UTILIZATION OF RESOURCES ON TECHNO-NAUTICAL SERVICES BY DEVELOPING A DYNAMIC SIMULATION MODEL: AN APPLICATION ON THE PILOTAGE SERVICE IN ISTANBUL STRAITS

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ABSTRACT

In Turkey, techno-nautical services' principles are determined in Port Regulations prepared by Turkish Transportation, Maritime Affairs and Communication Ministry. But the principles are set mostly empirically or experience based. This study helps decision-makers and stakeholders for the correct utilization of resources on techno-nautical services by developing a dynamic simulation model. For this purpose, the pilotage service algorithm has been developed according to structured interviews with pilots, with statistical data of Traffic in Istanbul Straits and all rules and regulations in effect on the waterway. It is found out that by the designed algorithm, it is possible to make correct decision about the required human resource as pilots even in a complex system as in Istanbul Straits. And due to dynamic nature of algorithm with application of simulation software different scenarios can be evaluated easily.

Keywords: *Techno-nautical services, Marine Pilot, Algorithm.*

1. INTRODUCTION

Techno-Nautical services are key factors for safety of maritime transportation. Due to their expensive and critical nature such a complex resource must be optimally utilized in any situation. Optimum utilization of resources is always a challenge for decision makers and it is also a well-accepted fact that the authority normally makes its decision on utilization of resources empirically or when such a decision has to be given due to apparent faults in systems which is feed backed by stake holders.

But in this information age, nearly all complex systems can be formatted so that a scientific decision might be predicted before the circumstances require so. One way of accomplishing such a task is by creating a simulation model of said system [3]. A good algorithm must be written in order to create a reliable simulation model. To create a good algorithm all inputs to system must be evaluated and the problem should be well-specified. Also, an algorithm must be correct, efficient and if possible easy to implement [4].

2. OBJECTIVE

2.1 Objective, Cost or Safety

This study is born by the authors' amazement when they have found that the utilization of techno-nautical resources, especially the use of pilots is conducted by empirical decisions.

It is clear that an algorithm might be designed to mirror the traffic in Straits and thus that algorithm might be used in a dynamic simulation model for optimization. Even then such optimizations are mainly based on the cost of the operations [1]. However, in this study the major aim of the application was the safety of traffic in Istanbul Straits. To this end, the fatigue element of the maritime pilots is taken into consideration [2]. But because the study is based on fatigue of the pilots it shall be the most cost efficient way for the relevant organizations nonetheless.

2.2 Importance of Istanbul Straits

Istanbul Straits is a well-known and highly busy waterway which connects Black Sea and Marmara Sea and leads to the Aegean and farther into Oceans. It is 17 nm long Straits and one of the most dangerous waterways to pass through, as a ship needs to alter her course at least 12 times with the sharpest turn of 45^0-80^0 at Yenikoy, while always struggling with ever changing surface currents which may go up to 6 knots because of the geographical shape and environmental conditions of the Istanbul Straits [5].

The safety of Istanbul Straits is a great concern for Turkey as this waterway directly divides the country's biggest city in half, but also all Black Sea countries care for it because it is the only open waterway for them to trade by seaway and The Straits has great geostrategic importance. Due to its utter importance, regulations governing the Istanbul Straits always become an international issue. After the Ottoman Empire declines in power in World War I, three consecutive international treaties signed about the Straits all over ruling the previous one, Treaty of Sevres (1920), Lausanne (1923) and Convention of Montreux(1936). Even today Istanbul Straits is governed by regulations in line with the Montreux Convention.

2.3 Importance of Pilotage Service in Istanbul Straits

Under Section I, Merchant Vessels, Article 2 of Convention, it is stated that in time of peace, merchant ships shall enjoy complete freedom of transit and navigation with any kind of cargo, without any formalities. Pilotage and towage remain optional. This article is in the convention for the safe and free passage through The Straits by merchant ships. But after years passed and Istanbul Straits traffic ever become more populated by transit vessels and inland traffic gets busier and busier due to the most populated city of Turkey enveloping the Straits, this article might be re-evaluated again for safety reasons. Statistically, 93% of ships involved in accidents in Istanbul Straits between 1982 and 2003 were without pilots [6]. And normally nearly all accidents in Istanbul Straits resulted in delays in transit traffic due to closed Straits while rescue operations taking place. One of the most infamous accidents of such kind was the Independenta Tanker collision (1979) in the Istanbul Straits resulting in loss of life, disastrous environmental impact and delay in transit.

