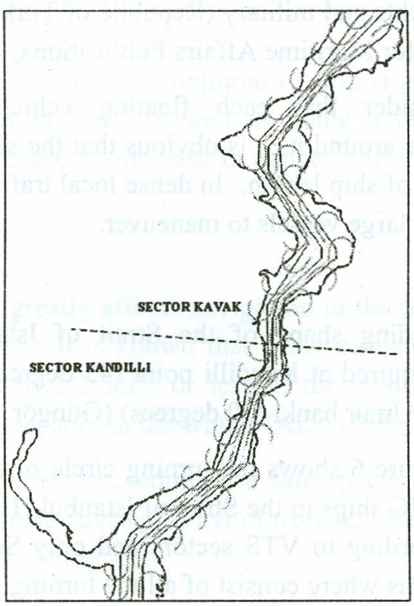

Figure 6. Turning circle tracks of a 199.93 meter- long –vessel in the Strait of Istanbul.

The length of the vessel affects the rate of turn and the size of turning circle (URL:1, 11.03.2010).

The increase in length is of vital importance to safe navigation in the narrow channel.

Empirical study and Results

The analytic hierarchy process is a method that helps a group of decision-makers evaluates complex judgemental problems. In the first stage of this study, a questionnaire is applied to VTS operators, Pilot Captains and experienced Captains in order to collect opinions on risk factors. In this way, the judgements of experts about ship length related criteria and the weights of the alternatives are stated.

Characteristics of the experts are listed below;

1. The number of people participated in the survey is 37,
2. 49% of the experts are Pilot captains who serve in the Strait of Istanbul,
3. 46% of the experts are VTS operators,
4. 5% of the experts are ocean-going captains who passed through the strait at least 15 times.

All participating experts have varying opinions about the criteria and risk based on ship length. The experts were requested to not be interested in other criteria when evaluating one criterion. In other words, all ratings should be done independently from each other.

In order to analyze the data obtained by survey in AHP, a 15 days trial version of expert choice 2000 software is used.

In the first step, in order to assess the relative importance of criteria a pair-wise comparison matrix is constructed. Priorities and inconsistency value derived from matrix are shown in Table 4.

Table 4. Pair-wise comparisons and ratings of criteria.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	Priorities
C_1	1	1	3	1	3	3	5	2	1	0.173
C_2	1	1	3	1	3	3	5	2	1	0.173
C_3	1/3	1/3	1	1/3	1	1	3	1/2	1/3	0.060
C_4	1	1	3	1	3	3	5	2	1	0.173
C_5	1/3	1/3	1	1/3	1	1	3	1/2	1/3	0.060
C_6	1/3	1/3	1	1/3	1	1	3	1/2	1/3	0.060
C_7	1/5	1/5	1/3	1/5	1/3	1/3	1	1/4	1/5	0.028
C_8	1/2	1/2	2	1/2	2	2	4	1	1/2	0.101
C_9	1	1	3	1	3	3	5	2	1	0.173
Inconsistency = 0.01										

The next step is to calculate the priorities of alternatives under each criterion (Table 5, 6, 7, 8, 9, 10, 11, 12, 13).

Table 5. Pair wise comparisons and priorities of alternatives for C_1.

	A_1	A_2	A_3	A_4	A_5	Priorities
A_1	1	1/4	1/5	1/6	1/5	0.044
A_2	4	1	1/2	1/4	1/4	0.102
A_3	5	2	1	1/3	1/3	0156
A_4	6	4	3	1	1	0.353
A_5	5	4	3	1	1	0.345
Inconsistency =	0.05					

Table 6. Pair-wise comparisons and priorities of alternatives for C_2.

	A_1	A_2	A_3	A_4	A_5	Priorities
A_1	1	1/2	1/4	1/5	1/5	0.055
A_2	2	1	1/2	1/4	1/4	0.088
A_3	4	2	1	1/3	1/3	0.154
A_4	5	4	3	1	1	0.352
A_5	5	4	3	1	1	0.352
Inconsistency =	0.02					

Table 7. Pair-wise comparisons and priorities of alternatives for C_3.

