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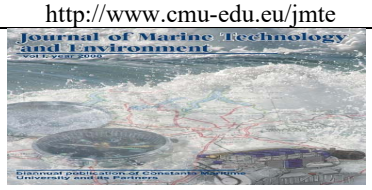

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ANALYSIS OF RIVER LEVEL AND OF THE VOLUME FLOW ON THE DANUBE CLOSE TO THE CITY OF TULCEA, BASED ON IN SITU MEASUREMENTS

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Abstract: This work presents a review of hydrological data known as water levels and volume flows that have been recorded and then processed to render a contour about the hydrological situation of the Danube River near Tulcea. On-site measurements have generated daily data on river flows and levels over a 3-year period (2003, 2004, 2006), their interpretation being important for knowing the water drainage regime. Moreover, the characteristic values can have a practical interest in some river design works, such as hydrotechnical flood defense constructions that may occur as a result of elevated levels above a certain threshold or may be beneficial during works or exploitation of river bed resources. In order to accurately present the importance of knowing the river level variation, it is necessary to process, verify and interpret all data on the levels and flows, establish links and graphical correlations, and determine the characteristic values over the multiannual period. The results obtained from the measurements are described in the four periods of the year, and the conclusion shows that each period is manifested both in climatic and hydrological terms by specific characteristics and phenomena.

Key words: Danube River, Tulcea, water level, volume flow, measurements.

1. INTRODUCTION

The Danube River is the second river in Europe, crosses 2840 km from the Black Forest, the Donaueschingen in Germany, to the Black Sea. The Danube has build up one of the most interesting and beautiful deltas in Europe and even in the world. The arms of the Danube are the major arteries by which the river provides the deltaic space, the solid and liquid flow. The deltaic space is directly influenced by the level and the amount of flow that the river carries in different proportions depending on the period [1], [2].

The hydrographic network of the Danube Delta is extremely complex, showing a particular geographic, economic, and tourist interest. It provides water supply to lakes as well as airworthiness. This hydrographic network comprises the Danube arms (Chilia arm, Tulcea arm, Sulina arm, Sfantu Gheorghe arm), lakes, ponds, marshes, channels, and sheds [3].

At present, the activities of valorizing the Danube's natural resources, the tourism and trade have increased the transport on water, requiring the balanced development of both the waterways and the types of ships, correlated with the conditions of protection the natural environment of the river, which requires knowledge of the Danube's drainage regime [4].

Very important issues in order to ensure a proper circulation of the water on the Danube are not the very large flows of the river, produced over a short interval in spring, but, in particular, the existence of a long period of time with relatively high flows. In this case, given the correspondence between flows and levels, an active circulation of the water can be ensured in the inner depression areas, facilitating the evacuation of the wastewater loaded with noxious waste at the end of the summer [5], [6].

The drainage regime of the river is depending on variation in time over a month, a season, a year or more of the amount of water flowing within a river section. The liquid leak can come from rains, snow and even from groundwater. The study of the regime is given by the knowledge of the variation in leakage and sources of supply. The variation of the river supply sources over a year requires a similar variation in the flow of the river water, uniformed in a sequence of characteristic periods, referred as drainage phases. The frequency and often the duration and the dimensions of the phases show the variation in time of the supply sources, which in turn are

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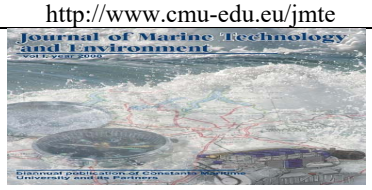

strictly dependent on the interference of the climatic factors in the climatic seasons [7].

Regarding the influence of the physical geography factors on the rivers, the processes and the hydrological phenomena within the river basins are determined by the position of our country, the height and orientation of the relief and, to a greater extent, the physical geography factors in the basin. In the processes of the leakage formation and evolution, the main role is played by the climate, which, due to the precipitation, temperatures, wind, evapotranspiration and frost regime, inflates decisively the water reserves as well as the leakage regime [8].

An important problem is the flooding of deltaic space, as a complex hydrological process. This is very important in the dynamics of the evolution of all components of the natural system. Strongly dependent on the Danube water regime, the degree of flooding supports both surface alluvial processes at elevated, linear levels at low levels, as well as the water supply of indoor lake depressions. Also, related to the process of flooding, the deltaic territory imposes restrictions on the location, sizing, and realization of various constructions, habitable surfaces, etc. [9]

The main premises that condition the flooding process are its hypsometric peculiarities, the amplitude, and periodicity of the Danube's maximum levels, to this being added, at present the restriction of flooded areas, having as a result the covering of some areas [10].

Both for the Danube Delta and for the Danube localities, there is a risk of failure, where it may occur the phenomenon of settlement the dam, or if not, there is a major danger of producing an infiltration because of the duration of the very long flood. Also, there is a permanent risk of erosion sometimes accompanied by landslides which endanger housing and households. At the same time, there is a permanent risk of erosion sometimes accompanied by slopes of ground that endanger habitats or households [11].

In this context, the present work describes the situation of levels and flows in different forms of analysis for a 3-year period, how these data were collected and the methods of analysis used.

2. MATERIALS AND METHODS

The target area is located on the Danube at Km 71 near the city of Tulcea. The location of the hydrometric station is shown in Figure 1.

The recording of the results of the water levels in the Danube River was determined by direct reading a hydrometer placed on the river, using a recorder called the limnometric device. It has the role of knowing the evolution over time, by discrete (discontinue) values of water levels and of checking and correcting the recorded levels [12].

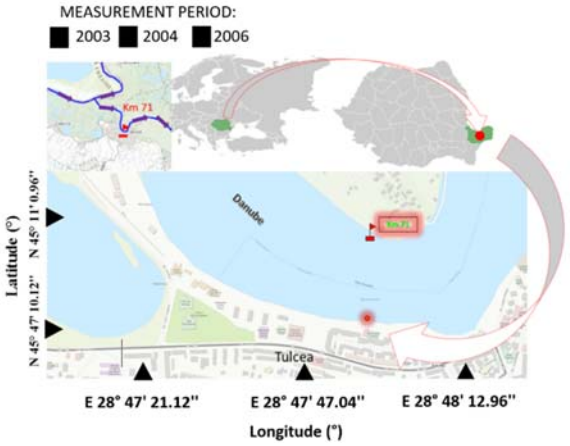

Figure 1 Map with the location of the hydrometer station at Km 71 on the Danube

The level measurement programs (hydrometric reading) are set by the hydrological station staff according to the flow regime (small, medium, or high water). When there is a constant treatment regime, the recordings of the level and the flow of the river are made at the standard observation hours (8 and 20).

The recorded water levels are used directly to indicate the imminence of production floods and indirectly to specify the hydrograph of the water flow using the limnometric key [13].

As regards the water levels, given the short time they have been observed or recorded, they are considered as instantaneous values. Level records are expressed in meters, relative to "0 graduated tool". The share "0 graduated tool" is expressed in mrMN (Black Sea landmark).

The level values are important, both as values in themselves, notably by specifying flood areas and the moment when the flood is produced, as well as indirectly by determining with the help of the limnometric key the hydrographic water flow and the hydrographs useful for hydrological forecasting and monitoring of basin water resources.

The evolution of water flow hydrographs over time is helpful for all activities of knowledge of the evolution of the river flow regime over time (hydrological forecast, hydrological parameters, integrated water resource monitoring).

The determination of the water flow hydrographs is achieved by: direct measurements with specific equipment or with the help of determinations (discreet values) of water flows and/or slopes and sections. On the basis of these and the levels existing at the time of the water flow determination, it is specified a correlation "flow-level" - limnometric key.

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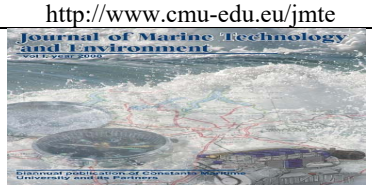


With the help of this, and the help of level hydrographs, the water flow hydrographs are then determined [14].

The frequency of the water flow measurements shall be determined by the personnel of the hydrological stations, mainly in the phase of the regime, by the requirements marking the limnometric keys. The basic condition is to specify at any time the value of instantaneous and average hourly / daily water flows with an error below 15%.

The determination of the water flow is done by measuring the speed rate of the water and the wetted section. The water flow results from the multiplication of the watered section at the average speed. Speed is the most difficult variable given by the determinant due to the fact that it varies with width and depth in the profile [15].

The usual hydrometric technique for measuring the water flow consists in launching into a watercourse, in the direction of the water flow a propeller in order to determine the water velocity at different points located on several vertical sections of the watered section. The method of calculating the flow is called " speed section ". The evolution of water flow rates over the course of the river is determined by means of level records and limnometric keys, "water flow-level" curves. The "speed-section" method, as mentioned above, is based on the determination of water depths at various points of the wet section and its velocity at different vertical points located within the perimeter of the wet section.

The method of determining the average velocity in one vertical is called the "five-point" method, which, depending on the depth of water in the bed, is reduced to the one-three-point method.

For measuring the water flow the hydrometric propeller has been used. The hydrometric propeller is a device designed to measure the water current for the calculation of water flows.

The operating principle of the hydrometric propeller is based on counting the rotations that make them in a unit of time a propeller under the influence of the water current.

In the present work there are presented developments in water levels and flows of the Danube River at the Tulcea arm for the years: 2003, 2004 and 2006. In those years, there were correlated daily data of water flows and levels in Tulcea harbor, the level records are expressed in meters, relative to "0 graduated tool". The share "0 graduated tool" is expressed in mr MN (Black Sea landmark). – Fig. 2 [subplots (a), (b), (c), (d), (f), (g), (h)], and the flows being expressed in m^3/s – Fig. 2 [subplots (a), (b), (c), (d), (e), (i), (j), (k)].

3. RESULTS

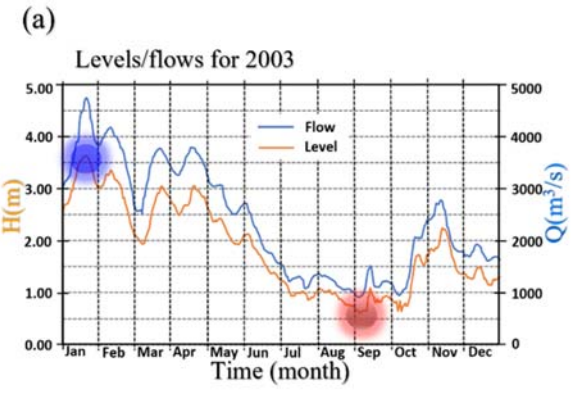
The results are presented in the first phase in the form of tables and in the second phase as figures. Figures are graphs showing the levels and the water flows of Danube near Tulcea for the years: 2003, 2004, 2006, in different forms of representation. Tables contain the volume water flows and levels for the four periods of the year: winter, spring, summer, and autumn periods.

Table 1. Sets of minimum and maximum levels distributed over the four periods of the year

Period	2003		2004		2006	
	Max Level [m]	Min Level [m]	Max Level [m]	Min Level [m]	Max Level [m]	Min Level [m]
Win. period	3.63	1.15	2.86	1.31	3.51	1.21
Spr. period	3.06	1.93	4.15	2.29	4.93	2.99
Sum. period	2.13	0.74	3.04	1.56	4.52	1.69
Aut. period	2.24	0.61	2.83	1.18	2.62	1.05

Table 2. Sets of minimum and maximum volume water flow distributed over the four periods of the year

Period	2003		2004		2006	
	Max Flow [m^3/s]	Min Flow [m^3/s]	Max Flow [m^3/s]	Min Flow [m^3/s]	Max Flow [m^3/s]	Min Flow [m3/s]
Win. period	4742	1612	3608	1629	4383	1683
Spr. period	3793	2510	5124	2937	7845	3291
Sum. period	2713	1010	3538	1975	6511	2197
Aut. period	2778	913	3367	1513	3056	1570



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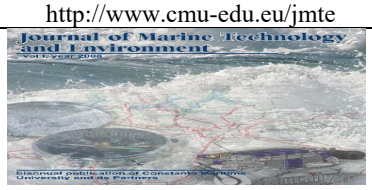

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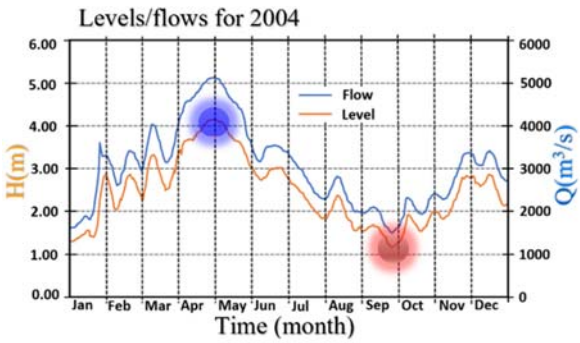

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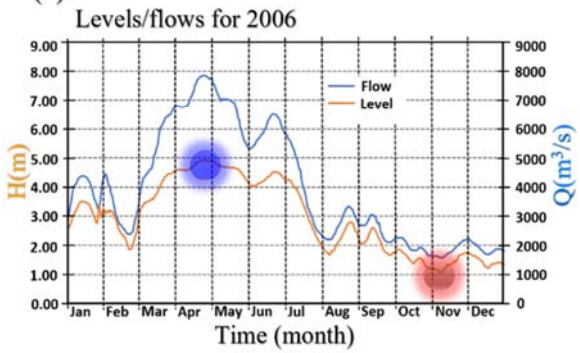

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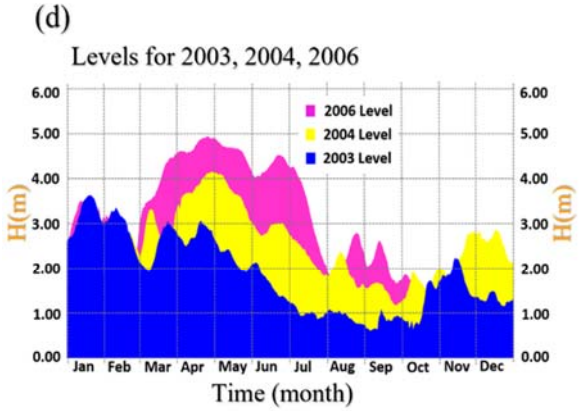

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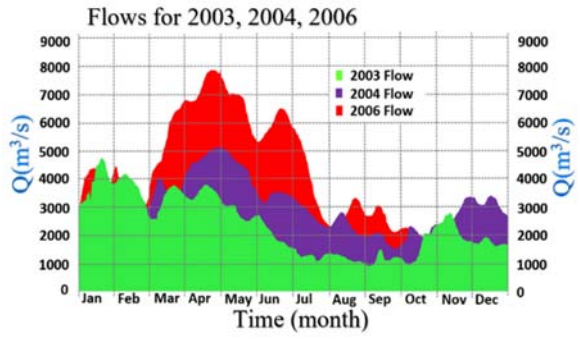

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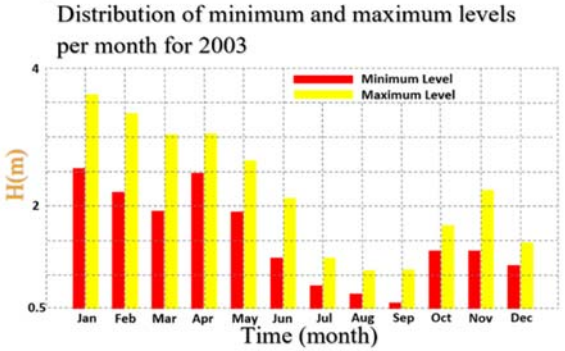

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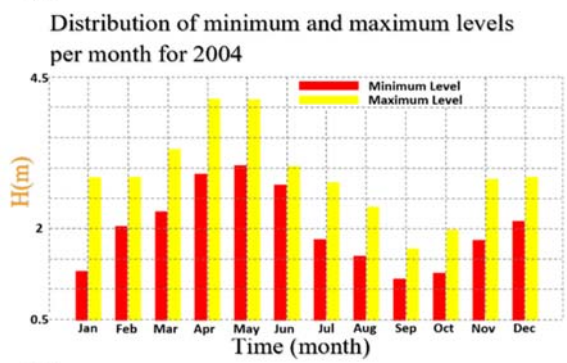

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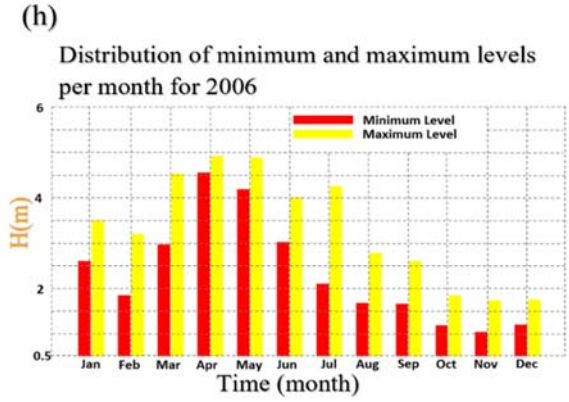

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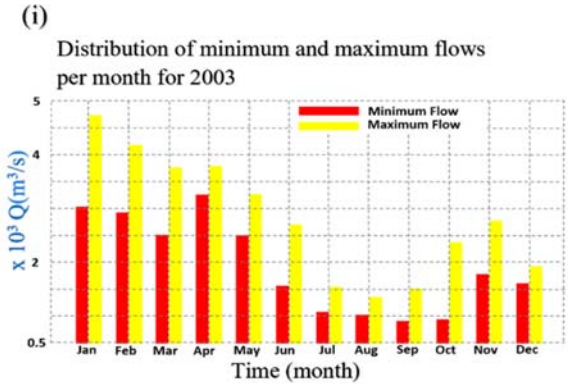

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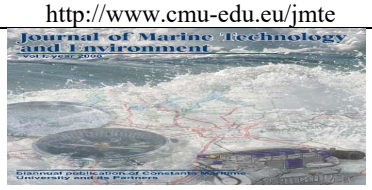

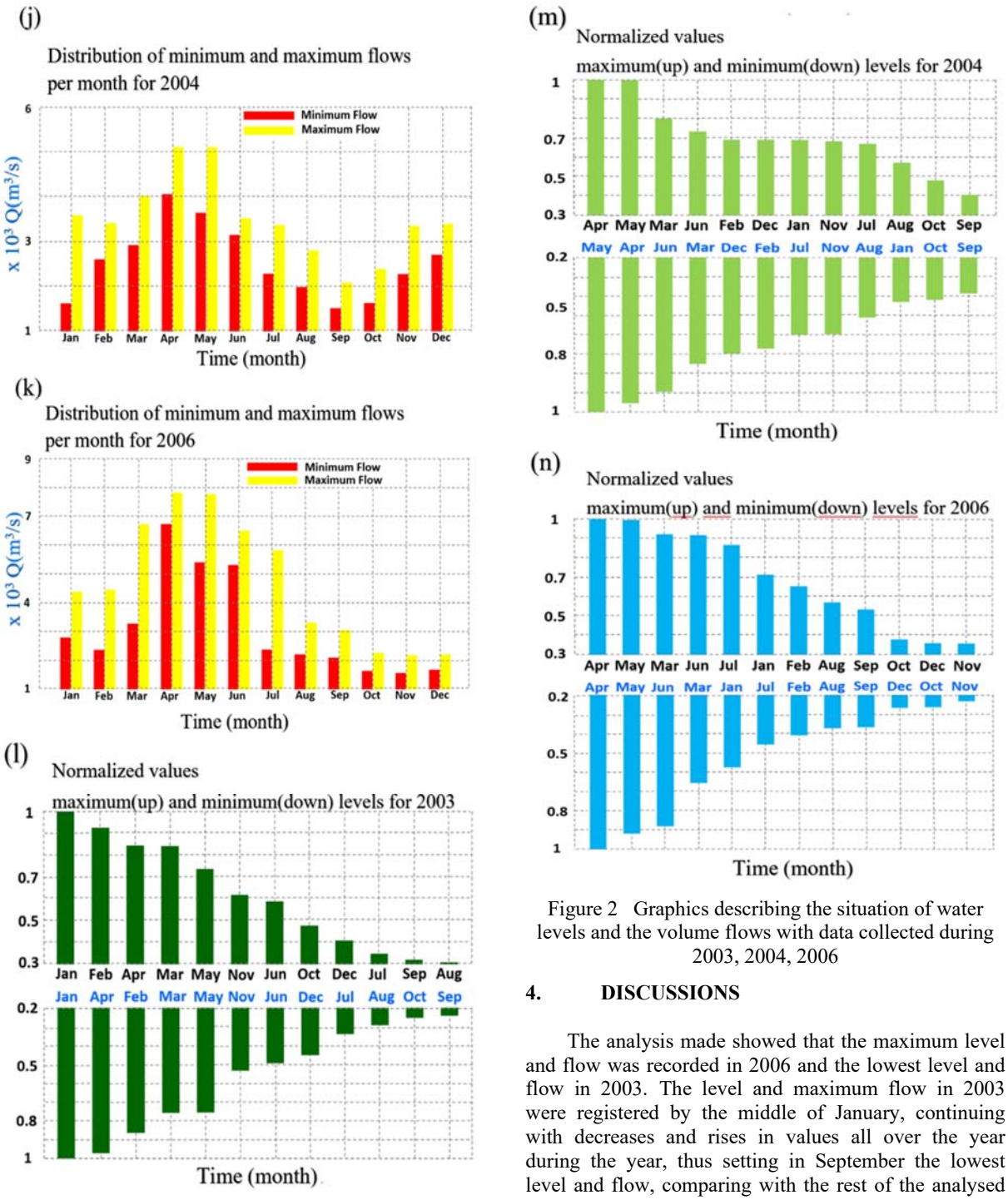

Figure 2 Graphics describing the situation of water levels and the volume flows with data collected during 2003, 2004, 2006

4. DISCUSSIONS

The analysis made showed that the maximum level and flow was recorded in 2006 and the lowest level and flow in 2003. The level and maximum flow in 2003 were registered by the middle of January, continuing with decreases and rises in values all over the year during the year, thus setting in September the lowest level and flow, comparing with the rest of the analysed years - Fig. 2 (a), Fig. 2 (d), Fig. 2 (e), Fig. 2 (f), Fig. 2 (i).