2.4 Pilots in Istanbul Straits

Pilots in Istanbul Straits are employed by the Republic of Turkey, Ministry of Transport, Maritime Affairs and Communications, Directorate General of Coastal Safety (KEGM). Pilots are employed according to “Competence, training certification and working procedures regulations” [7] published by the mentioned Ministry.

In this regulation in Article 5, Turkish Straits’ Pilots are differentiated from harbour pilots and also classified as junior and senior pilots based on experience.

Requirements to be a Turkish Straits’ Pilot are:

- Being a Turkish Citizen
- Being legally clear to be a civil servant
- Being a master mariner with at least 1 year of experience and a university graduate
- Being healthy according to seamen standards
- Being a fluent speaker
- Having successfully completed the basic pilot training

Once all these conditions are met, the pilot becomes an apprentice pilot and shall be under the supervision of a senior pilot who records his achievements in an apprentice book to be presented to harbour master at the end of its training. For the Straits pilots this training means apprentice pilot should attend to Straits passage manoeuvres of at least 160 vessels above the 5000 GRT for more than 4 months period if possible evenly distributed from both directions of passage. This training also includes some attendance to tugs and VTS operations.

After that, if training is found satisfactory, the apprentice pilot should take a written and oral exam prepared by authority. If all goes well, the apprentice pilot is granted a junior pilot certificate for 4 years duration and he is limited to handle ships below 20000 GRT [7].

As can be seen from above regulations, Istanbul Straits Pilots are highly trained individuals with great experience. But also due to this factor, utilization of this resource is extremely important as it is not possible to employ any mariner as a pilot in a whim.

2.5 Fatigue and Marine Pilots

It is a well known fact that fatigue interferes with concentration of marine pilots. Especially sleep deprivation is found a major factor of fatigue. Though most pilots claim that fatigue is not a major concern in their job due to fatigue management procedures, it is also apparent that due to commercial pressure of the business and maybe, due to lack of sufficient number of pilots, pilots might find themselves in fatigue condition more than they want to admit. Even though there are control procedures to prevent this kind of situations again commercial pressure might be too hard to avoid [8].

3. METHODOLOGY

3.1 Designing an Algorithm

To design an algorithm the question must be well known. This study’s question is “If ship traffic is predicted correctly, how many pilots will be sufficient for safe transit in Istanbul Straits in any given time according to pilots’ rest periods?”

Then inputs must be known. Here inputs might be summarized as below:

- Ships’ arriving rate to Istanbul Straits
- Probability of a ship to request pilot service
- Any regulations forcing ships to behave in a particular way
- Istanbul Straits traffic regime at the moment
- Pilot stations
- Pilot rest hours
- Pilot on duty times
- Duration of a passage through Straits

Then the output of this algorithm must be evaluated. The output will be the resting times of the pilots in this study. But lots of other statistical data can be analysed like waiting time of ships for pilots, average passage times, if use of pilot shortens the waiting time for passage etc. Anyway, such data is out of the scope of the study. The algorithm designed here can be used in any simulation software and optimizations can be calculated accordingly. Due to the changing nature of inputs of the Istanbul Straits, created simulation model will be also a discrete and dynamic simulation.

In this paper a pseudocode is created as an algorithm so it will be easy to understand and it may be replicated with success with any number of programming languages [9].

Also the algorithm is optimized to calculate the resting periods of pilots according to Number of pilots on duty. Even though other factors can change rest periods of the pilots, according to interviews with stakeholders, other methods will be hard to implement and unpractical.