	A_1	A_2	A_3	A_4	A_5	Priorities
A_1	1	1/4	1/5	1/5	1/6	0.044
A_2	4	1	1/2	1/3	1/4	0.109
A_3	5	2	1	1/2	1/3	0.170
A_4	5	3	2	1	1/2	0.262
A_5	6	4	3	2	1	0.416
Inconsistency =	0.04					

Table 8. Pair-wise comparisons and priorities of alternatives for C_4.

	A_1	A_2	A_3	A_4	A_5	Priorities
A_1	1	1/4	1/5	1/6	1/6	0.043
A_2	4	1	1/2	1/3	1/2	0.119
A_3	5	2	1	1/2	1/2	0.191
A_4	6	3	2	1	1	0.324
A_5	6	3	2	1	1	0.324
Inconsistency =	0.02					

Table 9. Pair-wise comparisons and priorities of alternatives for C_5.

	A_1	A_2	A_3	A_4	A_5	Priorities
A_1	1	2	1/6	1/5	1/6	0.057
A_2	1/2	1	1/8	1/7	1/8	0.036
A_3	6	8	1	2	1	0.346
A_4	5	7	1/2	1	1/2	0.216
A_5	6	8	1	2	1	0.346
Inconsistency =	0.01					

Table 10. Pair-wise comparisons and priorities of alternatives for C_6.

	A_1	A_2	A_3	A_4	A_5	Priorities
A_1	1	1/2	1/3	1/3	1/3	0.082
A_2	2	1	1/2	1/2	1/2	0.138
A_3	3	2	1	1	1	0.260
A_4	3	2	1	1	1	0.260
A_5	3	2	1	1	1	0.260
Inconsistency =	0.00					

Table 11. Pair-wise comparisons and priorities of alternatives for C_7.

	A_1	A_2	A_3	A_4	A_5	Priorities
A_1	1	1/7	1/7	1/8	1/8	0.030
A_2	7	1	1/2	1/4	1/4	0.109
A_3	7	2	1	1/3	1/3	0.156
A_4	8	4	3	1	1	0.353
A_5	8	4	3	1	1	0.353
Inconsistency =	0.05					

Table 12. Pair-wise comparisons and priorities of alternatives for C_8.

	A_1	A_2	A_3	A_4	A_5	Priorities
A_1	1	1/5	1/4	1/5	1/6	0.044
A_2	5	1	2	1/2	1/3	0.170
A_3	4	1/2	1	1/3	1/4	0.109
A_4	5	2	3	1	1/2	0.262
A_5	5	3	4	2	1	0.416
Inconsistency =	0.04					

Table 13. Pair-wise comparisons and priorities of alternatives for C_9.

	A_1	A_2	A_3	A_4	A_5	Priorities
A_1	1	1/2	1/3	1/5	1/5	0.058
A_2	2	1	2	1/4	1/4	0.090
A_3	3	2	1	1/3	1/3	0.145
A_4	5	4	3	1	1	0.354
A_5	5	4	3	1	1	0.354
Inconsistency =	0.01					

The last step for the AHP method is calculation of ranking scores. Ranking scores are calculated by summation of each row. Table 14 shows ranking scores of alternatives.

Table 14. Ranking scores of alternatives.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	Ranking Scores
A_1	0.002	0.001	0.004	0.008	0.009	0.018	0.005	0.002	0.003	0.053
A_2	0.005	0.002	0.010	0.021	0.006	0.031	0.018	0.008	0.005	0.106
A_3	0.008	0.004	0.015	0.034	0.057	0.057	0.25	0.005	0.008	0.214
A_4	0.013	0.009	0.034	0.057	0.036	0.057	0.057	0.013	0.020	0.296
A_5	0.020	0.009	0.033	0.057	0.057	0.057	0.057	0.020	0.020	0.331
Inconsistency =	0.02									

According to the ranking scores of the alternatives; 251m- 300 m interval has the highest priority. At this stage, it is important to determine the point where the largest rate of change is obtained. In other words, at which point is the abnormal increase in risk? Thus, figure 5 is drawn using analysis results. As seen in Figure 5, the 151m- 200 m interval is the point where there is a maximum increase in risk.