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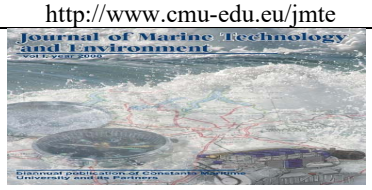


The 2003 situation is similar to the one of 2004 and 2006, only in terms of the minimum level / flow. The minimum level / flow for the three years considered in the analysis have been recorded during the autumn - Fig. 2 (a), Fig. 2 (b), Fig. 2 (c), Fig. 2 (d), Fig. 2 (e), Fig. 2 (f), Fig. 2 (g), Fig. 2 (h), Fig. 2 (i), Fig. 2 (j), Fig. 2 (k).

The autumn periods can also record extremely different situations from one year to another, as in other years not too many can trigger a rainy episode that can generate large autumn waters. The occurrence of such a massive leakage episode is also facilitated by the sharp decrease of the air and soil thermal regime. In the above-mentioned case, it was shown that at the end of the summer period and the beginning of the autumn period the precipitations were missing in the territory resulting in low levels / flows.

The year 2006 is similar to 2004 in terms of the maximum level / flow recorded during the spring period - Fig. 2 (c), Fig. 2 (d), Fig. 2 (e), Fig. 2 (g), Fig. 2 (h), Fig. 2 (i), Fig. 2 (k).

The spring season coincides with the season where the average daily air temperature is between 0^0C – 10^0C, favoring the melting of snow reserves in the territory. In this period, the river's levels and flows are increasing, sometimes faster, sometimes slower, depending on the rate of the snow melting, and the possible overlapping of rains over the snow.

It should be noted that the maximum annual drainage of the water can take two forms, namely: high water and floods.

In general, the two notions characterize the same phase of the regim, but they have quite a different content.

As far as floods are concerned, it is a very characteristic hydrological phenomenon for all rivers, being fed by surface sources (rain, snow melting). Analyzing the three years, we can conclude that the year 2006 shows a significant flood with values exceeding 7000 m^3/s - Fig. 2 (c), Fig. 2 (e), Fig. 2 (k). A similar situation was recorded in 2004, but with much lower values compared to 2006, with quantitative values slightly above 5000 m^3/s - Fig. 2 (b), Fig. 2 (c), Fig. 2 (e). Despite the large differences in values for the 2 years, their likeness is given by the flood period.

Floods can be defined as sudden and strong increases in the river level / flow due to the torrential rains, long-lasting rains, or accelerated snow melting.

The year 2003 recorded in January the highest level/ debit for that year. A less normal situation, comparing with the rest of the years, because in the winter period, the overlapping season in which the average daily air temperature is below 0^0C, precipitation is in solid form (snow) and the river has a generally low drain. On the river, frost formation of different kinds, of some intensity and duration, occurs during this period. In most of the territory, there is a minimum drainage period, called hydrology, the period of the small winter waters.

Various different climatic and hydrological situations can be recorded in the summer period, in spring floods can continue, an example being the first part of the summer of 2006 - Fig. 2 (c), Fig. 2 (d), Fig. 2 (e), Fig. 2 (h), Fig. 2 (k). Generally, during this period, there are periods of small summer waters, where the Danube gradually passes from surface feeding (rain) to pure underground feeding. At this stage, the river has a general trend of decreasing flows, from the maximum value to the minimum value, which in most cases occurs in September.

In the figures: [Fig. 2 (l), Fig. 2 (m), Fig. 2 (n)], the normalized values corresponding to the minimum (down) and maximum (up) levels are presented, providing a more detailed picture of these data.

Knowing the minimum and maximum levels / flows, is also relevant in designing, exploiting hydro-technical constructions and complex water management.

Knowing the duration of the levels / flows is also important for many practical activities, as: the placement of machines, hydro-aggregates and machines in the minor bed during the execution of works or the exploitation of resources from the bed (ballast, sand, water supply, etc.) in flood and ice protection, etc.

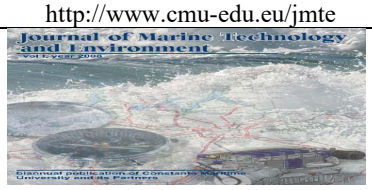
5. CONCLUSIONS

The analysis made in this work lead to the conclusion that during one year four characteristic periods occur in the hydrological regime of the river. These are: the winter period, the spring period, the summer period and the autumn period. Each period is manifested both in climatic and hydrological terms by specific features and phenomena.

Large waters occur most often in the spring, at the slow and prolonged melting snow. Their duration and intensity depending on the physical-geographic conditions that generate the leakage, namely the reservoir of the water in the basin, the rapidity of the melting of the spring snow, the overlapping or not with the beginning of the spring rains.

Having a detailed and comprehensive picture regarding the Danube flows and levels is important because knowing these values can be of a practical interest for the river development works, such as the protection of the dikes' height (avoidance of a major flood risk).

As a general conclusion, the scientific and practical importance of knowing the fluctuation of the river levels /flows, it can be highlighted by several important aspects, such as the knowledge of level variations during the year or in a multiannual profile, allows for a general understanding of the determinant role of the physical-



geographic factors on the formation and the characteristics of the leakage through the bed.

To playback as eloquent as possible the importance of knowledge of the level fluctuations of a river, it is necessary to process, verify and interpret all data on the levels / flows, establish links and graphical correlations, and determine the characteristic values over the multiannual period.

6. ACKNOWLEDGEMENT

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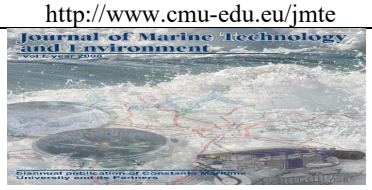

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SUPPRESSING CHAOS IN POPULATION DYNAMICS DISCRETE MODELS BY ADDING PERIODIC PULSES TO THE SYSTEM VARIABLES

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Abstract: The inability to predict the evolution of population dynamics in the presence of chaos can lead to catastrophic situations so chaos-control techniques must be applied to direct the system towards a predictable behaviour. This can be done either by controlling chaos, so the system's final state is an unstable periodic orbit embedded in the strange attractor of the original system, or by suppressing chaos and producing a controlled regular state of an auxiliary system. A simple and efficient algorithm that suppress chaos by adding constant and periodic pulses to the dynamic system variables has been proposed by Guemez and Mathias. The pulses are introduced into the system either in multiplicative or additive ways. The performance of the method depends critically on the period and the strength of the feedback. With the aim of proving the merits of the method and providing multiple numerical evidences concerning the ability of the approach to change the chaotic state into a periodic one, in the paper we analysed a discrete-time two species food chain model having a rich spectrum of dynamical behaviours including chaos. Because the system parameters were chosen so the system behaves chaotic but close enough to a period-6 window in the bifurcation diagram, we concentrated mainly in stabilizing orbits having periods multiple of six. However, other cases were also considered. The influence of feedback strengths on the stabilization process was highlighted by computing and drawing colour maps presenting the period of the stabilized orbits. They show that even small interventions on system variables can direct the system to the desired goal.

Key word: Additive and proportional feedback, chaos control, Lotka – Volterra prey-predator model.

1. INTRODUCTION

Population dynamics is the branch of mathematical biology, with a history of two centuries that studies mainly the size and age composition of a population regarded as a dynamical system. Its first principles and models have been formulated by Malthus (1798), Verhulst (1845), Howard and Fiske (1911), Lotka (1925), Volterra (1926), Gause (1932) and Pearl (1942). After the second world's war, the number of studies concerning the population dynamics has increased exponentially.

From mathematical point of view, there exist two major modelling strategies in the field: the continuous time approach based on ordinary differential equations and having the Verhulst's logistic model as the first attempt, and the discrete time approach using difference equations that was pioneered by Fibonacci (1203). If the continuous population models are necessary for large populations, where births and deaths can occur at any time, the discrete models are more appropriate when the populations have non overlapping generations or all births and deaths occur almost simultaneously. In the second category many insects and annual plants may be included.

As Robert May pointed out [1] by studying the logistic equation, even the very simple nonlinear ordinary or difference equations can possess a rich spectrum of dynamical behaviours including fixed points, cascades of stable cycles or chaos. A well-known example in this sense is the Lotka – Volterra predator – prey equations used to describe the dynamics of two species populations, one being the prey and the other the predator [2].

Generally, chaos is associated with an unpredictable behaviour and this may be inconvenient in some research area (as population dynamics) where a more ordered comportment is desirable. For such a situation, the suppression of chaos and its substitution with a regular behaviour may be achieved by control techniques [3, 4].

In the paper, we use a discrete version of the Lotka – Volterra continuous model to test two schemes for chaos control, namely the periodic proportional and periodic additive feedback control. We prove that these approaches are able to transform a chaotic behaviour into a periodic one even with a very small change in the system variables.

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2. MODEL DESCRIPTION

The discrete-time two species food chain model used in the paper is described mathematically by the following system of nonlinear difference equations in non-dimensional form

$$x_{n+1} = r\,x_n\left(1 - x_n\right) - a\,x_n\,y_n\,,\; y_{n+1} = -c\,y_n + b\,x_n\,y_n \tag{1}$$

where x_n and y_n are the prey and the predator at the n generation, respectively, while r, a, b and c are positive constants related to the rate of growth of the prey, per capita searching capacity of the predator or per-prey clutch of the predator [5]. The system (1) has three equilibrium points, $E_0 = (0, 0)$, $E_1 = \left(\frac{r-1}{r}, 0\right)$ and $E_2 = \left(\frac{1+c}{b}, \frac{r(b-1-c)-b}{ab}\right)$. Only E_2 corresponds to a coexistence of the two species. It can be either a sink, a source or a saddle, depending on the parameters r, a, b and c [6].

In our numerical simulations the fixed values a = 1.43, b = 3.91 and c = 0.25 have been considered while r was varied in the range [2.0, 3.9]. In Figure 1, the bifurcation diagram was plotted for the prey population as a function of parameter r. The initial conditions were $x_0 = 0.2$ and $y_0 = 0.3$.

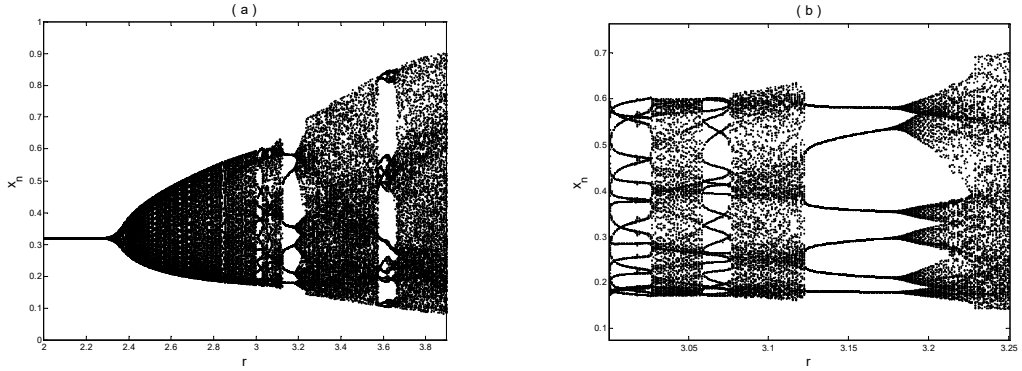
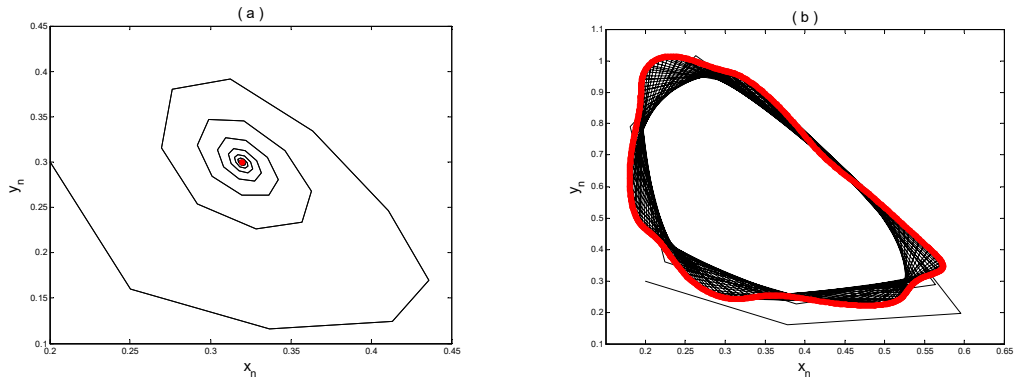


Figure 1 Bifurcation diagram for discrete-time two species food chain model (1) for a = 1.43, b = 3.91, c = 0.25 and (a) $r \in [2, 3.9]$; (b) $r \in [3, 3.25]$

From the figure it is obvious that the fixed point E_2 is stable for r < 2.35. Increasing r, E_2 loses its stability and an invariant cycle enclosing it appears instead. Around r = 3, the cycle is replaced by periodic orbits with large periods. As r increases further, the periodic orbits become irregular and the chaotic behaviour makes its presence felt at $r \cong 3.03$. The last two stages are repeated before a large window corresponding to a six-period orbit (between r = 3.13 and r = 3.19). For $r \in [3.19, 3.6]$ and $r \in [3.65, 3.9]$ the system behaves chaotically, the range for the two variables becomes larger and larger as well as the degree of chaoticity. Starting with r = 3.9 the system (1) is unstable and the values for x_n and y_n go to infinity. The different stages of this complex dynamics are illustrated through examples in Figure 2.



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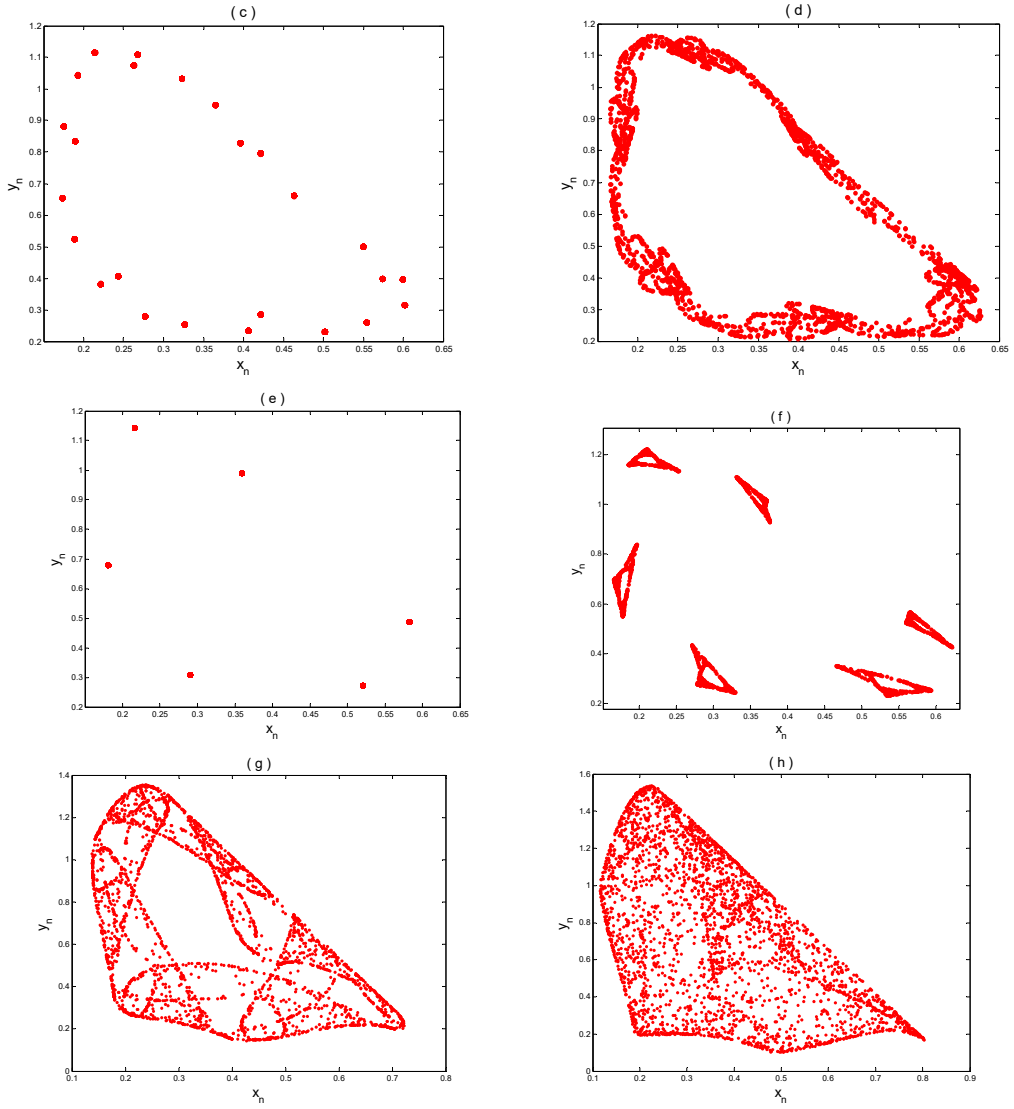

Figure 2 Phase plane diagrams for discrete-time two species food chain model (1) for $a = 1.43$, $b = 3.91$, $c = 0.25$ and (a) $r = 2.1$ (stable fixed point); (b) $r = 2.9$ (invariant cycle); (c) $r = 3.06$ (25 - period orbit); (d) $r = 3.1$ (chaos); (e) $r = 3.15$ (6 – period orbit); (f) $r = 3.21$ (six chaotic small curves); (g) $r = 3.3$ (chaos); (h) $r = 3.5$ (chaos).