3.2. Gathering Data

The data for the algorithm was gathered from various resources. For example, the arrival spread of the ships to Istanbul Straits is gathered from KEGM’s statistical data of 2010 and 2011. Samples are used to analyse the arrival spread of the ships from North to South and vice versa. Even though a regular spread could not be achieved according to chi square tests, the least square error is achieved by using exponential spread, this analyse is computed by Rockwell, Arena Input Analyser V10. Low chi square test results means might be interpreted that there are far too many variables affecting the first contact report times of ships to be accepted as exponential spread. But as shown in figure 1 spread closely resembles an exponential curve and exponential spreads commonly used for arrival intervals. Thus in this study exponential spread is used for arrival times of the ships.

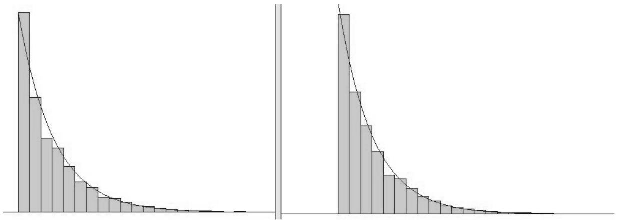

Figure 1 Visual familiarity between ships arrival times from N to S and S to N and exponential spread.

According to these analyses from 100690 sample data, for arrival intervals from North to South exponential spread of 20.7 and for South to North exponential spread of 20.5 is computed. Type of ships also calculated from this data. But before that it should be considered what types of ships need to be evaluated for a scheduling algorithm.

There are studies about the scheduling problem of the Istanbul Straits [9]. It should be noted that Turkish Coastal Safety General Directorate classifies vessels in different groups to schedule the transit passage of vessels. These types can be described as follows:

MPR : Passenger, Yachts, Live stock carrier
NAV : Military
Ships other than Tankers without IMDG Cargo
G 12 : Ships less than 150 meters
G 3 : Ships between 150 – 200 meters
G 4 : Ships between 200 – 250 meters
G 5 : Ships longer than 250 meters
Tankers and other ships carrying IMDG Cargo
T 12 : Ships less than 150 meters
T 3 : Ships between 150 – 200 meters
T 2, 5 : Ships longer than 200 meters
Towed Ships
Ships larger than 300 meters

According to KEGM's application procedures [11], MPR and NAV have priority over other vessels. G5, T4, T5, Towed vessels, Ships larger than 300 meters can only pass Straits in day light conditions. Tankers and IMDG cargo carrying vessels have lower priority as safety conditions are re-examined for passage. So a tentative scheduling can be determined as follows:

MPR=NAV>G12>G3>G4>G5>T12>T3>T2,5>Towed (1)

Of course, day time and night time passage will shift according to the requirements of only day light passage vessels and scheduling must be reorganized accordingly. It must be remembered that vessels longer than 300 meters require special permission to transit the Straits.

In following table statistical data about the Istanbul Straits for years 2010 and 2011 have been analyzed to find out the frequency of these types of vessels for the creation of model. So it is noted that some types of vessels transit the Straits extremely rare and modelling of such vessels will not contribute to the model in the scope of analyzing pilot fatigue, because such vessels actually stop the Straits traffic causing a long rest period for other pilots not onboard the vessel. For example vessels over 300 meters long are in these category and G5 vessels are extremely rare.

Table 1. Frequency of Vessel Types Transiting Istanbul Straits in 2010 - 2011

	South to North		**North to South**	
	All	**Freq.**	**All**	**Freq.**
MPR	585	1,16	591	1,18
NAV	96	0,19	104	0,21
G12	32886	65,38	32728	65,07
G3	5874	11,68	5966	11,86
G4	554	1,10	588	1,17
G5	6	0,01	6	0,01
T12	5163	10,27	5345	10,63
T3	4463	8,87	4417	8,78
T4-5	670	1,33	648	1,29
TOTAL	50297	100	50393	100

Source: KEGM Statistical Data

After the scheduling algorithm, another important part of the model is the Straits pilot working conditions. To gather this data, structured interviews have been completed by Istanbul Straits pilots.