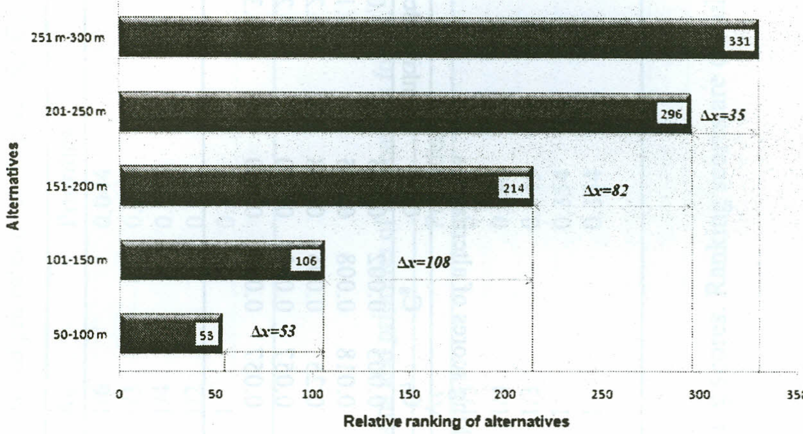

Figure 5. Rate of increase in ranking scores (Keçeci 2010).

Another important issue is the consistency ratio of the selection, which according to Saaty should be less or equal to 10%. In the present study, the inconsistency ratio of 0.02 is obtained.

Furthermore, according to the results, the most important criteria are current, restricted visibility, narrowness of the area and existence of pilot on board.

Conclusion

This paper investigates what a large vessel is in terms of ship length in the Strait of Istanbul. For this purpose, applicability of a common strategic selection tool, AHP, is investigated. Moreover, factors affecting the rate of change in risk due to the increase in ship length are studied.

Criteria put into practice according to expert advice and statistical research are chosen as turning circle of ships, narrowness of the area, loading condition of ships, wind effect, ship speed, restricted visibility, local traffic and the existence of pilot on board. Alternatives are set in five intervals. The intervals are 50-100 m, 101-150 m, 151-200 m, 201-250 m, 251-300 m.

After selection of criteria and alternatives for the AHP method application, the Saaty's scale for pair-wise comparison is used to determine the importance of criteria and alternatives which are compared for each criterion. In order to analyze the data in AHP; a 15 days trial version of expert choice 2000 program is used. The results of the calculation revealed the global weights of the alternatives.

According to the final ranking scores of alternatives, the point where the largest rate of change is obtained. 151m- 200 m interval is determined as the point where the maximum increase in risk is seen.

For further research, the present study should be improved for particular ship size groups by creating a model of the system in order to identify and understand the factors which control the system and/or predict the future behavior of the system.

Özet

İstanbul Boğazı değişken kuvvetli akıntıları ve keskin dönüş yerleri ile zor bir yapıya sahip olan kıvrımlı bir dar kanaldır. Bu özellikleri nedeni ile dünyanın en tehlikeli dar kanallarından biri olarak kabul edilmektedir. İstanbul Boğazı'nda seyir kurallarını düzenleyen Montrö Sözleşmesi'nin imzalandığı 1936 yılında İstanbul Boğazı'ndan geçiş yapan gemi sayısı yıllık olarak 4500 iken, şimdilerde bu sayı yılda 54000 e ulaşmış durumdadır. Trafik yoğunluğundaki bu artış gemi kazaları sayısında da yükselmeye neden olmuştur.