3. CHAOS CONTROL TECHNIQUES

Starting with OGY method [7], several other approaches for controlling chaos have been suggested and implemented [8-10]. The idea of most of these techniques consists in stabilizing one of the unstable periodic orbits embedded in the chaotic attractor by changing one or more of the state variables or parameters. In this contribution, we focus on the technique proposed in [11], based on periodic proportional changes in the system variables, and on an alternative of it consisting in periodic additive perturbations on the system.

For a two-dimensional map like (1), the first control algorithm consists of a proportional feedback applied to the variables x_n and y_n, every Δn iterations:

$$\tilde{x}_n = x_n(1+\gamma_1), \tilde{y}_n = y_n(1+\gamma_2) \qquad (2)$$

with γ_1 and γ_2 representing the intensity of the feedback for x and y, respectively. If $\gamma_2 = 0$, then only x

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variable is modified and vice versa. A positive γ_i denotes an infusion of individuals into the population, while a negative γ_i represents a removing. An important advantage of this technique consists in its wide applicability to different flows and mappings. However, the scheme (2) assumes that the system variables are determined at each generation and this could be time consuming and expensive in practice.

The other control mechanism applied in the paper requires periodic additive pulses on the system variables:

$$\widetilde{x}_n = x_n + \gamma_1, \ \widetilde{y}_n = y_n + \gamma_2, \qquad (3)$$

when $n \equiv 0 \pmod{\Delta n}$. Again, the signs of γ_i determine if some individuals are removed or introduced into the system. In applying scheme (3) one needs just to fix the values for $\gamma_{1,2}$ at the beginning and then no other information about the system is required. As a drawback, the method seems to fail to work properly for some dynamical systems.

It must be pointed out that the success of these techniques in suppressing chaos depends strongly on the parameters $\gamma_{1,2}$ and Δn. Additionally, the chaotic behaviour will be replaced by an ordered one with a much higher probability if the system evolves in the proximity of a window of regularity.

4. APPLICATION TO MAP (1)

To show the effectiveness of the two techniques described above in stabilizing a periodic dynamics, the difference equations (1) were iterated first for parameter values a = 1.43, b = 3.91, c = 0.25 and r = 3.1. The system behaves chaotic (see Figure 2(d)) but it is close enough to two periodic windows, one corresponding to period – 6 orbits. For this reason we tried Δn = 6 and, for simplicity, $\gamma_1 = \gamma_2 = \gamma$. After a transient lasting 100 iterations, we switched on the control scheme (2) and observed that there exist an impressive range of γ values that direct the system towards a periodic dynamics. As always happened, the obtained period was a multiple of Δn. Figure 3 (a) displays the stabilization of a period-6 behaviour by using $\gamma = -0.02$ while Figure 3 (b) indicates a similar trend towards a period-12 cycle for γ = - 0.13. The proportional feedbacks succeeded to supress chaos even only one variable is periodically altered. Figure 3 (c) presents the case $\gamma_1 = -0.02, \gamma_2 = 0$. Similar results have been obtained for additive control scheme (3) (for brevity, they are not reported here). Depending on γ_1 and γ_2, the stabilization of a periodic orbit lasted between several dozen and hundreds of iterations.

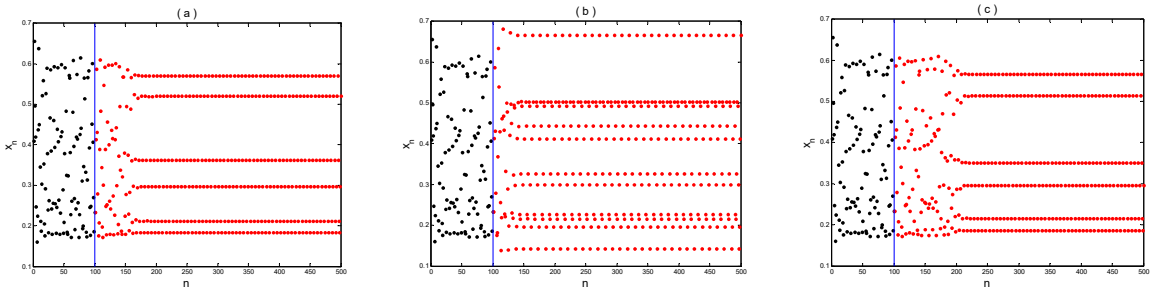

Figure 3 Stabilization of different periodic orbits for the map (1) with a = 1.43, b = 3.91, c = 0.25 and r = 3.1 by a proportional feedback at every Δn = 6 iterations : (a) $\gamma_1 = \gamma_2 = -0.02$; (b) $\gamma_1 = \gamma_2 = -0.13$; (c) $\gamma_1 = -0.02, \gamma_2 = 0$.

To have a better idea about the two schemes' efficiency we plotted the bifurcation diagrams $\gamma - x_n$ by reporting only the last 100 values of variable x_n (from 3000). We tried different combinations between γ_1 and γ_2, both positive and negative, and we always observed extended windows of periodic behaviour. As expected, a lot of them correspond to period-6 cycles.

Moreover, a large set of pairs (γ_1, γ_2) has the property $|\gamma_1|, |\gamma_2| << 1$, meaning a minimal intervention in the population dynamics.

Figures 4 and 5 show some of our findings for proportional and additive control, respectively. It is interesting to note the numerous discontinuities appearing in the bifurcation diagrams.

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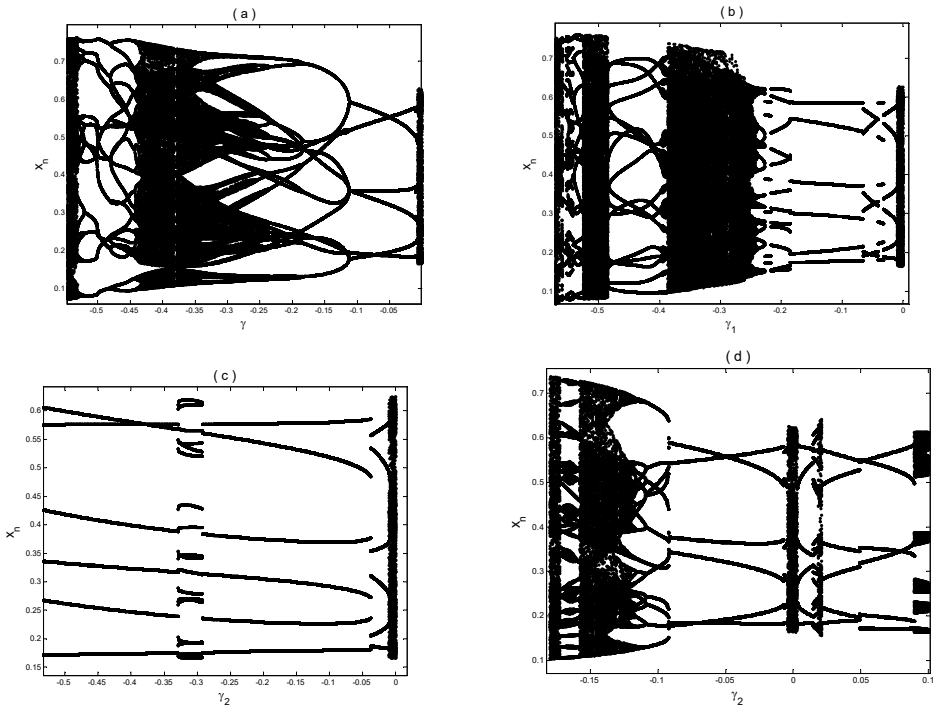

Figure 4 Bifurcation diagram $\gamma - x_n$ of the map (1) with $a = 1.43$, $b = 3.91$, $c = 0.25$ and $r = 3.1$ for the proportional feedback control case and $\Delta n = 6$: (a) $\gamma_1 = \gamma_2 = \gamma$; (b) $\gamma_1 = \gamma, \gamma_2 = 0$; (c) $\gamma_2 = \gamma, \gamma_1 = 0$; (d) $\gamma_2 = \gamma, \gamma_1 = 2\gamma$.

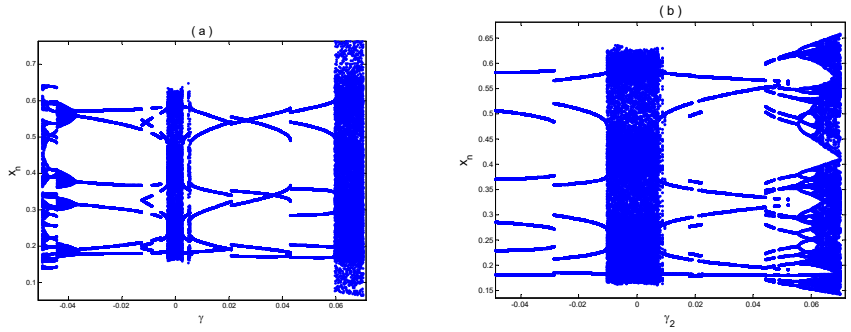

Figure 5 Bifurcation diagram $\gamma - x_n$ of the map (1) with $a = 1.43$, $b = 3.91$, $c = 0.25$ and $r = 3.1$ for the additive feedback control case and $\Delta n = 6$: (a) $\gamma_1 = \gamma_2 = \gamma$; (b) $\gamma_2 = \gamma, \gamma_1 = 0$.

Even more, to analyse the effectiveness of the discussed techniques for chaos control we followed the steady-state behaviour of map (1) for a large grid of 200 x 200 equally distributed pairs (γ_1, γ_2) on the squared area $[-0.35, 0.05] \times [-0.35, 0.05]$ in the proportional feedback control case and on the $[-0.05, 0.07] \times [-0.05, 0.07]$ set for the additive feedback control. The parameters were a = 1.43, b = 3.91, c = 0.25, $\Delta n = 6$ and $r \in \{3.1, 3.21\}$. We counted the number of pairs (γ_1, γ_2) which succeeded to stabilize orbits of periods 6, 12, 18 and 24 and reported our findings in Table 1 and Figures 6 and 7. For both techniques the chaotic behaviour was easier to turn into a regular one for r = 3.1 than for r = 3.21

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Table 1 The number of orbits having period 6, 12, 18 and 24 stabilized by proportional and additive feedback control

Period	Proportional control		Additive control	
T	$r = 3.$	$r = 3.21$	$r = 3.1$	$r = 3.21$
6	18,745	3,215	33,535	12,295
12	7,233	2,142	1,817	1,381
18	214	5,424	577	2,923
24	2,839	1,804	655	608
Others or chaos	10,969	27,415	3,416	22,793

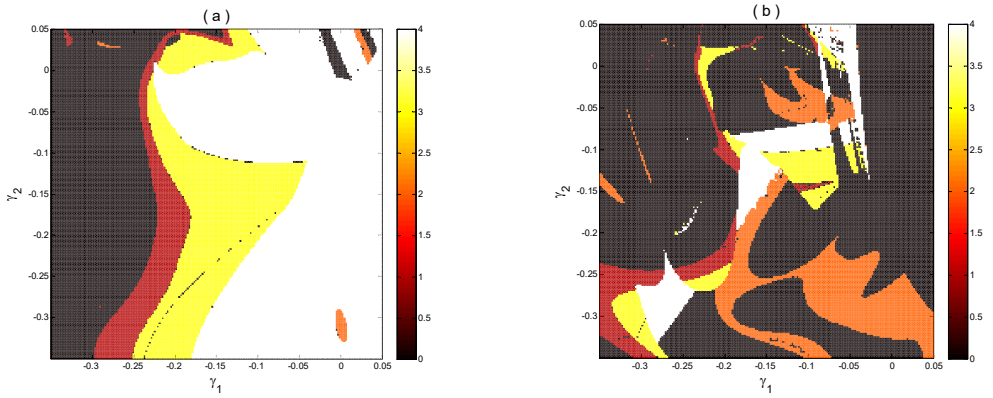

Figure 6 Pairs (γ_1, γ_2) inside the square $[-0.35, 0.05] \times [-0.35, 0.05]$ for which the chaotic behaviour of the map (1) with $a = 1.43$, $b = 3.91$, $c = 0.25$ and $\Delta n = 6$ is turn into a regular one using proportional feedback control. The values from 4 to 0 on the colour bar correspond to periods 6, 12, 18, 24 and greater than 24 (or chaos), respectively. a) $r = 3.1$; b) $r = 3.21$.

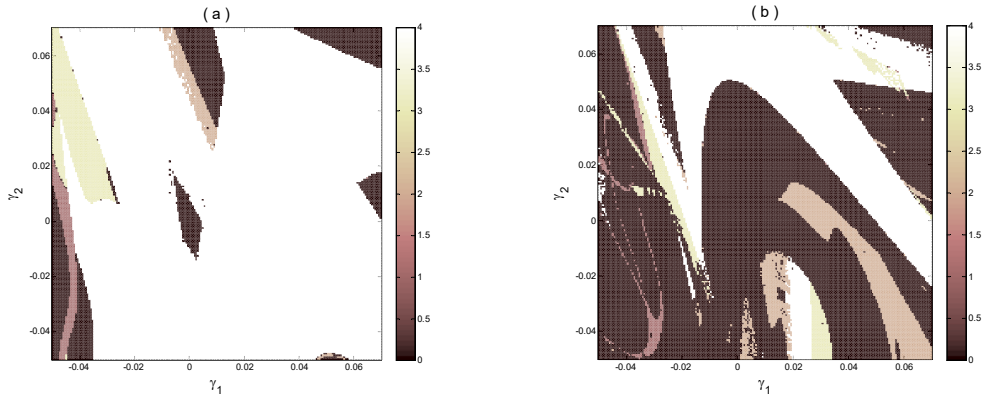

Figure 7 Pairs (γ_1, γ_2) inside the square $[-0.05, 0.07] \times [-0.05, 0.07]$ for which the chaotic behaviour of the map (1) with $a = 1.43$, $b = 3.91$, $c = 0.25$ and $\Delta n = 6$ is turn into a regular one using additive feedback control. The values from 4 to 0 on the colour bar correspond to periods 6, 12, 18, 24 and greater than 24 (or chaos), respectively. a) $r = 3.1$; b) $r = 3.21$.

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By changing Δn , all sorts of other periodic dynamics were stabilized. Table 2 contains samples of $(\Delta n, \gamma)$ pairs, where $\gamma_1 = \gamma_2 = \gamma$, for which the two algorithms worked properly in obtaining a T – period cycle, with $T = 1,2,...,14$. Only scheme (3) failed to transform chaos into a regular behaviour in the cases T = 1, T = 3 and T =11. They were included those pairs that involved a minimum effort. A lot of other pairs (γ_1, γ_2) that lead to chaos suppression for r = 3.1 and Δn = 5, both for multiplicative or additive feedback control, are shown in Figure 8.

Table 2. Examples of $(\Delta n, \gamma)$ pairs for which a T – period cycle was stabilized

Period T	Proportional control		Additive control	
	Δn	$\gamma_1 = \gamma_2 = \gamma$	Δn	$\gamma_1 = \gamma_2 = \gamma$
1	1	- 0.12	none	none
2	2	- 0.2	2	- 0.2
3	3	- 0.5	none	none
4	4	- 0.23	2	0.14
5	5	- 0.135	5	- 0.07
6	6	- 0.01	6	0.01
7	7	0.04	7	- 0.02
8	8	0.06	8	- 0.054
9	9	- 0.332	9	- 0.068
10	5	- 0.2	5	0.09
11	11	- 0.1196	none	none
12	12	0.02	12	- 0.01
13	13	- 0.06	13	- 0.028
14	7	- 0.25	14	0.046
15	5	- 0.162	5	0.089

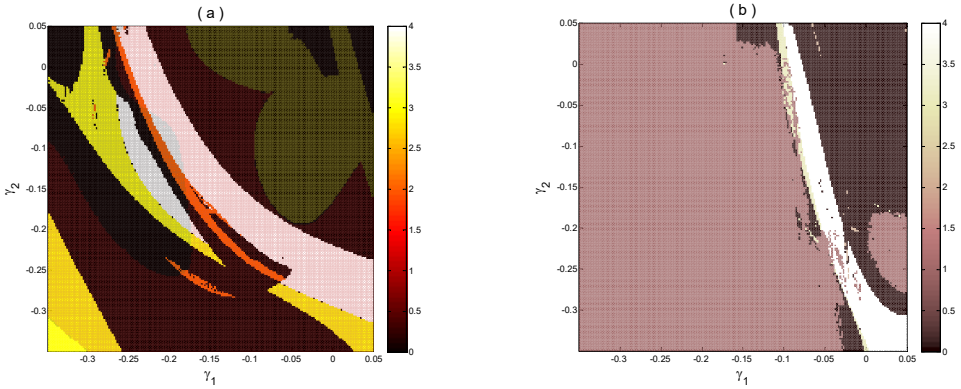

Figure 8: Pairs (γ_1, γ_2) inside the square $[-0.35, 0.05] \times [-0.35, 0.05]$ for which the chaotic behaviour of the map (1) with a = 1.43, b = 3.91, c = 0.25, r = 3.1 and $\Delta n = 5$ is turn into a regular one. The values from 4 to 0 on the colour bar correspond to periods 5, 10, 15, 20 and greater than 20 (or chaos), respectively.
a) proportional control; b) additive control.

5. CONCLUSIONS

The paper es food chain model known for its interesting behaviour. The study has conducted to interesting conclusions including:

a) The method is easy to implement, either from numerical point of view or to a concrete two species food chain biological system. It only involves that small part of population is injected into or removed from the system every Δn iterations (or generations);

b) There exist an imposing number of triplets $(\gamma_1, \gamma_2, \Delta n)$ leading to periodic behaviours of all kinds

of periods. Often, only a slight intervention on the system variables is sufficient to achieve this goal;

c) For different Δn, bifurcation diagrams or colour maps can be quickly realized to show the influence of control strengths on chaos suppression process. They can be used in practice to choose the appropriate behaviour.

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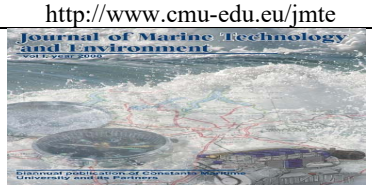

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SUDIES CONCERNING FLORA FROM DIFFERENT PROTECTED AREAS IN CONSTANTA COUNTY BY APPLYING ECOLOGICAL AND STATISTICAL METHODS

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Abstract: This study presents our results concerning the geographical distribution, ecological and anthropic impact aspects of the wild flora from three protected areas (Fantaniţa Murfatlar, Gura Dobrogei and Hagieni forest). All three nature reserves studied belong to the Natura 2000 European network protection. From this point of view we watched the current state and future premises on the maintenance of vulnerable species / endangered in the natural habitats. The study is based on monitoring for 3 years (January 2015-December 2017), in which we identified: main plant families, distribution of species in geoelements and analysis of ecological categories (moisture factors, temperature and soil reaction). For a better tracking of the similarities between species in three distinct areas, we used the statistical method of processing data. The results showing important similarities between the three types of protected areas with respect to the balance of positive and negative effects using Pearce coefficient and respectively with respect to structure and function of natural biota.