The most important findings of these interviews can be summarized as follows:

- There are two pilot stations in Istanbul Straits. One is located at South and other is at North entrance of Straits.
- Each shift of pilot consists of 23 pilots
- Pilots arrive for their 48 hours shift at south pilot station. They rest for 96 hours after each shift and start their shift "well rested" according to their perception.
- Straits traffic is one way due to safety precautions of KEGM and Turkish government.
- Due to one way traffic, there is a transportation problem between south and north pilot stations.
- This problem is generally solved by a dedicated service boat for pilot transfer and generally 8 pilots transferred with each service (this number may greatly vary, but 8 people is average)
- Pilot transfer generally completed between 45 minutes to 1 hour.
- There are other possible ways for transporting pilots when need is immediate or need requires a few of pilots, but they are uncommon and not

- convenient and usually takes more time due to land traffic congestion. (Mini-bus, taxi etc.)
- General scheduling frequency is 6 vessels in an hour, 7 when Straits is congested. (According to KEGM statistical data approximately 1 vessel per 8 minutes.)
- One way traffic changes direction in roughly 12 hours periods but also subject to lots of other considerations as available pilots, ship number in queue, weather or other conditions.
- It takes approximately 15 minutes for a pilot to board a vessel from pilot station and nearly 15 minutes disembark from a ship and arrive to pilot station.

There are some special points analysed from above declarations. It is clear that 2 models must be simulated as one from south to north and other from north to south. But there is only 1 resource available and that is Istanbul Straits. Real limitation of Straits is the distance between navigating ships, though in practice a time limit is used as rule of thumb. Due to pilot boarding and disembarkation times, 30 minutes must be added to transit times of vessels to calculate real working hours. A transportation system must be modelled and 1 hour should be taken as transit time and must be counted as working hour.

And final transit times are important as it actually shows that pilot is on-board the vessel and working.

Vessel passage times are subject to great change due to lots of external factors and analyse of KEGM data points out there is not an optimum spread for passing times. Thus average time for ship type is taken as transit times of vessels.

As it can be seen from the table below, average transit from South to North takes considerable more time (apprx.26%) than the passage from North to South. The main reason of this phenomenon is the surface currents affecting the Istanbul Straits under normal conditions.

Table 3. Average transit times for Vessels Transiting Istanbul Straits in 2010-2011.

In Hours	South to North	North to South
MPR	1.657	1.555
NAV	1.736	1.6
G12	2.029	1.583
G3	1.634	1.414
G4	1.542	1.381
G5	2	2.002
T12	1.8	1.447
T3	1.517	1.376
T4-5	1.491	1.411
TOTAL	1.89	1.53

Another consideration about the model is frequency of pilot service usage for the vessel transiting the Straits. Again KEGM data is analysed for this purpose. It shows that nearly half of the vessels passing through the Istanbul Straits use pilots. And there is a slight more pilot usage when vessels transiting from South to North.

Even though frequency is not much to consider, probably same phenomenon of surface currents is also in affect in this selection of pilotage service.

Table 3. Frequency of Pilot Service Usage for Vessels Transiting Istanbul Straits in 2010-2011

	South	**To**	**North**	**North**	**To**	**South**
	TTL	**W/P**	**FREQ**	**TTL**	**W/P**	**FREQ**
MPR	585	512	87.52	591	518	87.65
NAV	96	24	25	104	29	27.88
G12	32886	13134	39.94	32728	11731	35.84
G3	5874	4638	78.96	5966	4767	79.90
G4	554	554	100	588	588	100
G5	6	6	100	6	6	100
T12	5163	2906	56.29	5345	2652	49.62
T3	4463	4351	97.49	4417	4326	97.94
T4-5	670	670	100	648	648	100
TOTAL	50297	26795	53.27	50393	25265	50.14

Source: KEGM Statistical Data

4. ALGORITHM

There are different parts of this model. Firstly, some parts must be created to check the time in simulation software. Such an algorithm in pseudocode can be written as follows:

4.1. Time Creation

Even though different simulation software might have an internal clock, due to discrete event simulation specifications it is safer to create a time logic to specify important times.

First part is the checking of day light. 12 hour day light is taken as average for the purpose of this simulation.

1. Create 1 entity at experiment start (Experiment time 1000)
2. Assign entity that sun is up.
3. Delay entity for 480 minutes (8 hours).
4. Assign entity that sun is down. (Experiment time 1800)
5. Delay entity for 720 minutes (12 hours).
6. Assign entity that sun is up. (Experiment time 0600)
7. Delay entity for 240 minutes (4 hours)
8. Loop entity to line 3.