Bu problemi çözümlemek üzere 1994 yılında Boğazlar ve Marmara Bölgesi Deniz Trafik Düzeni Hakkında Tüzük Kabul edilmiştir. Bu tüzük 1998 yılında yeniden düzenlenerek Türk Boğazları Deniz Trafik Düzeni Tüzüğü olarak yürürlüğe girmiştir. Tüzükte büyük gemi tanımı ön plana çıkmış ve tüzüğün 2. maddesinde tanımlanmıştır. Gemi boylarındaki bu artış İstanbul Boğazı'nın sahip olduğu özellikler göz önüne alındığında, 'İstanbul Boğazı için büyük gemi nedir ?' sorusunu akıllara getirmektedir. Bu çalışmada, bu soruya cevap aranmış ve İstanbul Boğazı'nda görev yapan pilot kaptan, VTS operatörleri ve Boğazlarda seyir yapmış tecrübeli kaptanlar ile anket çalışması gerçekleştirilmiştir. Kantitatif değerler elde etmek maksadıyla çok amaçlı karar verme yöntemlerinden biri olan AHP (Analytic Hierarcy Process) metodu kullanılarak sonuç alınmaya çalışılmıştır.

Acknowledgements

The authors are grateful to Mr. Okan Duru and Mr. Emrah Bulut sincerely for their critical comments and suggestions during the study period.

References

Akten, N. (2002). The bosphorus: Factors contributing to marine casualties. *Turkish J. Mar. Sci.* 8: 179–195.

Akten, N. (2003). The Strait of Istanbul (Bosphorus): The seaways separating the continents with its dense shipping traffic. *Turkish J. Mar. Sci.* 9: 241-265.

Akten N. (2004). Analysis of shipping casualties in the Bosphorus. *The Royal Institute of Navigation* London, 57: 345-356.

Birpınar, M. E., Talu, G. F. and Gönençgil B. (2009). Environmental effects of marine traffic on the strait of Istanbul. *Environmental Monitoring and Assessment* 152: 13-23.

Güngör, S. (1999). Turkish Straits and passage. Ph.D. Thesis. Istanbul Technical University, Institute of Marine Science and Management, 20-21.

İstikbal, C. (2006). Turkish Straits: Difficulties and the importance of pilotage. The Turkish Straits: Maritime safety, legal and environmental aspects. Turkish marine research foundation, Vol: 25 pp.72.

Keçeci ,T. (2010). The Analysis of the Effects of Ship Length Factor to Safe Navigation in the Strait of Istanbul by AHP Method. Istanbul Technical University. Institute of Science and Technology, Istanbul. pp.51

Maritime Traffic Regulations in the Turkish Straits. (1998). Official Gazette, No: 23515.

Navigation Safety of Turkish Straits. (2000). *Republic of Turkey Prime Ministry Under secretariat for Maritime Affairs Publications*, 28-30 Sept. Istanbul.

Republic of Turkey Prime Ministry Under secretariat for Maritime Affairs. (2003, 2004). Navigation Safety Department, Ankara.

Saaty, T.L. and Vargas, L. G. (2001). Models, methods, concepts & applications of the analytic hierarchy process, *International series in operations research & management sciences*. Kluwer academic publisher. pp.1-9.

Sarıöz, K. and Narlı, E. (2003). "Assessment of Manoeuvring Performance of Large Tankers, in Restricted Waterways: A Real-Time Simulation Approach", *Ocean Engineering*, Vol. 30, No. 12.

The best seamanship. (2008). Maneuverability of very large ships. *A guide to ship handling*. Japan Captains' Association. pp: 118-138.

Ulusçu, S. Ö., Özbaş, B., Altıok, T. and Or, İ. (2008). Navigating Troubled Waters: Mitigating transit vessel traffic mishaps, *OR/MS Today*, October.

URL.1: http://shipsbusiness.com/turning-circle-factors.html,11.03.2010

Vaidya, O.S. and Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *Eur. J. Operat. Res*. 169: 1-29.

Received: 18.06.2010
Accepted: 30.06.2010