Key words: anthropogenic influence, protected areas, ruderal flora similarity.

1. INTRODUCTION

For development plants have a range of fundamental requirements for the environment, especially for spreading and their association in special habitats. Changing of the climatic factors (such as temperature, light, rainfall regime) in recent decades can cause significant changes in the current structure of ecological communities [4]. In this context, we must be prepared to act in time for not being forced to witness a dramatic reduction in plant diversity in the protected areas. The current biodiversity is the result of a long process of species adaptation to various conditions of abiotic and biotic environmental. At the moment, under the influence of anthropogenic impacts we witness both to a reduction in biodiversity and an explosion of another type of biodiversity, namely to adapt to the conditions created by human of eurioic and invasive species. The natural habitats presented within the Constanta County include all media: aquatic, terrestrial and subterranean. Recognition of the value of biodiversity in Constanta is achieved by special protection, including Natura 2000 sites. The distinctiveness of the protected region is representative by endemic flora (usually expressed as percentage).

In Dobrogea region there are two biogeographic regions (Pontic- Black Sea and steppe), with a total of 21 Special Areas of Conservation (SAC) and a total of 25 Special Protection Areas (SPA) under the Habitats Directive and Birds Directive. Also in Dobrogea region is encountered Romania's largest numbers protected areas and Natura 2000 sites (more than 65% of the territory), these region it's representative for the Pontic and European Union steppe bioregions [8]. Hagieni Forest Nature Reserve presents an exceptional national and international importance due to its geographical position at the crossroads of migration Pontic, Balkan, Mediterranean, Central European, Aralo-Caspian and Illyrian-Moesiac flora, which determines a mixture of floral elements of great richness and variety [3]. In Fantanita Murfatlar Nature Reserve predominate the Pontic, Balkan, Continental, sub-Mediterranean and Eurasian species. Changes over the time in flora structure were determined primarily on tourism and uncontrolled waste disposal inside the reserve. Gura Dobrogei Reserve belongs the steppe area in whose breakthroughs occur silvosteppe island, which mostly concern the portions rugged terrain. It is characterized by a great diversity of plant taxa, due to interference temperate continental climate with Mediterranean colors.

The main goal of this paper is to highlight the geographical distribution of elements flora protection in three sites distributed differently in Constanta County

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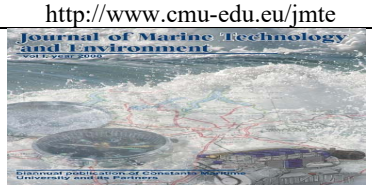

(Hagieni - south, Fantanita Murfatlar - center and Gura Dobrogea – north), to assess the degree of association and their maintenance on the territory in relation with the ecological balance of positive and negative effects.

2. MATERIAL AND METHODS

Registration patterns of flora and establishment of the registration algorithms. The floristic conspectus is based on the field data (monitoring on the same representative transects by 1.5 km / each protected area) over a period of three consecutive years (January 2015 - December 2017) in prevernal and vernal season. Our sampling strategy was based on some advantages such as, maximum efficiency, easy applicability on the field, and that does not require great financial effort. For each area were established in the field the representative transects, which included the largest variety of environmental conditions such as, peaks or areas with slopes to express as clearly as the space occupied by the representative species of flora. For each taxon was considered the phytogeographical element and ecological categories depending on species behaviour to moisture, temperature and soil reaction, in the sight appreciation of their indicator value in relation with the environmental conditions in the three areas studied [7]. In Fantanita-Murfatlar Reserve were identified 171 taxa, 69 taxa in Gura Dobrogei Reserve and 113 taxa in Hagieni Forest Reserve, respectively. They were followed the differences phytocenologic and the potential geographic preserve flora in the comparable areas.

We made a series quantitative / qualitative observations in order to obtain more comprehensive information about the vegetal associations organization. This information was made according to the Braun-Blanquet [11]. We compared ours floristic lists with the flora species lists from the scientific documentation from each of three protected areas (http://www.mmediu.ro, accessed January 2015 - January 2017) to quantify their abundance and endangerment status. We obtained a basic data recorded in the form of a species list and the quantities of each species, respectively.

Findings of the floral cover is done visually, evaluating the sample surface covered by foliage of investigated population. For this purpose we used a Nikon camera D3300 model, 21.4 mega pixels, Nikkor 18-55 mm, in which we framed the metric frame (1x1m). Measurements were made in the same areas to eliminate a number of variables, focusing mainly on the ecological categories. The statistical interpretation of the data was done by encoding of the most representative 11 families, the rest of the families have less than 10 records (Table 1). We take into account this aspect to make observations on the habitat maintaining capacity of the representative flora from the three zones.

Table 1. Encoding of representative families from the three research areas

No crt.	Cod	Family
1	300	*Asteraceae*
2	800	*Convolvulaceae*
3	400	*Boraginaceae*
4	3800	*Cruciferae*
5	900	*Fabaceae*
6	1200	*Lamiaceae*
7	2800	*Liliaceae*
8	1500	*Poaceae*
9	1900	*Ranunculaceae*
10	4600	*Umbelliferae*
11	2100	*Schrophulariaceae*

Also, to observe the human impact on the outskirts of the 3 protected areas we consider most striking plant associations that were studied on the basis of analysis of the similarity indices (Sörensen Coefficient, Jaccard Coefficient and Simple Matching Coefficient) according to Pang-Ning et al., (2005) [10]. We resorted to such analysis, to draw attention to the need of sustaining the integrity of the peripheral natural areas against human aggression (such as, building the wind farms near the protection areas, the expansion of stone quarries, expanding human habitation, etc).

3. RESULTS

We considered valid by taxonomically point of view, 353 taxa (Figure 1). Analysing flora from all three protected areas (from Nothern, Central and Southern Constanta County) it shows that these belong to 45 botanical families, the best represented ones being *Asteraceae* (42 taxa), followed by *Fabaceae* (36 taxa), *Poaceae* (31 taxa). At the opposite pole there are families such as *Urticaceae, Rutaceae, Orchidaceae, Araliaceae* or *Dipsacaceae*, where there is only one taxon.

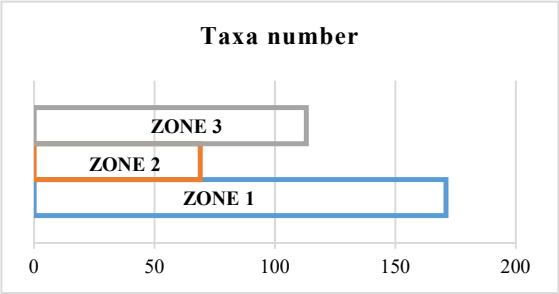

Figure 1 Floristic distribution in the three areas (zone 1- Fantanita Murfatlar; zone 2- Gura Dobrogei; zone 3- Forest Hagieni)

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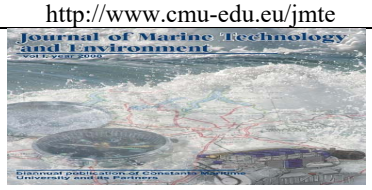


The habitats present in the protected areas study are: Ponto-Sarmatic deciduous thickets 40C0* (10% in Fantanita Murfatlar / Hagieni and 5% in Gura Dobrogei), Ponto-Sarmatic forest vegetation with the pubescent oak 91AA (30% in Fantanita Murfatlar / Hagieni and 10% in Gura Dobrogei), Ponto-Sarmatian steppes 62C0*(60% in Fantanita Murfatlar, 70% in Gura Dobrogei, 30% Hagieni), Caves with restricted access to the public - 8310 (0,2% in Gura Dobrogei), Pannonian-Balkanic turkey oak – sessile oak forests - 91M0 (0,5% in Hagieni), Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation - 3150 (1% in Hagieni), Fringe communities with high hydrophilic grasses of the plains to mountain and alpine floors - 6430 (1% in Hagieni) [6].

Further, we take into account the representative families for the three areas. We noticed that in zone 2 (Gura Dobrogei) there are the fewest families of 1, 4, 6, 7, 8, 9, 10 to 11 category, these being dominant in zone 1 (Fantanita Murfatlar), also we noticed that the families 4, 6 and 10 are found only in zone 1, totally lacking in other zones. In zone 2 prevails family 2 and 5, and in the zone 3 predominate the families 1 and 5 (Figure 2).

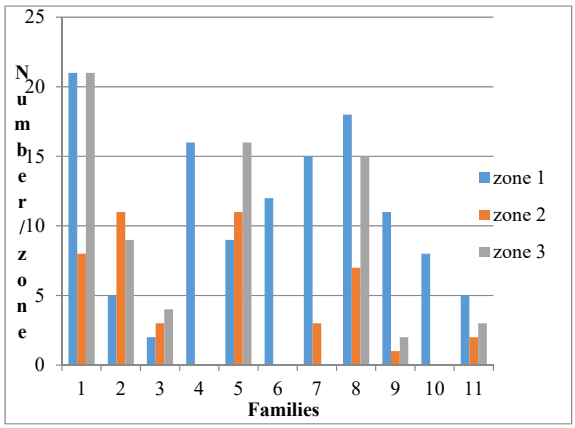
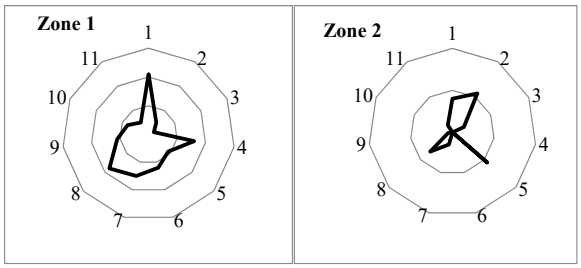


Figure 2 The diagram of the 11 families analyzed according to the three zones

The percentage analysis of the families from the three areas confirms the above diagram (Figure 3).



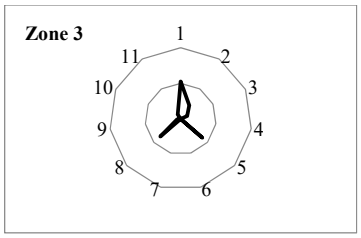


Figure 3 The percentage chart of families living in the three analyzed areas

We chose the representative families with codes 300, 900 and 1500 to study the conditions of humidity, temperature and soil reaction that may influence the number and distribution of plant families in these areas. For the code 300 were traced several charts, such as T = f (U), R = f (T) and R = f (U) to observe the zone of values prevailing for the species. From the environmental requirements point of view (Temperature, Humidity, Soil Reaction- T, H, R), the similarities on the zones 1, 2, 3, for the code 300 represented by dominant *Asteraceae* family, are shown in the figures below (Figures 4, 5, 6).

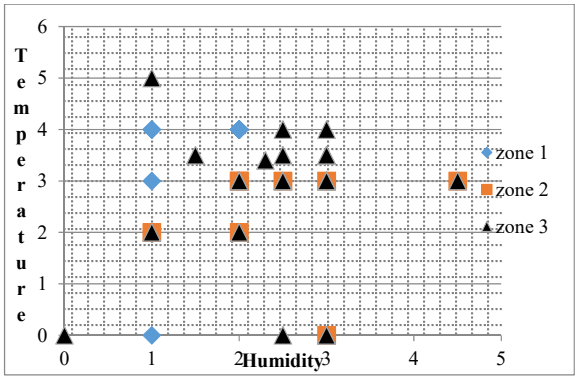


Figure 4 The environmental requirements (Temperature depending on Humidity) for the code 300 in the three zones

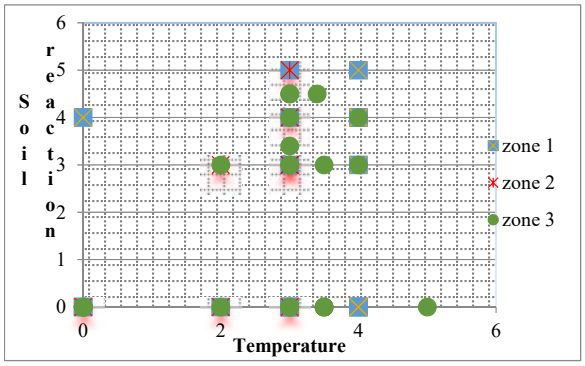


Figure 5 The environmental requirements (R- soil reaction depending on Temperature) for the code 300 in the three zones

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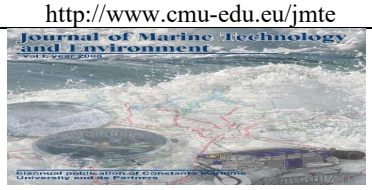

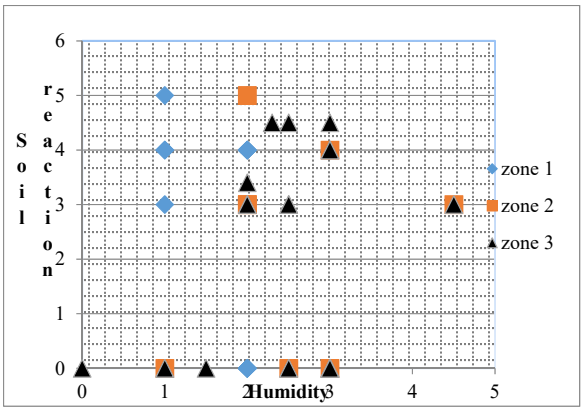

Figure 6 The environmental requirements (R-soil reaction depending on Humidity) for the code 300 in the three zones

We notice that species of the *Asteraceae* family are growing around the 0 - 4 thermal value of environmental requirements, with rare euritherm species and respective predominant mesothermal species (73%). These species evolution in relation to temperature are characteristic for hilly area climate in the studied areas, with average annual temperature of 10.4°C in the north-west and 11.4°C in the southeast of the Dobrogea County. From the temperatures point of view, Hagieni protected areas are located approx. 8 km west of the seaside and it benefits of the highest average temperatures over 11°C associated with high humidity atmosphere.

In the moisture spectrum we can mention the variability from xerophilous elements to mesophilous elements (from 38% to 59%) making up the specific species to the Constanta areas.

From soil reaction point of view witch is poorly acid, neutrophilous species are well represented by 56%, followed by neutro-basophilous species (31%). Studying a mean of the three ecological requirements values (T, H, R) for 300, 900, 1500 families of the three zones, it is observed that the values do not differ greatly, which led us to realize an error between these values (Table 2).

Table 2. The average of T, H, R values in zones 1, 2, 3

Families codes	U/ z1	T/ z1	R/ z1	U/ z2	T/ z2	R/ z2	U/ z3	T/ z3	R/ z3
900	2.11	2.55	2.11	2.60	2.85	1.95	2.61	2.59	2.22
1500	1.70	3.13	2.58	2.53	3.56	2.90	2.55	3.09	2.11
300	2.00	3.05	2.00	2.30	2.38	2.25	2.33	2.65	1.81

From the observations of graphs 4, 5, 6 made for family 300, it is observed that small errors are for this family, concerning the geographical influence on the spread of species (Table 3).

Table 3. Presentation of errors between the averages

Fam. codes	U/z1-U/z2	T/z1-Tz2	R/z1-R/z2	U/z2-U/z3	T/z2-Tz3	R/z2-R/z3	U/z3-U/z1	T/z3-Tz1	R/z3-R/z1
900	-0.49	-0.30	0.16	-0.01	0.26	-0.27	0.50	0.04	0.11
1500	-0.83	-0.43	-0.32	-0.02	0.46	0.79	0.85	-0.03	-0.47
300	-0.30	0.67	-0.25	-0.03	-0.28	0.44	0.33	-0.39	-0.19

It certifies that *Asteraceae* family (code 300) has a representativeness for zone 1 and 2 in terms of heat and for zone 2 and 3 respectively in terms of soil quality. *Poaceae* family (code 1500) is representative in terms of heat and soil quality for zones 2 and 3.

In contrast, the family *Fabaceae* (code 900) shows the greatest geographical spread, having the potential to maintain its territory. In order to observe the degree of similarity of the three areas we have developed an analysis with the Pearson coefficient (see tables 4, 5, 6). Pearson product-moment correlation coefficient it is widely used in the sciences as a measure of the degree of linear dependence between two variables and it is a measure of the linear correlation between two variables X and Y, giving a value between +1 and −1 inclusive, where 1 is total positive correlation, 0 is no correlation, and −1 is total negative correlation [12].

Table 4. Similarities of the three representative families for the moisture factor using the Pearson coefficient

Families codes	zone 1-zone 2	zone 2-zone 3	zone 1-zone 3
900	0.842901	0.941058	0.841526
1500	0.321606	0.609835	0.862676
300	0.808736	0.953858	0.798137

We can notice from the Pearson coefficient analysis for moisture that the most similar properties for the spread of the three families are posed in zones 1 and 3, and in zones 1 and 2, respectively zones 2 and 3, the degree of similarity approaches at 1 only for the code 900 and code 300 families.

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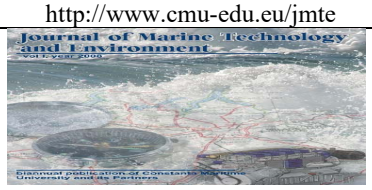


Table 5. Similarities of the three representative families for the thermal factor using the Pearson coefficient

Families codes	zone 1-zone 2	zone 2-zone 3	zone 1-zone 3
900	0.796831	0.817549	0.593971
1500	0.406927	0.543489	0.868829
300	0.791985	0.606161	0.902721

Upon analyzing of the similarities for temperature we observed that the 1500 and 300 families in zones 1 and 3 illustrate environmental compatibility, while for the 900 family there are compatibilities for areas 2 - 3 and 1 - 2.

Table 6. Similarities of the three representative families for the soil reaction factor using the Pearson coefficient

Families codes	zone 1-zone 2	zone 2-zone 3	zone 1-zone 3
900	0.859282	0.531066	0.349347
1500	0.771822	0.666239	0.798068
300	0.700649	0.620064	0.984112

Regarding the soil reaction we observed that values differ from one area to another, the highest degree of dissimilarity starring areas 1 - 3 and 2 - 3 for the 900 family. In terms of requirements for the soil reaction (pH scale), predominate the neutrophilus plant species in relation to the pH of the soil in the areas of research, ranging between 6.1 and 8.3 (soil slightly acidic to alkaline). This analysis reinforces what was observed in Table 3 errors, namely that the greatest degree of similarity for environmental categories analysed, it shows the 300 family.

4. DISCUSSION

4.1 Ecological analysis of flora by means of indicator value

The indicator values (regarding temperature, moisture, soil reaction and region) represent the most used system to classify the vascular plant species for all three protected areas that we have considered in this study. Environmental gradient analysis is an ecological tool that take into account the floristic areal origins, which is important in recognition of the vegetation variability in a particular region. In this study we identified three flora families (*Asteraceae, Fabaceae* and *Poaceae*) which were dominant in all three protected areas based on floristic dominance-type classifications. Among other things, floristic monitoring was done taking into account the coverage footprint of representative species, plant stature and the life form (perennial or annual form).The representative plants of the three protected areas show different degrees of specificity or selectivity. Based on data related to soil reaction, temperature and humidity, we can say that the *Asteraceae* family can be considered eurioic type with a good environmental adaptation. In combination with other representative species, this could amplify or reduce the differences in competitive abilities between plant species. Among the families of plants, *Asteraceae* and *Poaceae* appear with the largest ecological plasticity, with species able to adapt to various environmental conditions. For example, *Asteraceae* has a large number of seed covered with structures that allow long-distance transport and a high rate of germination; these are just some of the strengths of their conquest of new territories.