Another time logic must be created to check the availability of Straits for north to south or south to north traffic. This is a rough guide to see which side of passage must be open for the Istanbul Straits in any given time in experiment. This logic will be evaluated with other considerations too.

1. Create 1 entity at experiment start (Experiment time 1000)

2. Assign entity that Straits is open from South to North
3. Delay entity for 720 minutes (12 hours).
4. Assign entity that Straits is open from North to South. (Experiment time 2200)
5. Delay entity for 720 minutes (12 hours).
6. Loop entity to line 2.

Also different time logic must be created for pilot transfer times, as it will be unnecessary to send pilots to a pilot station when the traffic shifts its directions before the pilots arrive.

1. Create 1 entity at experiment start (Experiment time 1000)
2. Assign entity that transfer is allowed from North station to South station.
3. Delay entity for 660 minutes (11 hours).
4. Assign entity that transfer is not allowed.(Too late for transfer)
5. Delay entity for 60 minutes (1 hour).
6. Assign entity that transfer is allowed from South station to North station.
7. Delay entity for 660 minutes (11 hours).
8. Assign entity that transfer is not allowed.(Too late for transfer)
9. Loop entity to line 2.

4.2. Queues Creation

There are 4 queues in this model: 2 for pilot station and pilots and 2 for arriving ships from two sides of the Straits.

For pilots:

1. Create number of pilots required in experiment start.
2. Assign each entity a name to distinguish them in model.
3. Mark each pilot's time now in experiment.
4. Send each pilot to first queue.
5. Name the queue Pilot Station South
6. Queue ranking First In - First Out.
1. Create a Queue for North Pilot Station.
2. Queue ranking First In - First Out.

Other 2 queues have more sophisticated models and will be explained in Istanbul Straits Models.

4.3. Istanbul Straits Model

1. Create ships according to exponential spread.
2. Assign created ships type
3. Branch ships according to their type
4. Assign ships a priority for the Entrance Queue according to their type
5. Assign a random pilot request to ships based on their type and KEGM data
6. For ships types that requires day light to pass through Straits check if sun is up, if sun is up give them highest priority for Straits. If sun is down delay them 60 minutes and send them to line 4
7. Check if ship is requesting pilot and update priority over ships without pilot.
8. Put ships in a queue (Istanbul Straits South Entrance)
9. Queue ranking rule is lowest priority first
10. Seize entities from queue if Straits is open for transit for correct direction. If not, do not accept ships to Straits.
11. If Straits is open, seize the highest priority ship from queue first in - first out between two same priorities.
12. If ship has requested, pilot check availability of pilot in pilot station, if there is no pilot delay ship for 10 minutes and send back to queue.
13. Use Straits as a resource
14. Release resource after 10 minutes for pilot requested ships and 8 minutes for other ships.
15. Check if ship requested pilot
16. Take a pilot from South Pilot station
17. Mark time for specific pilot. Subtract time from the pilots' arrival time to pilot station queue.
18. Record time as Rest period, record pilot name, record experiment time.(This data will be analysed to see pilot resting times)
19. Delay pilot in ship according to average time from KEGM statistics.
20. Drop off pilot from ship
21. Mark dropped off pilot's time now in experiment
22. Send pilot to next station
23. Dispose of ship that finished its transit of Straits.

Create same model for other direction of Istanbul Straits passage. Here most important part is marking times of each pilot before entering the pilot station queue and after exiting from the pilot station queue.

5. CONCLUSIONS

If above pseudocode is created in any discrete simulation software and resting period data is analysed this created dynamic simulation model can be used to safely assess the required number of pilots in Istanbul Straits according to their recommended rest periods.

In this algorithm, cost of pilots and ship delays due to shortage of pilots are not evaluated. But such additions can easily be modified to algorithm.

Also, the model can easily be altered for more or less arriving ships, different number of pilots, more frequent pilot requests, for faster pilot transfers, etc.

In this paper KEGM data is analysed to give numerical examples and clearly demonstrate what the required data is to design an algorithm for Istanbul Straits pilotage service.

Though with these key elements any such water way can be modelled easily and analysed clearly.

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