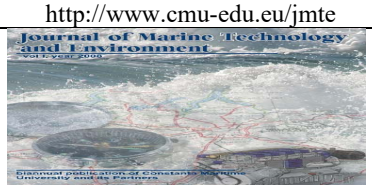
Poaceae has other advantages: their inflorescences are compact, producing small seeds that have a great ability to be transported by wind or animals [1]. The most competitive invasive species have been shown to be the perennial grasses (*Poaceae*), showing a perfect ecological plasticity: *Cynodon dactylon, Poa* sp. (species that are found in our phytocenologic studies).

In *Fabaceae* family are included woody plants and herbaceous plants. The great majority of species in this family are resistant to drought and have not soil requirement and also are resistant to pollution. Thus, the vast majority of *Fabaceae* species shows a stability in the territory.

4.2 Human impact on vegetation in the peripheral protection areas

Anthropogenic influence is present on the periphery of such protected areas for example, the installation of wind turbines in adjacent area of the forest Hagieni, development of human habitation in the Fântâniţa Murfatlar area and also, intensify pastoral tourism in Gura Dobrogei. For this reason we have taken into account changing plant associations in the peripheral area of protected areas. In terms of the peripherals plant associations study was based on the phytocoenological relevés method, taking into account the most obvious associations' ruderal flora. Thus, in the Gura Dobrogei protected area we have identified three types of associations, studied based on analysis of the similarity indices [9].

Consolido- Polygonetum / Caucalidio-Adonietum association shows no degree of similarity and Sörensen Coefficient is (0.44), and Jaccard Coefficient and Simple Matching Coefficient has the value of 0.28. Instead, the *Adonieto-Delphinietum/Consolido-Polygonetum* association has a high degree of similarity, with the binary coefficient value greater than 0.57 (for example, the



Sörensen Coefficient being 0.72), which means that species are very resistant to human impact, and they can be found in the arid and dry places and used by man. Characteristic species from these associations have a quick installation, with a high degree of coverage, over 53%. In the Fântânița Murfatlar area, the *Schlerochloo-Polygonetum avicularis/Poetum annuae* has a high degree of similarity, with the binary coefficient value greater than 0.62. Moreover, these two associations include species of grasses (*Poaceae*) with a quick installation, less choosey at the soil conditions. These have a high degree of coverage in the studied region, about 70%, the specialty literature specifying that they are among the most aggressive invasive species.

In the Hagieni Reserve the associations which we had studied based on the similarity indices analysis, show that the species of grasses (*Schlerochloa-Poa association*) have most ability to adapt of the habitats subject to human impact. The threats to which they are subject are currently mainly generated from human activities on the protected areas, which may significantly change the conditions necessary for maintaining a proper state of natural values.

Currently, studies are oriented towards the specific indicators identifying each type of biota / association, so that, the state of the ecosystem will be better reflected. In the future it is necessary to continue to monitor the dominant species status because every issues related to them masks the real situation of the ecosystem and is closely related with the evolution of opportunistic and exotic species [5]. The European Union considers that the Natura 2000 network is incomplete and imposes the addition of new sites, including in Romania [2]. In this European context have been established the three areas of Natura 2000 protection into Constanta County. Gura Dobrogei natural area overlaps the Natura 2000 site - Cheile Dobrogei (ROSPA0019). Fantanița Murfatlar is included in the Natura 2000 site (ROSCI0083) and Hagieni forest in two Natura 2000 sites (ROSCI0157 and ROSPA0094). In order to preserve wild species in their own natural habitat is necessary to implement a management plan and documentation referring to the protected area.

The importance of developing a Management Plan in these three Natura 2000 sites, has several reasons: it is a tool for communication and education; it provides the background information and description of the protection site; implementing the current policies and strategies; identifying the tools to measure the effectiveness of management, promoting the recognition of a set of values for the local protected area biodiversity.

5. CONCLUSIONS

The conclusion drawn from the current study is that the representative species have a greatest degree of similarity for all ecological categories investigated, which means a good competitive ability in the region. This study is closely related to the continuous monitoring of species resistance to the stress caused by human impact, even seen as green energy development in the Constanta region. Sustainable development of the green projects, in the proximity or inside the protected areas, involves conducting impact studies before implementing the project and publicly presenting and discussing them.

6. ACKNOWLEDGMENTS

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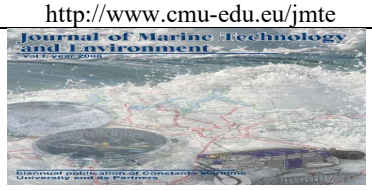

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A POINT OF VIEW ON PREREQUISITES IN THERMODYNAMICS FOR FUTURE MARINE ENGINEERS

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Abstract: A career on board the ships as engineers is an interesting option for young people graduating high schools in Constanta county and not only. Thermodynamics plays a vital role in the academic life of future marine engineers. This is why physics professors and Thermodynamic lecturers from "Gheorghe Duca" Technological High School and Constanta Maritime University decided to test the level of retention of perquisites in Thermodynamics, with focus on internal combustion engines (ICE).

A group of 30students from "Gheorghe Duca" Technological High School have been tested in order to quantify the gained knowledge on ICE. They have been selected from the last year of study, they being interested in maritime jobs. The testing was based on a questionnaire containing theoretical and calculus aspects. The time of solving was established at 50 minutes.

The results showed that our future graduates (and potential future maritime professionals) proved a good knowledge retention. Also the analysis of the questionnaire results is able to provide to the CMU lecturer a profile of its potential students. In the same time, he can improve his activities during classes, in order to achieve the right level of knowledge requirement.

Key words*:* prerequisites, thermodynamics, marine engineers, questionnaire.

1. INTRODUCTION

Marine engineering is an attractive profession for young people graduating high schools in Constanta county; students of "Gheorghe Duca" Technological High School also follow this trend.

The reason of this situation can be found in the fact that maritime transportation is an important sector of the economy of a county which implies the exploitation of complex systems and leads to the development of the coastline areas [1]. And these facts are challenges in the mentality of young generation.

Moreover, maritime higher education is considered to be suitable due to the advanced technology curricula – as a result of the latest requirement of the maritime industry and the opportunity of a later shore – based profession [2].

Thermodynamics is a customary discipline in the curricula of the future engineers dealing with thermal and energy systems, at different levels such as exploitation, design or improvement [3].

Also, in the last decades, concepts from thermodynamics are used by engineers as tools to find solutions having an ecological perspective too [4].

The above mentioned underlines the significance of thermodynamics in the academic life of future marine engineers, aspect which is going hand in hand with the need of highly trained professionals leaving the maritime faculties, all over the world [5].

In these conditions, the task of "Gheorghe Duca" Technological High School is to provide graduates with a high level of knowledge, in order to facilitate their adaptability to the status of students in maritime higher education and training institutions.

It is our duty, to be providers of theoretical and practical education which will ensure specialists having self – trust in the world's fleets [6].

This paper is discussing aspects related with prerequisites in thermodynamics for future marine engineers from the perspective of students graduating "Gheorghe Duca" Technological High School from Constanta.

"Gheorghe Duca" High school is a technological high school having a long tradition in the educational field. It was established in 1919 under the name of "CFR Apprentice School." Over the years its name has changed but the main domain remained the same.

Starting with the year 2010, our school has "Marin Sorescu" School as structure, so we have pupils a number

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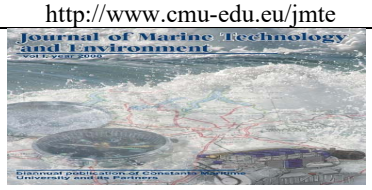

of 766 pupils. Our pupils do not come only from town but also from nearby villages.

The main qualifications of our school are: electro technician, mechatronic technician, mechanical maintenance and repair technician, electromechanical technician, computer operating technician. We have qualified staff for all the qualification mentioned above, one of our teachers having a degree in the energetic domain.

We may state that" Internal Combustion Engines" is part of the curriculum to be studied at the end of the 10th form, as part of the chapter entitled" Thermodynamics Elements".

The content is mainly made up from" The Otto Engine" which deals with the function and calculation of return and" The Diesel Engine, dealing with the same topics.

It can be carried out in 2 classes per week, but 4 classes are the perfect number to have time to deepen the knowledge (problem solving). At the end of their courses our pupils get the necessary abilities to work in the field they have studied for.

Around 20 per cent of our students aim to have a job as a sailor.

Thermodynamics for marine engineers presents as prerequisites disciplines such as: chemistry, physics and mathematics.

In the curricula of students enrolled in maritime faculties are included topics on the laws of thermodynamics, cycles of thermal machines or heat transfer.

A group of 30 students from "Gheorghe Duca" Technological High School, enrolled in their last year of study and expressing their option for a future carrier in maritime engineering, agreed to reply to a questionnaire developed by lecturers of physics and thermodynamics from the high school and Constanta Maritime University (CMU).

The analysis of the replies will offer a clear view of the profile of future students of Constanta Maritime University.

The aim of this action is to indicate to the thermodynamics professor from CMU the steps to be done in order to adapt its course and the laboratory and seminar activities in order to facilitate the gaining of knowledge to its students. Also, it is aimed to be registered higher rate graduation of the written paper specific for this discipline.

The activities of testing the prerequisites level in Thermodynamics for future marine engineers through the questionnaire is a result of a request received from lectures from CMU.

The management of "Gheorghe Duca" Technological High School accepted to support this initiative in order to contribute to the success of the academic life of its graduates.

2. THERMODYNAMICS OF INTERNAL COMBUSTION ENGINES FOR FUTURE MARINE ENGINEERS

Diesel engines are mostly used in transportation since they show a high fuel efficiency and low cost in comparison with other fuel engines [7]. These are the engines on board the ships, thus the decision was to deal in the questionnaire submitted to our students with this type of engines.

Briefly, the important aspects of thermodynamics in connection with these engines are presented below.

The request for a wise use of fossil fuels in internal combustion engines with low emissions implies the understanding of thermodynamics of this systems [8].

The main task of specialists is to assess the thermodynamic efficiency of internal combustion engines. Traditionally, the approach is based on the mass and energy balance, according the first law of thermodynamics applied to cylinder control volume [9]:

$$dU = \sum_i h_i dm_i - dQ - dW \qquad (2.1)$$

where:

U – total internal energy of the gas mixture inside the cylinder,

Q – amount of heat exchanged throughout the walls of the cylinder,

W – work of the piston,

h_i – specific enthalpy of the thermodynamic system,

dm_i – mass flow entering or leaving the cylinder.

But results obtained strictly based on the first law analysis are not offering a clear view on the real situation. The difference is due to the existence of internal thermodynamic irreversibilities during the combustion and heat transfer processes, aspect which cannot be revealed by the first law of thermodynamics.

So, it is vital to consider irreversibilities which are inherent no matter the process [10].

Thus, a complete analysis should be based on both first and second principles of thermodynamics, since the second law deals with the quality of the energy.

The second law introduces the concept of exergy which shows the existence of irreversibilities, being defined as the measure of the maximum useful work performed by a system on its surroundings; the analysis using exergy is an efficient tool used in the design, optimisation or performance assessment of internal combustion engines [11], [12].

For a closed system, the equation to be written is:

$$Av = Ex + p_0 V - T_0 S \qquad (2.2)$$

where:

Av – total availability,

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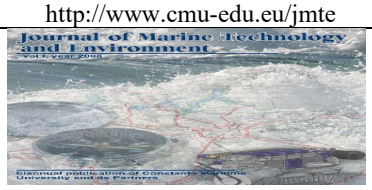


Ex – total exergy, expressed by the sum between the internal, kinetic and potential energies,

V – total volume of the system,

S – total entropy of the system,

p_0 / T_0 – pressure / absolute temperature of the dead state.

The most important benefit of the exergy analysis is that it offers the possibility to assess the part of the energy presenting the potential to produce work and also the part of the energy at close to the dead state, having less potential to produce work.

The understanding of this aspects allows the realistic assessment of the performance of internal combustion engines.

3. METHODOLOGY AND QUESTIONNAIRE

The questionnaire aimed to quantify the level of prerequisites, in connection specially with physics, of the students ready to graduate the "Gheorghe Duca" Technological High School from Constanta, by giving a brief after class test under the form of a questionnaire to a group of 30 voluntary students.

The questionnaires were taken anonymously to avoid anxiety.

The questionnaire consisted in a theoretical part and a part requesting calculation skills. The time for solving was established to 50 minutes.

The questionnaires were collected and scored by the lecturers of physics and thermodynamics from the two institutions involved: the high school and CMU.

Next day, score results were announced to the participants, together with a discussion on how the questionnaire would be correctly solved. The participants were encouraged to actively participate in the discussion process.

In Figure 3.1 it is provided the questionnaire while in Figure 3.2 are seen the results from the 30 students.

Questionnaire containing theory and calculus related with ICE knowledge.
Circle the correct answer

1. The result of the comparision between the thermal efficiency of the ideal cycle of an ICE is less than the thermal efficiency of a Carnot cycle operating between the same minimum and maximum temperatures.
a) False b) True

2. The meaning of the area enclosed by the cycle of an ICE in pressure – volume diagram is the network
a) False b) True

3. What do you understand by clearance volume?
a) the maximum volume formed in the cylinder
b) the minimum volume formed in the cylinder
c) the volume displaced by the piston as it moves between the top dead center and the bottom dead center

4. The compression ratio for ICE is the rate between
a) minimum and maximum volumes in the cylinder
b) minimum and maximum pressures in the cylinder
a) maximum and minimum volumes in the cylinder

5. In spark ignition engines the combustion is initiated by:
a) compressing the air above the self ignition temperature of the fuel
b) a spark
c) by both ways mentioned above

6. In a Diesel engine, the heat is added during an:
a) isobaric process b) isochoric process c) isothermal process

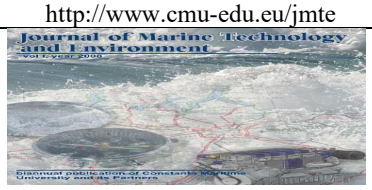
7. The heat rejection from an ICE is an:
a) adiabatic process b) isobaric process c) isochoric process

8. For an air – standard Otto cycle are known: temperature prior to the isentropic compression process (35°C) and the compression ratio (9.5). Find the value of the absolute temperature at the end of this compression.
a) 781,12 b) 757,9 K c) 775,29

9. For an air – standard Otto cycle are known the cutoff ratio (2) and the absolute temperature at the end of the isentropic compression (909,4 K). Find the absolute temperature at the end of combustion.
a) 1818,8 K b) 1919,9 K c) 11819,9 K

10. Find the value of the thermal efficiency for an air – standard Diesel engine for which the amount of heat rejected is 353 kJ/kg and the amount of heat absorbed is 919,9 kJ/kg
a) 61,4% b) 68,7% c) 71,3%

Figure 3.1 Questionnaire on prerequisites in thermodynamics, with focus on internal combustion engines (ICE), for future marine engineers



4. RESULTS AND DISCUSSION

In Figure 4.1 is given the situation of the results resulted after the correction.

Question No.	Correct answer	No of correct answers
1.	b	28
2.	a	25
3.	b	28
4.	c	28
5.	c	27
6.	a	26
7.	c	27
8.	b	14
9.	a	10
10.	a	26

Figure 4.1 Results of the questionnaire

The majority of the students were able to provide correct answers for the theoretical questions, but they seemed to face difficulties with calculation. But the calculus specific to the thermal efficiency was again correct for the majority of the students. This indicates that aspects involving basic theoretical knowledge are still remembered even if the physics course was concluded 2 years ago. Also, since the test was not graded, it is possible be encountered a degree of inventiveness.

5. CONCLUSIONS

The results of the questionnaire are a measure of the retention degree of prerequisites in Thermodynamics for future marine engineers.

Tested students proved that they are sufficiently competent in the prerequisites for ICE, at least in the theory of this chapter of thermodynamics. The lecturer from CMU can allocate more time to the calculus and less to the basic concept – which are already known.

It is suggested to be done the testing of prerequisites in other high schools too, in order to be established a realistic profile of the candidate to this profession.

In the case in which other high school graduates show similar prerequisites retention level, CMU lecturer has the oportunity to allocate more time to the second law analysis of ICE, during the courses. Seminars might be dedicated to short projects dealing with thermodynamic calculus of ICE, instead of solving problems, based on the fact that problems might involve basic theory – which is already gained.

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REVIEWING STUDIES ON PORT SECURITY: WHAT HAS BEEN DONE?

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Abstract: This paper aims to analyze and evaluate studies on port security, which is an increasing concern, and summarize them to put them in order. It was obviously seen with the 9/11 terrorist attacks that terrorists also have suicide capabilities to maritime targets. Consequently, International Ship and Port Security (ISPS) Code came into force by International Maritime Organization (IMO) in 2004. In this paper, port security, as one of the main subjects of ISPS Code with the ship security, is analyzed. Therefore, Dokuz Eylul University Online Library is searched with some constraints which includes "port+security" in title and all articles should have "full text" and "academic journals" status. Searching was completed with 145 articles and 58 of them were analyzed. Articles were categorized under such four different subtitles as "importance of security", "economic, financial and legal dimensions of security", "security threatening elements", and "technological advances in security". It can be said that studies on port security mainly focused on the ISPS Code. However, the great majority of the studies have been addressed to port security and the ISPS Code in the same manner. In order to ensure port security, it is necessary to concentrate on those studies that will centre on different aspects of port security.

Key words:article review, ISPS Code, port security.

1. INTRODUCTION

Port facility security can be defined as protecting from and taking measures for any security threats to port facilities, ships, people, cargoes, transport units and ship stores. Port facility security, which is a versatile issue concerning national and international economy, has become such an important issue that notably IMO (International Maritime Organization) and other marine organizations and also academicians make research on it. Thus, IMO developed a set of measures to protect port facilities and ships under the name of ISPS Code (International Ship and Port Facility Code) published in 2002 and it came into force in July 2004. It has become important to make academic studies in this field because of the fact that there is limited inspection on container transportation. Port facilities as a complex system affect global economy, and ports are vulnerable to the terrorist threats despite precautions taken. This study tries to handle port facility security issue from different perspectives and to find solutions to rising security needs. The main objective of this paper through addressing to the related academic studies to present advancements on port security issue. Besides, the relation between security measures and port performance, impacts of the ISPS Code on port security and the challenges about its implementation, quantitative solutions to the problems and lack of the studies on this issue are emphasized. It is also aimed to show that studies on port security has been handled in the same manner and most of the studies with the same subject have been adapted for different countries despite the fact that there are excessive unsolved security problems.

2. METHODS

In this paper, the studies are examined by using content analysis technique. Content analysis is generally used for statistical data for any subject, but this study also includes summary of every analyzed study. Content analysis is a systematic technique used to characterize the same data for comparing or for more advanced analysis [1]. Studies are reached from Dokuz Eylul University Online Library by using "*full text databases"* tab. It is limited as to be peer reviewed and including "port + security" in the title. As of the date of April 2017, the search reached 145 studies. The studies were examined for their contents and such articles as repeated articles, not directly related to aforementioned issue, aiming advertising, having unspecified sources and dealing with port security with regard to environmental issues only (i.e. plankters and other marine animals)

were eliminated. Besides, results included conference papers and they were also eliminated because of this study's samples were consist of articles. As a result, 58 articles were examined in this study.

3. RESULTS

The studies are classified under 7 categories which comprise security awareness of port managers and workers, need for providing security for ports, difficulties in providing port security, quantitative studies on port security, what has been done and what is to be done about port security, effects of the ISPS Code on port security and shortage of the ISPS Code and impacts of the port security practices on port activities.

3.1 Security Awareness of Port Managers and Workers

There are two studies on "Security Awareness of Port Managers and Workers" title which are shown in Table 1.

Table 1. Studies on Security Awareness of Port Managers and Workers

Author(s) Name (Year)	Journal	The Topic of Study
Mileski et al. (2015)	WMU Journal of Maritime Affairs	Making Lemonade Out of Lemons: Port Operators' Perception of Their Port Security Regulation Compliance
Bennett T.(2014)	Sea Technology	US Port Security In The Post 9/11 World

Port managers confront some problems during implementation of the ISPS Code because of the fact that practices which are related to port security are not standardized. Therefore, it changes depending upon the diverse perceptions of port managers likely to imply that there are not any additional benefits of the security practices. Two studies are handled in this subject.

A study conducted in USA and EU ports tries to observe security awareness of port managers and workers and the perceptions of the investors in security practices related to the mandatory applications. The results of this study show that a great majority of the ports which were observed believes that security investments do not grant any additional benefits to ports and also it is not a preference criterion for customers [2]. Another study compares pre – and – post 11 September attacks with regard to security investments and advancements and reveals that after the 11 September attacks, it has been noticed that ports have vital importance in security and there are lots of security gaps. Therefore, there have been taken a series of measures to iron out these security gaps. In addition, it is pointed out that there have been some programs and practices, for instance, training and raising awareness of port personnel, establishing security funds, and innovations in screening the containers [3].

3.2. Need for Providing Security for Ports

There are two studies on "Need for Providing Security for Ports" title which are shown in Table 2.

Table 2. Studies on Need for Providing Security for Ports

Author(s) Name (Year)	Journal	The Topic of Study
Leonard, T.J. et al.(2015)	Transportation Security	Security Challenges in United States Sea Ports: An Overview
Davidson, C. (2008)	Middle East Policy	Dubai: The Security Dimensions of The Region's Premier Free Port

Most of the studies show that port security has a vital impact on safety and security of life, national and international economy, politics and trade. A study(Leonard et al., 2015) conducted in USA emphasizes that USA has too much container traffic despite container's lack of detection. And so, it results in weakness at the ports. Therefore, supply chain stakeholders are advised (supplier, transporter, customs, security initiatives etc.) to be in tandem with each other and take security measures to minimize this weakness [4]. Davidson(2008) points out that there is a rising terrorist threat especially in Dubai and other UAE countries. So, it forces these countries to make additional investment in port security. This study also emphasizes that Dubai's economy depends on oil exporting. For this reason, any terrorist attack to the ports can damage the national economy seriously. Terrorist attacks, human trafficking, slavery and money-laundering subjects occurred in more recent times are also discussed in this study. According to Davidson, Al-Qaeda is the most serious threat for Dubai and nowadays, they are threatening the country explicitly. So, there should be taken some immediate actions to counter this threat. Otherwise, they can sabotage ports making an issue of the security weaknesses and then they can also threat other countries and ports [5].

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2.3 Difficulties in Providing Port Security

There are four studies on "Difficulties in Providing Port Security" title which are shown in Table 3.

Table 3**.** Studies on Difficulties in Providing Port Security

Author(s) Name (Year)	**Journal**	**The Topic of Study**
Sciascia, A. (2013)	Contemporary Southeast Asia: A Journal of International and Strategic Affairs	Monitoring The Border: Indonesian Port Security and The Role of Private Actors
Wengelin, M. (2006)	Journal of Homeland Security & Emergency Management	The Swedish Port Security Network - An Illusion or Fact?
Banomyong, R. (2005)	Maritime Policy & Management Journal	The Impact of Port and Trade Security Initiatives on Maritime Supply-Chain Management
Gunasekaran, P. (2012)	Australian Journal of Maritime & Ocean Affairs	Malaysian Port Security: Issues and Challenges

The studies examined show that there are some other difficulties besides security investments, for example, personnel's security training and inspection of the security system. A study conducted with regard to Belawan and Medan in Indonesia points out that there is a controversial issue about providing security (Sciascia, 2013). Ports have their own security guards but in addition to them there are also military based security companies and paramilitary security organization- Pemuda Pancasila- members. Sciascia underlines that this situation itself results in security weakness because of the fact that these groups conflict with each other due to controversy of authorization and problematic relationship [6]. Likewise, Wengelin (2006) shows that there are some difficulties in implementation of ISPS Code and relationship between security units are weak. Wengelin reminds that investing in security awareness is more important than technological investments [7].

Port security issue is handled by another study (Banomyong, 2005) in respect to effects of port and maritime trade initiatives. Thus, it examines one of these initiatives named CSI (Container Security Initiatives) and informs about its practices. It describes CSI and C-TPAT (Customs and Trade Partnership Against Terrorism) as necessary initiatives which should be implemented in all countries. The study also discusses who should finance these initiatives and to what extent these financing could be [8]. Gunasekaran (2012) who conducted a study in Malaysian ports examines security practices with regard to before and after implementation of the ISPS Code. This study emphasizes challenges in providing requirements of the ISPS Code and CSI. The study also points out how necessary publication of the ISPS Code is but it is seen as a burden for the countries which have not been exposed to any terrorist threats. Besides, some of the ISPS Code practices cannot be implemented in Malaysian ports. Consequently, it results in discrepancy in security plans. Besides, it is indicated that constitutions of CSI units for inspecting cargoes in ports are performing in some countries trading with USA on a volunteer basis. In fact, beyond the voluntariness, it is about avoiding damage to the trade relation with USA. Furthermore, this situation causes some compatibility problems in providing security [9].

2.4 Quantitative Studies on Port Security

There are 14 studies on "Quantitative Studies on Port Security" title which are shown in Table 4.

Table 4. Studies on Quantitative Studies on Port Security

Author(s) Name (Year)	Journal	The Topic of Study
Yang, Z. Et al.(2014)	Transportation Research	A New Risk Quantification Approach In Port Facility Security Assessment
Yeo, G.T. et al. (2013)	Transportation Research Part A: Policy & Practice	Analysis of DinamicEffects on Seaports Adopting Port Security Policy
Concho, A.L. et al.(2009)	Reliability Engineering and System Safety	An Evolutionary Algorithm for Port- of-Entry Security Optimization Considering Sensor Tresholds
Greenberg, M. (2011)	Annals of Operations Research	Risk Analysis and Port Security: Some Contextual Observations and Considerations
Kumar, S. et al.(2008)	Transportation Journal	Risk Assessment for The Security of Inbound Containers at U.S. Ports: A Failure, Mode, Effects and Criticality Analysis Approach
Wilhelm, W.E. et al.(2010)	IEEE Transactions on Automation Science & Engineering	Branch and Price Decomposition to Design a Surveillance System for Port and Waterway Security
Ung, S.T. et al.(2007)	Quality and Reliability Engineering International	The Application of The Six Sigma Concept to Port Security Process Quality Control
Ung, S.T. et al.(2008)	Marine Technology	The Risk Assessment and Management of Port Security Using Fuzzy Modeling
Harrald, J.R. et al.(2004)	Journal of Homeland Security & Emergency Management	A Framework for Sustainable Port Security
Harris, S.P. et al.(2013)	Journal of Defense Modeling and Simulation	Simulation Modeling for Maritime Port Security
Yan, X., and Nie X.(2016)	Transportation research part E: logistics and transportation review	Optimal Placement of Multiple Types of Detectors Under a Small Vessel Attack Threat to Port Security
Romero, P. et al.(2016)	European Journal of Operational Research	A Multi-Tree Committee to Assist Port-of-Entry Inspection Decisions
Williams, A. D. (2015)	Journal of Transportation Security	Beyond a Series of Security Nets: Applying STAMP & STPA to Port Security
Yoon, D. et al. (2014)	Journal of Advanced Transportation	A Study of Economic Efficiency In Port Security Inspection

Acquisitions of the security investments should be presented with quantitative analyses. Otherwise, managers and workers cannot see advancements and so security practices will be underestimated. There are only a few studies which handle port security issues with regard to quantitative analyses. One of them (Yang et al., 2014) emphasizes that there is not any standardization in port investment and security practices and perception of the security changes from port to port. For this reason, it is important to carry out quantitative studies in this field. Using port facility security indicators which are described in ISPS Code, fuzzy logic can be implemented to measure security level as a standardized approach for

every port. It is claimed in this study that by means of this approach port managers will have a chance to measure port security performance and so they can invest in security effectively [10]. Another study carried out by Yeo et al. (2013) indicates that while effects of number of berths, the area of port yard and the number of port labors have linear relation with port efficiency, port security relation with port efficiency is in a non-linear way. Thus, the relation between port security level and container volumes is analyzed via using system dynamics approach. With this approach, security level, costs, time and reliability of ports can be observed and so level of security investments can be determined [11].

Port security is handled by another study in terms of container inspection (Concho and Ramirez-Marquez, 2009). In this regard it sets a decision tree model which tries to find optimal threshold values for every inspection sensor and the optimal configuration of the inspection strategy [12]. Greenberg's study (2011) is about making risk analysis for port security. Port security risk analysis can be implemented by adaptation of nuclear power plant risk analysis. In respect to this, stages of risk analysis implementation are discussed. Challenges in calculation and information gaps are also indicated and it is advised to consider these challenges while implementing analysis. Besides, this study explains how risk analysis is being implemented in nuclear power plants is also explained [13].

Kumar and Verusso (2008) indicates that risk assessment can be used for providing container security at ports. In this way, threats can be identified. Threats can be classified as human errors, sabotage, equipment malfunction and security lapse and these threats can be analyzed and threats can be averted by using fault tree model. The assessment not only assesses from the port's aspect, it also includes each modes from factory to the destination port [14]. Additionally a programming model is provided by Wilhelm and Gokce (2010) to design surveillance system for port security. With this model, in the first stage, it is aimed to design a surveillance system according to port condition, weather condition, type and numbers of each sensor while minimizing the cost. In the second stage, the model is implemented to the port by proper techniques. In the final stage, it is aimed to measure the effect of the model on the port after the implementation and to show validity of the model by analyzing total system cost [15].

Port security process is handled by another study via measuring quality control (Ung et al., 2007). In this study, Six Sigma approach is used for the quality control. In order to implement this approach, each step of the port security process is distinguished and it is asked to specify requirements of each step by port managers. Six Sigma approach is used for improving port security and time is used as a measuring index. Customer satisfaction which is gained via time savings is also used as a measuring criterion for achievements [16]. According to Ung et al. (2008) indicates that it is difficult to make security assessment at ports because of unpredictable outcomes and consequences. However, security risks can be modelled by using FMEA (Failure Mode, Effects, and Criticality Analysis). Due to the fact that probable threats to the ports and their consequences are unpredictable, security assessment of each level is proposed to use this model by determining critical elements of each level which are under the control of port authority [17].

Ports are described by Harrald et al (2004) as a set of coupled economic systems. It is claimed in this study that security initiatives can be performed with a proper risk management approach. By assessing efficiency and economic impacts of determined security initiatives, it can be determined whether initiatives are useful for port security or not. Besides, it can also be examined whether these initiatives cause serious harm to the port [18].

In a study carried out by Harris et al (2013) a computer based model is developed to prevent attacks using mass destruction weapons from vessels which are not qualified as ships, nor are these vessels inspected properly. The model used with a commercial software can be applied for every port. With this model, it is aimed to review security practices, implementing new practices and to define the areas which have to be protected [19].

Yan and Nie (2016) deals with the attacks that could be done with small vessels in the ports, and shows how various detectors used to prevent these attacks could be placed. Two algorithms and a greedy heuristic are used for this purpose. The study also presents a case study conducted in the port of New York [20].

A study points out that port security is handled by inspections of goods and the danger classification of containers is hypotetically made by customs officers (Romero et al, 2016). Matching a hypothetical container classification with a logical container classification obtained by considering the specific container inspection level is aimed in this study. For this purpose, a new "Multi-Tree Committee" method has been developed by combining the strengths of binaryl decision tree and minimization methods of logical functions. The efficiency of the method created is measured by the actual data received from the Port of Montevideo [21].

The security for ports that play an important role in global trade is conducted by using traditional accident models and this leads to inconsistent and independent security strategies in port security according to Williams (2015). Williams also claim that recent works on new security designs that combine hierarchy, control and communication have crreated a new paradigm in assessing port security. By using Systems- Theoretical Accident Model and Process and accordingly analysis process – Systems Theoretical Process Analysis- security design features that will reduce the security vulnerabilities of ports can be determined. The study

aims to shot how STAMP can broaden the view of complexity and causality of the security components of ports [22].

In addition to such a wide range of studies, Yoon and Gim (2014) develops a model to prevent delays because of rising security inspections. So, economical efficiency can be gained by preventing delays and equipment of requirements which are used to provide security can be determined [23].

2.5 What Has Been Done and What Is To Be Done About Port Security

There are 21 studies on "What Has Been Done and What Is To Be Done About Port Security" title which are shown in Table 5.

Table 5. Studies on What Has Been Done and What Is To Be Done About Port Security

Author(s) Name (Year)	**Journal**	**The Topic of Study**
Urciuoli, L. et al.(2013)	Journal of Transportation Security	Achieving Harmonized Port Security Training In Europe-A Critical Review of EU Legislative Frameworks
Urciuoli, L. (2016)	Maritime Policy & Management	Port Security Training and Education in Europe—A Framework and a Roadmap to Harmonization
Bateman, S. (2012)	Journal of The Indian Ocean Region	Maritime Security and Port State Control In The Ocean Region
Chulkov, D.V. (2012)	Journal of Transportation Security	Managing New Technology Investment For Underwater Security of Ports
Huang, S.W. et al.(2012)	Advances in Transportation Studies: An International Journal	Implementing a Passive RFID E-Seal System for Transit Container Security: A Case Study of Kaohsiung Port
Scholliers, J. et al.(2016)	Transportation Research Procedia	Improving the Security of Containers in Port Related Supply Chains
Eski, Y. (2011)	Criminology & Criminal Justice: An International Journal	'Port of Call': Towards a Criminology of Port Security
Khalid, N. (2008)	Maritime Studies	Protecting Port Cities and Communities from Security Threats
Hlaca, B. et al.(2008)	Journal of Maritime Studies	Influence of ISO:27001:2005 on The Port of Rijeka Security
Sim, J. H. et al.(2016)	International Information Institute (Tokyo). Information	Construction of Port Logistics Security System Based on the Information Security Management System
Altiok, T. (2011)	Annals of Operations Research	Port Security/Safety, Risk Analysis, and Modeling
Helmick, J.S. (2008)	Journal of Transportation Security	Port and Maritime Security: A Research Perspective
Johnson, B.A.S. (2013)	Global Studies Journal	Transnational Terrorism: Globalization, Voluntary Compliance and U.S. Port

		Security
Brown R.S. et al.(1953)	The Yale Law Journal	Security Tests for Maritime Workers : Due Process Under The Port Security Program
Al Akkoumi M. et al.(2011)	Journal of Transportation Technologies	A Personnel Detection Algorithm for An Intermodal Maritime Application of ITS Technology for Security at Port Facilities
Roach, A. (2003)	International Journal of Marine & Coastal Law.	Container and Port Security: A Bilateral Perspective
Keefer, W. J.(2007)	Campbell Law Review	Container Port Security: A Layered Defense Strategy to Protect the Homeland and the International Supply Chain
Firestone, J. et al.(2003)	Widener Law Symposium Journal	Maritime Transportation: A Third Way for Port and Environmental Security
Bralliar, R.B. (2005)	Military Law Review	Protecting US Ports with Layered Security Measures for Container Ships
Marian, T.P. (2007)	Tulane Law Review	Port Security From The Inside Out: A Systems Approach to Safeguarding Our Nation's Port
Chlomoudis, C.I. et al.(2010)	European Research Studies	An Internationalized Approach to European Perspectives for The Safety and Security in Port Industry

A study points out that in addition to the security investments, port security requires training for awareness of port personel. By customizing the content of the training according to port security and training all of the port personnel, port security can be provided. In this context, the study forms a framework for content of the training [24].

Another study consecutively aims to present the current situation of training and education courses on port security in Sweden. In this context, it is stated that there is a lot to be done about security courses and is created a roadmap for the harmonization of the states with respect to security [25].

Bateman (2012) handles Indian Ocean with regard to the port security. It emphasizes that PSC (Port State Control) should be implemented precisely. The reason why piracy and armed robbery rises in the Indian Ocean Region (IOR) according to Bateman is irregularities in the PSC inspections. Because of bribery and misconduct, officials do not report the non –conformities in inspected ships. It causes increase in number of substandard vessel using this region for trading. Being aware of these substandard vessels, pirates and armed robbers hijacking these vessels for ransom or attacks other ships by these vessels. To solve this problem, it is advised to implement Paris Mou, Tokyo Mou or US Coast Guad practices which are more effective than Indian Ocean Mou or Riyadh Mou [26].

Chulkov (2012) attracts attention to the investments on ports and especially on waterways. Threats can come from underwater vehicles posed mines, improvised explosive devices, manned or unmanned underwater vehicles to the ports, oil platforms and underwater pipelines. For this reason, it is emphasized how important to invest in underwater security [27]. A study which is conducted in Kaohsiung Port deals with security of containerized cargoes (Huang et al, 2012). It describes RFID (Radio Frequency Identification) e-seal system instead of imitable plastic seals. By using this RFID e-seal, it can be alarmed in case of any security breach about seals, cargoes can be tracked, and location of the container can be determined easily. Therefore, thefts can be avoided and it enables tracking suspicious containers [28]. Furthermore, it is indicated that

containers are the biggest security weakness in the supply chain process and therefore ports and terminals which are the convergence point of containers have similar weakness (Scholiers et al, 2016). For this purpose, technological possiblities used for the development of container integration in the port based supply chain process are discussed. Besides, possible security solutions such as e-seals, tracking devices, camera imaging systems and entrance operations are reviewed and applications that can be done to increase container security are advised [29].

Port security threats are identified as terrorism, drug smuggling, human trafficking and environmental pollution. To avoid these threats, security investments mustn't be exceeded, since excessive investment tampers port operations and causes traffic congestion. Consequently, this situation ends up with new security gaps. Using customs and trade initiatives which are implemented in USA and EU to avoid security threats are more efficient than other security investments [30]. Moreover the themes which were presented at the conference on "The Security Global Port Cities" at Indiana University in 2008 are summarized by Khalid (2008). The themes are categorized and summarized as "*Security awareness pre and post 11 September attacks*", "*Rebuilding port cities with regard to safety and security*", and "*Environmental security as a component of the security matrix*" [31].

The effects of the ISO 27001:2005 (Information Security Management System) is examined on Rijeka Port for providing security (Hlaca et al, 2008). Since The Rijeka Port is a rapidly growing port, it is recognized as a strategic resource by port managers and also Republic of Croatia. So they need to maintain its growth and provide security to protect it. Implementing ISO 27001:2005 which enables information and communication security is one of the actions to be taken for providing security. The study begins with explaining ISO 27001:2005 in detail, then describes how it can be implemented to the port, and finally presents its contributions to the port [32]. Additionally, Sim and Cho (2016) deals with creating a Port Logistics Security System with using Information Security Management. It is emphasized that the increasing use of information technologies and automation systems in port operations brings some cyber problems together. For this purpose, within the context of Information Security Management System, port logistics handled with in terms of physical and technical aspects and a framework of Port Logistics Security System is created [33].

Altiok (2011) describes ports as backbone of the national and international economy and maritime trade. So it is important to protect them. This study suggests that risk analysis should be made to provide security, avoid threats, and minimize consequences of possible threats. Security practices are short-lived and should be reviewed and renewed in case terrorists find out security practices. Otherwise it can cause new security gaps. The changes in the security practices can be determined by using game theory models [34].

Helmick (2008) examines researches on port and maritime security and tries to determine priorities on this issue. It is emphasized that many researches can be conducted and many developments about vehicles, technology and processes can be achieved but without a systematic research agenda, there will occur repetition, fragmentation, loss of time and weakness against threats in researches. According to Helmick, to avoid this, a long-term, consistent and sustainable maritime security agenda should be created. This agenda can promote stakeholders to conduct efficient studies on maritime security [35]. Johnson (2013) discusses the effects of the terrorism on ports and maritime trade and makes suggestions about what is to be done to avoid terrorism. The study seeks for answers about why ports are important for terrorists, what threats uninspected containers have, and what kind of methods can be used to avoid terrorist attack. It is also emphasized that to avoid terrorism which is globalized now, it is necessary to form internationally recognized practices and implement them in common [36].

Possible threats for port security are dealt with discussed by Brown and Fasset (1953). In this study, security measures for different port conditions are also pointed out. According to Brown and Fasset, to provide port security, it is essential to educate and identify port personnel. Because unauthorized people can enter to the ports easily. So this situation creates opportunities for people who try to sabotage ports. The study also mentions political conflicts in USA and effects of the communism on the port workers that changes ports into threat points. Employees who want to work at ports should be tested by US Coast Guard and then eligible employees should be certified [37]. A low cost human detection system is proposed instead of numerous patrols for protecting the ports (Mouhammed et al, 2011). By establishing camera and sensors at different areas at ports, it can be possible to detect moving humans via a program which uses these cameras and sensors. After the detection any human, the program will check patrol records of that area. If it does not match with the patrol records, then the system will be alarmed. By using this system, a number of patrols and patrol personnel can be reduced [38].

Another study handles the relation between ports and containers are handled by Roach (2003), who emphasizes that containerized cargoes have potential threats for ports. Since there is no mechanism for monitoring the containerized cargoes and identifying possible threats, inspections should be enhanced. The study also describes CSI practices and other security initiatives implemented by US Coast Guard [39]. Another study discusses developments of container ports

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and concordantly rising security threats. Reefer (2007) also explains what the threats are and what measures can be taken to provide security. The study conducted over US container ports and established initiatives in accordance with national strategies for providing port security [40].

In another study, a maritime security policy is established by considering security and environmental policies as a whole (Firestone and Corbett, 2003). Besides, it is suggested that an international law is being required to avoid collision between port state and flag state actions. The study also defines responsibility limits of the port state control over protecting environmental security of the sea. It also emphasizes to what extent port state controls can comply with other countries or in international area to providing maritime security [41]. Port security issue is handled in five chapters by another study (Bralliar, 2005). In the first chapter, the necessity of the port security and the effects of the terrorist attacks to the USA and to the international economy are discussed. The second chapter is about threats of containerized cargoes coming to the USA. Effects of these cargoes will be devastated on the national and international stage. Security weaknesses on this subject are also discussed in this chapter. The third chapter advises to establish a layered security system with other countries to minimize the effects of terrorist attacks. In the fourth part, it is discussed whether ISPS Code requirements provide security against threats caused from containerized cargoes. In the last chapter, practices and initiatives implement by USA to provide port security are presented [42].

Marian (2007) underlines importance of port security to USA and gives a brief security history of the USA. The study examines security initiatives with regard to Marine Transportation Security Act and SAFE Port Act (Security and Accessibility for Every Port Act) [43]. Chlomoudis and Kostagiolas (2010) discusses coordination of safety and security practices implemented by EU to provide security for EU ports. Besides, standards of the safety and security practices and relations between these standards and their qualities are examined [44].

2.6 Effects of the ISPS Code on Port Security and Lack of the ISPS Code

There are 13 studies on "Effects of the ISPS Code on Port Security and Lack of the ISPS Code" title which are shown in Table 6.

Table 6. Studies on Effects of the ISPS Code on Port Security and Lack of the ISPS Code

Author(s) Name (Year)	**Journal**	**The Topic of Study**
McNaught, F. (2005)	Geddes Papers	Effectiveness of The International Ship and Port Facility Security (ISPS) Code in Addressing The Maritime Security Threat
Hendrapati, M. (2015)	JE Asia & Int'l L	International Ship and Port Facilities Security Code and Its Implementation in Indonesia
Larrucea, J.R. (2012)	Universitat Politechnica de Catalunya	The International Ship And Port Facility Security And Port Facility Security Assessment (ISPS) Code
Okoroji, L; Ukpere, W. (2011)	African Journal of Business Management	The Effectiveness of The International Ship and Port Facility Security Code (ISPS) in Nigeria
Heathcote, P. (2004)	Maritime Studies	An Explanation of The New Measures for Maritime Security Aboard Ships and In Port Facilities

Dekker, S. et al.(2007)	Maritime Policy & Management	Maritime Security In The European Union - Empirical Findings on Financial Implications for Port Facilities
Anyanova, E. (2007)	Journal of International Commercial Law and Technology	The EC Enhancing Ship and Port Facility Security
Schoenbaum, T. et al.(2003)	Tulane Law Review	An All Hands Evolution: Port Security in the Wake of September 11th
Clyne, R.C. (2003)	Tulane Law Review	Terrorism and Port/ Cargo Security: Developments and Implications for Marine Cargo Recoveries
Booth, F. et al.(2002)	Maritime Law Journal	Maritime and Port Security, Piracy and Stowaways : Renewed Conderns Over Old Problems
Suppiah, R. (2009)	Journal of The National Maritime Foundation of India	International Ship and Port Facility Security (ISPS) Code and Crew Welfare
Khalid N. (2006)	Defense & Security Analysis	Too Much of Good Thing? Some Reflections on Increased Por Security and Its Costs
Flynn, S.E. (2006)	Far Eastern Economic Review	Port Security is Still House of Cards

It is seen that the importance of port security rises after the ISPS Code's entering into force. For this reason, it is essential to understand The ISPS Code practices correctly.

Whether the ISPS Code is sufficiently effective in preventing maritime threats is discussed in a study handled by McNaught (2005). For this purpose, firstly threats in the maritime area are discussed and then the content of the ISPS Code and how the ISPS Code is applied on the international arena are explained [45].

The development process of the ISPS Code, its contents and the institutions in which the ISPS Code is conducted in Indonesia is the point of another study carried out by Hendrapati (2015)[46].

Another study explains the ISPS Code with its publishing reasons and the terms which are used in the ISPS Code. The study also explains how practices can be implemented. However, it is stated that the ISPS Code, as a guide, is a general framework for providing security for ships and ports. Specific practices are required for ports to develop their own security practices with regard to this framework [47]. The effects of the ISPS Code on the Nigerian ports are discussed by Okoroji and Ukpere (2011). The study indicates that there are 75 ports in Nigeria but 65 of them perform the ISPS Code requirements. Consequently, to solve this problem, it is necessary to train these ports and other related institutions. However, Nigeria does not have any training system because of economic problems. So, stakeholders related to this problem can invest in this subject and solve the problem [48]. In the study carried out by Heathcote (2004), security measures are examined to prove security for ships and ports which are taken after the 9/11 attacks. So, the study gives information about IMO, SOLAS (Safety of Life At Sea), SUA Convention (Convention for the Suppression of Unlawful), ISPS Code and other developments on security subject. The study mainly explains ISPS Code practices, implementation of these practices and forms measures to provide different implementations of these practices [49]. Another study (Dekker and Stevens, 2007) carries out an analysis about costs of the security implementations to the EU ports. It is indicated that after the publication of the ISPS Code, some additional investments come into existence to implement ISPS Code requirements. It is seen that the average investment cost is €464.000 and running cost is €234.000 for a year. Costs per security measure by percentage is shown as Landside -Accesses and entrances: %44, Electronic systems: %34, Seaside Access: %14, Landside – railways and roads: %4, Inspections and Insurances: %3 and Personnel: %1 [50].

Relations between requirements to provide security for ports and EU's existing laws are discussed by Anyanova (2007). The study also discusses whether EU's existing security systems are compatible with

countries' benefits and needs. The study also expresses possible conflicts between EU's maritime security practices and international security laws [51]. The subject of the study by Schoenbaum and Lanston (2003) is the effects of the 11 September attacks to the ports on national, international and regional level. The international effects are examined according to IMO's requirements. On the international level, effects of the rules which were implemented by IMO are handled. On the national level, it is examined according to practices which are implemented by institutions related to USA. The effect on the regional level is examined with regard to Georgia and Savannah ports [52].

A brief history of the maritime terrorism is given by another study(Clyne,2003) which handles security initiatives and laws which were made after the 11 September attacks. Besides, the effects of the security requirements and initiatives on the maritime trade are examined [53]. The security measures which are taken on ships and ports in the period of the 11 September attacks and after are examined by Booth and Altenburn (2002). The study also examines the effects of these attacks on the maritime trade. Besides, the study states national and international security initiatives providing security to ships and ports [54]. The relation between security requirements to provide security for ships and ports and ship personnel is discussed by Suppiah (2009). It is emphasized that these security requirements are additional burden for ship crew. It is hard for them to fulfill security practices with these new security tasks in addition to their usual tasks. So, regulating the crew numbers and their tasks with regard to the security requirements is necessary since the crew is expected to provide security requirements perfectly. The study gives a formula for calculating the number of person required per day to run ship in order to implement the requirements of ISPS Code without difficulty [55].

According to Khalid (2006) port security cannot be provided by implementing strict rules. In contrast, flexible rules can enhance applicability and efficiency of the port security. The study also points out that security practices without considering stakeholders' opinion related to the security of ships and ports cannot be efficient and sustainable. There is a perception of the necessity of the port security but in return for this perception there is not any standard model of security to implement. Another important issue in the study is about cost apportionment of the security investments. The question is "*Who, and to what extent finance these security costs?*" [56]. Flynn (2006) underlines that necessity of the inspections rises in parallel with increase in number of containerized cargoes. Any terrorist attack by these cargoes can affect the economy globally. The study handles security programs and initiatives to avoid these threats and also discusses whether these security measures provide security enough to avoid these threats in actual fact. Besides, terrorists can breach any security measures, so the study explains how security can be provided practically to overcome this problem [57].

2.7 Impacts of the Port Security Practices on Port Activities

There are 2 studies on "Impacts of the Port Security Practices on Port Activities" title which are shown in Table 7.

Table 7. Studies on Impacts of the Port Security Practices on Port Activities

Author (s) Name (Year)	Journal	The Topic of Study
Bichou, K. (2011)	Maritime Economics & Logistic	Assessing The Impact of Procedural Security on Container Port Efficiency
Chang, C. H. et al.(2016)	Maritime Policy & Management	Do Port Security Quality and Service Quality Influence Customer Satisfaction and Loyalty?

A study which is carried out over container terminals deals with the impacts of the security investments to the port performance (Bichou, 2011). To achieve this, 420 terminal records which were operated from 2002 to 2008 are analyzed and then impacts of the security practices and investments on operational efficiency are examined. Operational efficiency tested in different subcategories and accordingly results vary. While some security measurements have negative impacts on operational efficiency, the others affect positively. Besides, operational efficiency is tested according to the impacts of the security initiatives such as CSI and 24-h Advanced Manifest Rule [58].

The relationship between port security quality, port service quality, customer satifaction and customer loyalty are evaluated in a case study conducted at Kaohsiung port (Chang and Thai, 2016). For this purpose it is conducted a survey with freight forwarders and maritime companies in Taiwan. As a result of the study, it is observed that all variables have direct and positive effect on each other. However, it is seen that the effect of the service quality is much higher than the security quality [59].

3. CONCLUSIONS AND RECOMMENDATIONS

The security of ships and ports has become an important issue especially after the 11 September terrorist attacks and it is seen that ports have very important security gaps. To avoid these threats and establish a standard of the security practices, ISPS Code is developed. With this, some countries, especially USA,

launched some security initiatives and programs which are implemented nationally and internationally to provide maritime security. The studies which are examined in this paper show that most of the academical studies are conducted by the USA.

The studies show that port security issue is handled by its political, economic, judicial and financial aspects and models are formed by doing quantitative and qualitative analyses. The studies are summed up under seven subcategories and authors' assessments, critics, comments, advice, solutions and modelling are indicated in this paper.

While assessing the studies, it is seen that ISPS Code makes an important progress on port security, but there are different implementations in different countries and it has some deficiencies on providing port security. ISPS Code, in fact, includes what is to be done to provide security but how it should be implemented is not mentioned. Thus, it creates different security implementations. Besides, there are some conflicts with regard to security practices because of the fact that responsibility of ports, ships and port authorities are not mentioned in the ISPS Code clearly.

General view of the studies is that containerized cargoes have big risks with regard to terrorist attacks. The rising number of containerized cargoes and in contrast with lack of inspection opportunity forms a basis for terrorist attacks. Thus, security practices are usually implemented according to containerized cargoes. For this purpose, the studies concentrate on monitoring inside of the container, tracing containers' movements, providing security by using e-seal and promoting customs-trade partnerships. Initiatives which are launched by the USA also concentrate on providing security especially for containers.

Another important issue to provide port security is financing security investment without affecting port performance negatively. The studies show that security inspections affect port performance directly and most of the time, it results with operational delay. Thus, the studies advise that it is necessary to determine optimum level of the security inspections. To achieve this, some models and equations are created.

It is obviously seen that there are a lot of studies which are concentrated on same subject. Since there are excessive threats for port security, studies should handle these threats with different manner. An analyzed study also advises that there should be an agenda of security studies for ensuring not wasting time by handling same subjects with same manner. This study tries to collect all these studies under one title for facilitating examination of port security issues and to show that how port security issues are handled.

While assessing our country from the maritime security view, despite being surrounded on three sides by the sea and having 192 (UDHB, 2012) ports and berths, Turkey has limited academical studies on port security issue. Conducted studies are also about quantitative analyses which includes progress and implementation of the ISPS Code. Being a hub port for Asia, Europe and Africa, Turkey can be exposed to terrorist attacks directly with the intention of damaging global economy or nuclear, radioactive, chemical and mass destruction weapons and any other hazardous equipment can be transported via Turkey's ports with high possibility. Because of similar reasons, providing port security is crucial for Turkey. So, we need to assess port security with quantitative analyses to develop risk management models, to create equations to provide security, cost and efficiency balance, to launch security initiatives and to make standardization of the security practices for our ports to comply with the ISPS Code.

Having entered into force, ISPS Code has created a common sense about port security and security related technologies and establishment of international partnerships enhanced. Besides, some algorithms have been created to determine the optimum level of the security investments and inspections. As a result of these studies, security level of ports is improving day by day, but it is still not at the desired level.

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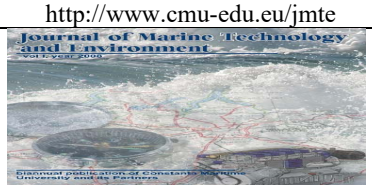

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THE SIMULATION OF WASTE WATER TREATMENT PROCESSES

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Abstract: Simulation of processes in a wastewater treatment plant is very effective because it reduces operational times, reduces costs for the preparation of uninitiated human resources in the field and also reduces utilities consumption. This can be done using many specialized programs. The purpose of this work is to present such a simulation using the GPS program-X-Hydromantis.

Key words : efficiency, operational, resource, treatment, simulation, wastewater.

1. INTRODUCTION

Simulation of processes in a wastewater treatment plant is very effective because it reduces operational times, reduces costs for the preparation of uninitiated human resources in the field and also reduces utilities consumption. This can be done using many specialized programs. The purpose of this work is to present such a simulation using the GPS program-X-Hydromantis.

2. METHOD AND RESEARCH

In order to accomplish this work, a program was used to design a wastewater treatment plant and input the necessary entry data, program called GPS-X, version 6.1.1, which is the most advanced tool available for the mathematical modeling, simulation, optimization and management of Waste Water Treatment Plant (WWTP) [1].

The first step consists in designing the WWTP flow (Fig. 1) [2], [3], [5]:

- Influent WW;
- Primary settler tank (was chosen by the rectangular shape);
- Aeration basin;
- Hybrid bioreactor (anaerobic biodegradation, biogas generation used subsequently as a power source);
- secondary settler tank (radial form),
- for the advanced purification stage , from the available options –slow filtration, quick filtering, sand filters, filtration membranes, disinfection –the disinfection equipment has been chosen.

2.1 Setting of installations

Configuring the settings of the component installations, as follows : primary settler tank (Fig. 2) , aeration basin (Fig. 3), hybrid bioreactor (Fig. 4), secondary settler tank (Fig. 5), advanced purification stage-disinfection (Fig. 6) [4], [5].

2.2 Change the input data:

- type of loading-diurn with modification of input data (Fig. 7)
- The composition of the influence will have CCO (COD-Chemical oxygen Demand) of 500g/m^3, Kjeldhal total nitrogen (TKN) of 40 g/m^3, total phosphorus –15 g/m^3;
- The quantity of phosphate compounds (soluble orto-phosphate) will be 9 g/m3, and nitrogen compounds will include the following values: 29 G/m^3 free and ionized ammonia, 0.2 g/m^3 nitrates and nitriti.
- The alkalinity of the influence will be 9 mol/m^3.
- CCO/SSV reports (volatile solid suspensions), BOD_5/CBO expanded, SSV/SST (total solid suspensions) will have values 1.1, 0.53 and 0.81 respectively.
- The organic fraction of the influence: the fraction of the inert soluble matter at CCO Total 0.05, the fraction of the biodegradable matter by fermentation at CCO Total 0.7, the inert particle fraction at CCO total 0.13.
- The amount of insoluble solid suspensions will be 26.7 g/m^3,that of inert organic materials –

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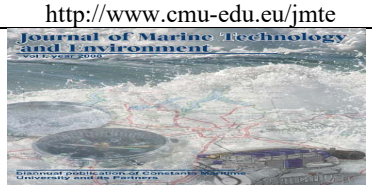

25gcco/m^3, slightly biodegradable substrate –350 gcco/m3, inert organic matter –65 Gcco/m^3, biodegradable hard substrate –60 gcco/m^3.

- The scales of SST, SSV and SSIT (total inorganic solid suspensions) will be 140.3 g/m^3, 113.6 g/m^3, and 26.7 g/m^3 respectively (Fig. 8).

3. RESULTS

Start the simulation of wastewater treatment process, display the values of wastewater parameters monitored by simulation, before evacuation (Fig. 9).

The results are obtained for: influent (Fig. 10), primary settler tank (Fig. 11), aeration basin (Fig. 12), hybrid bioreactor (Fig. 13), secondary settler (Fig. 14), disinfection (Fig. 15), efluent discharge in the natural emissary (Fig. 16).

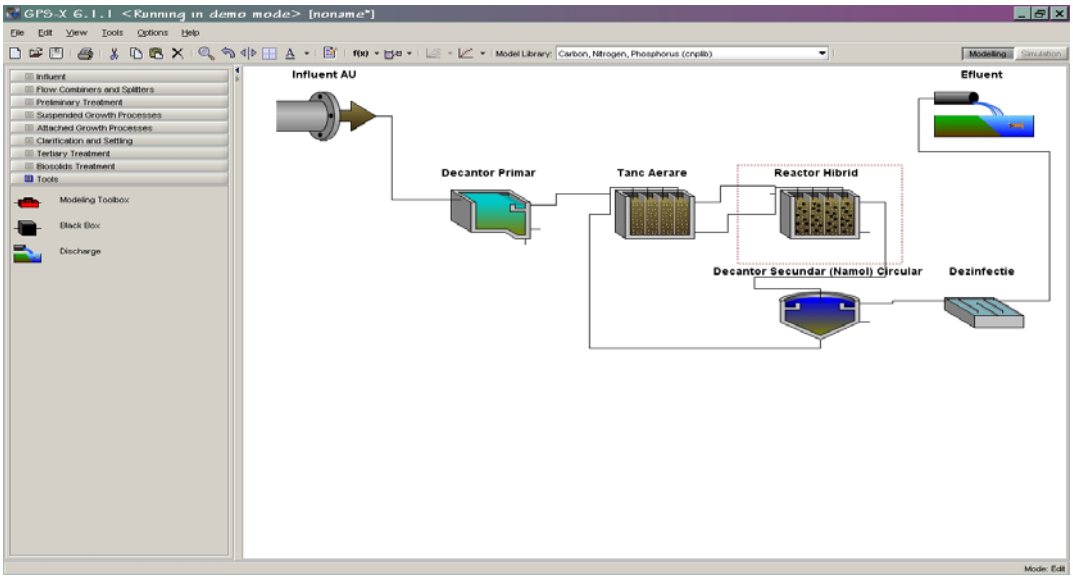

Figure 1 The design of WWTP [1] [4] ,[5]

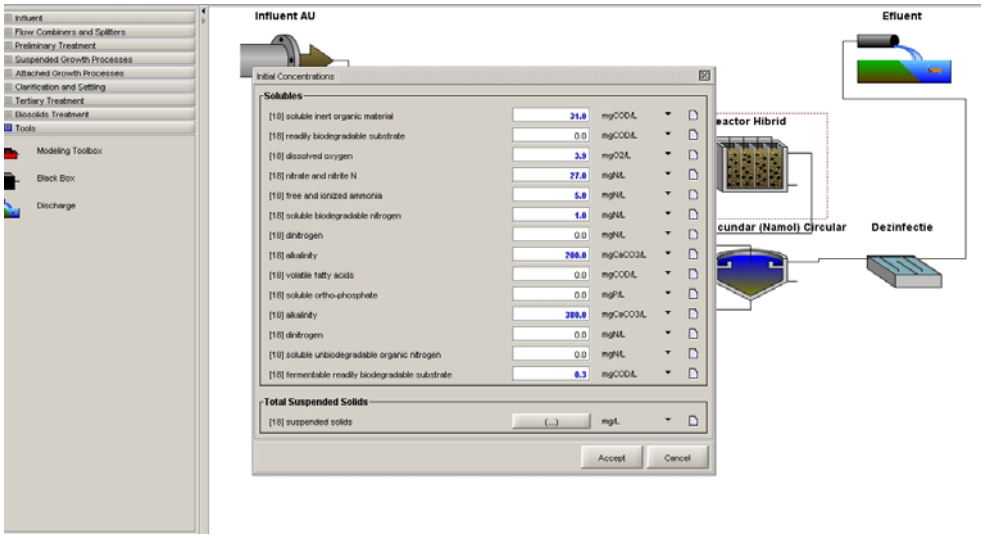

Figure 2 Primary settler tank

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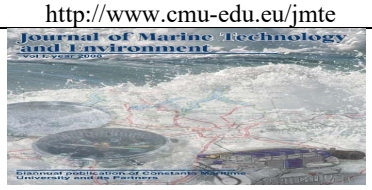

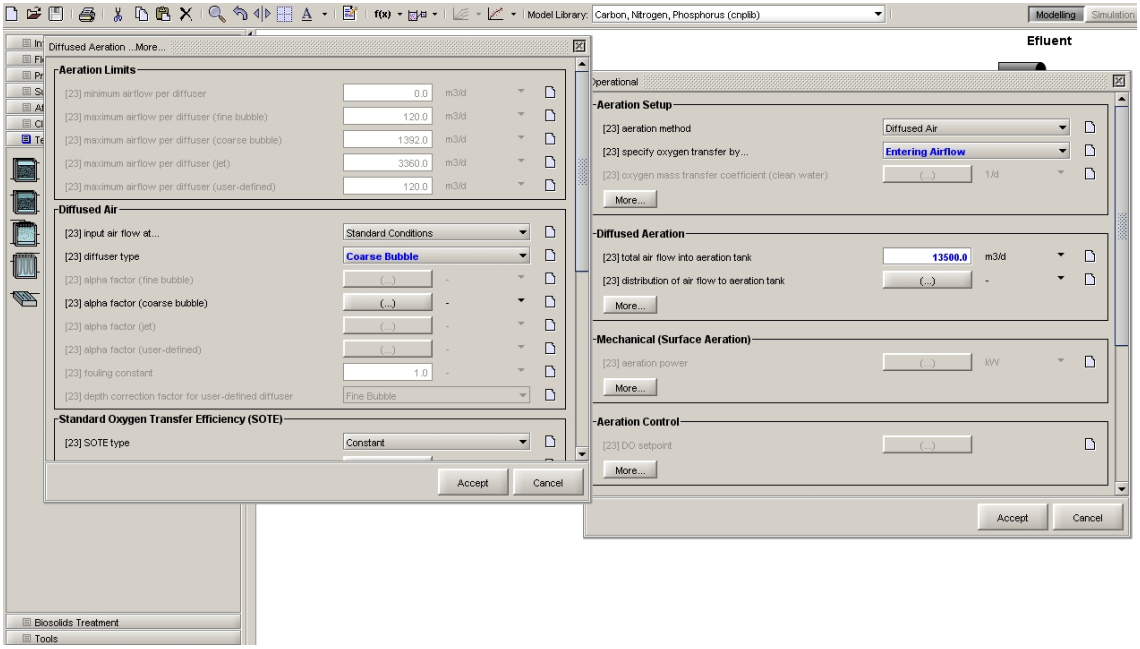

Figure 3 Aeration bazin

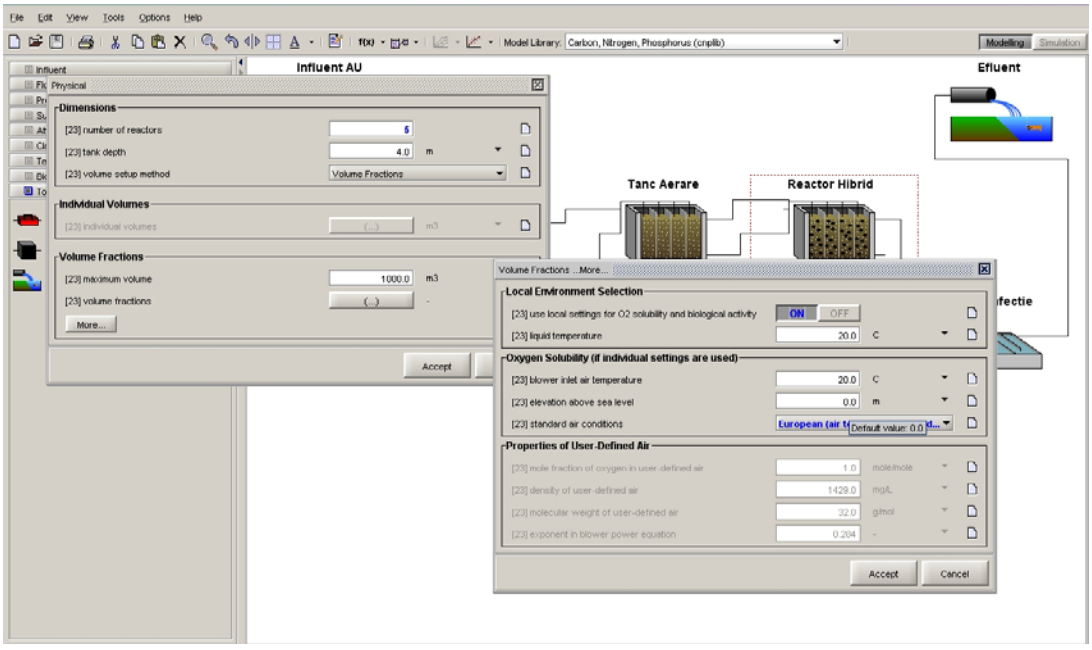

Figure 4 Hybrid bioreactor with 4 bioreactor chambers, bioflim 530 1/m (standard UE)

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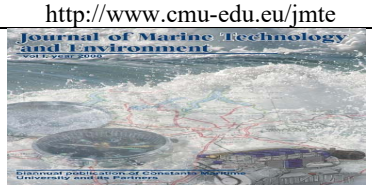

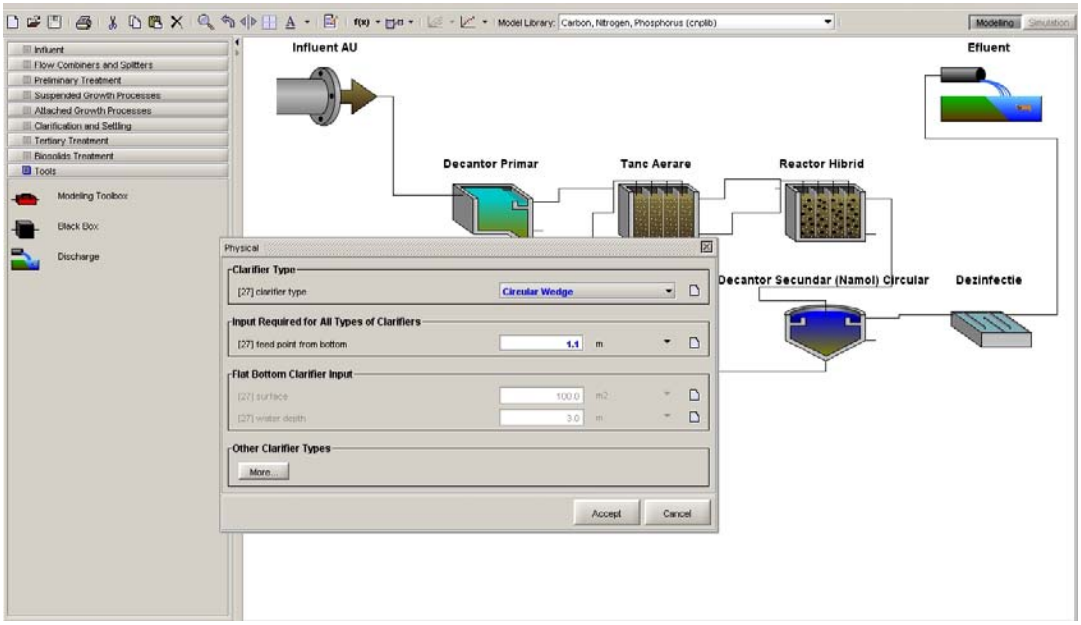

Figure 5 Secondary settler tank

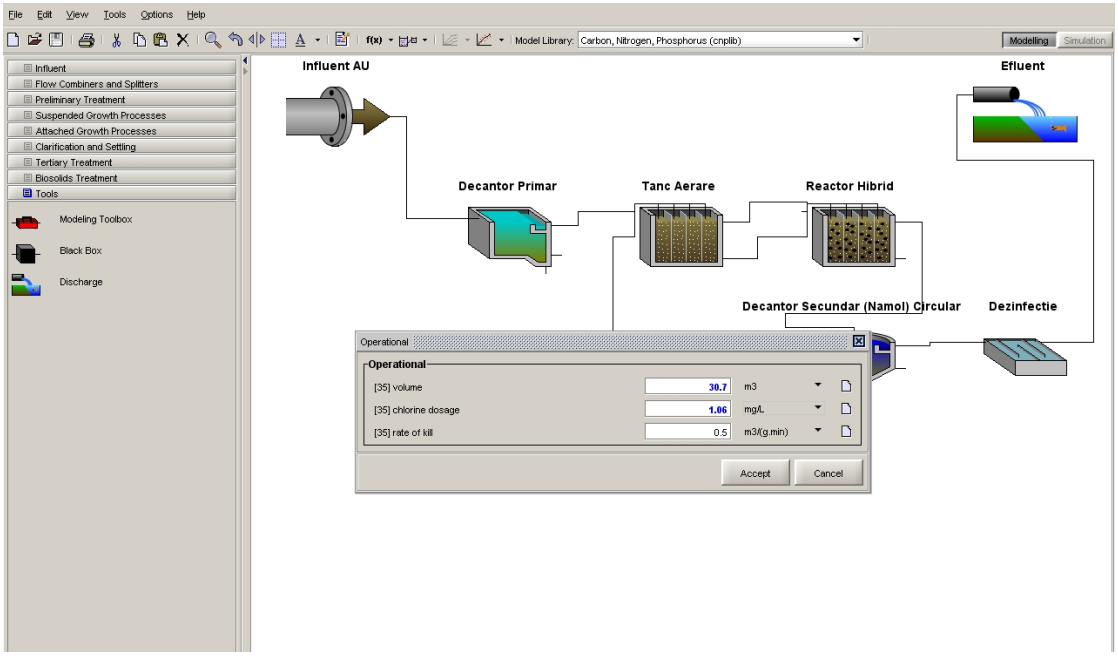

Figure 6 Advanced purification stage-dezinfection with Clor 1.06 mg/l.

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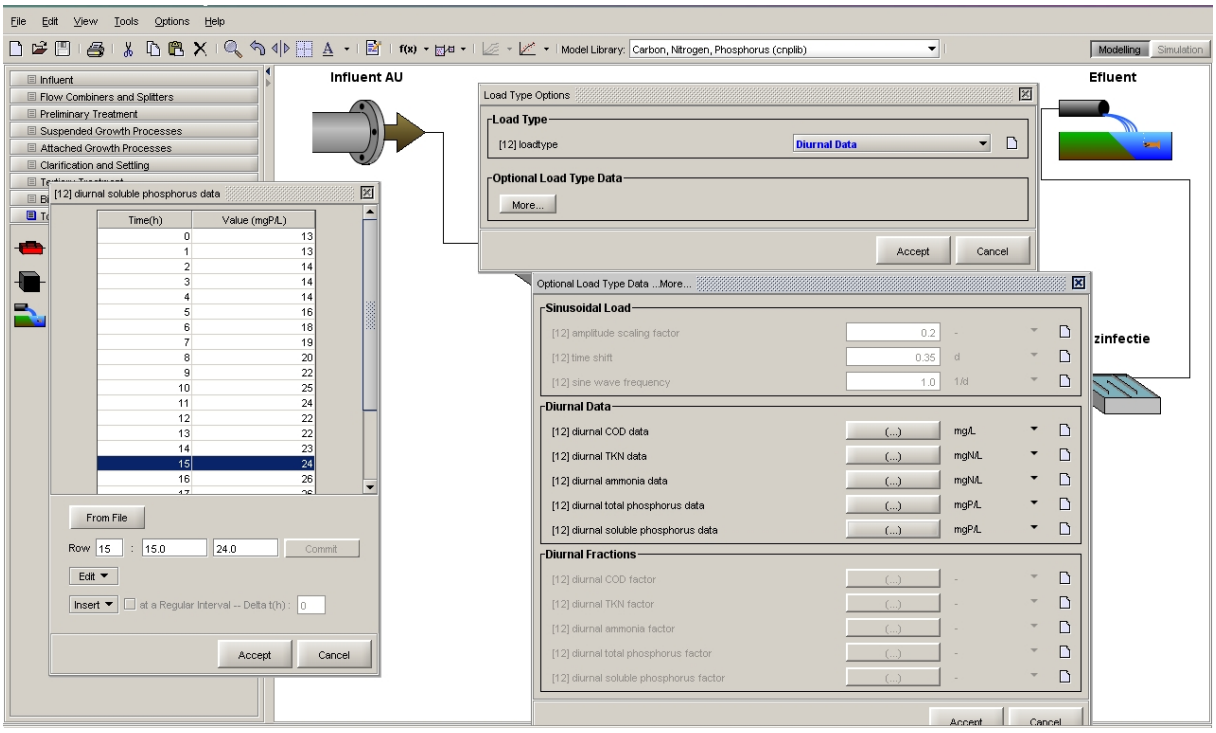

Figure 7 Type of loading diurn

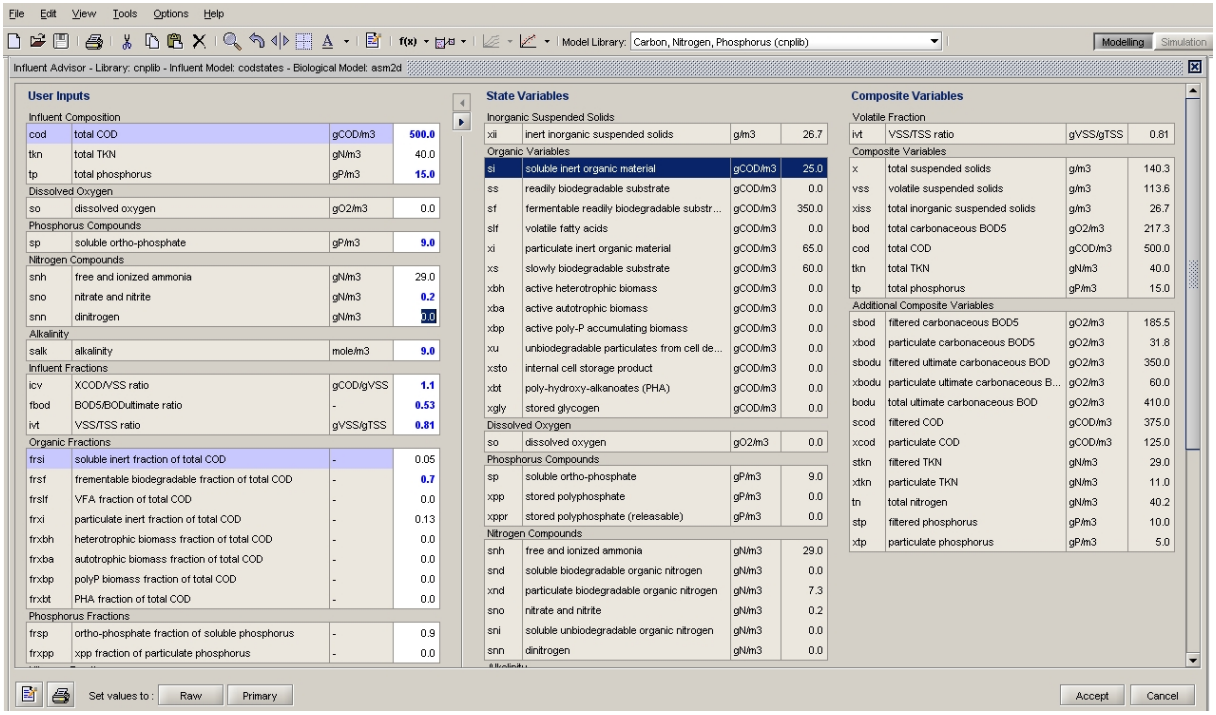

Figure 8 Modification of input data

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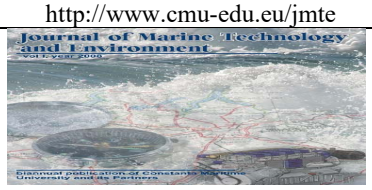

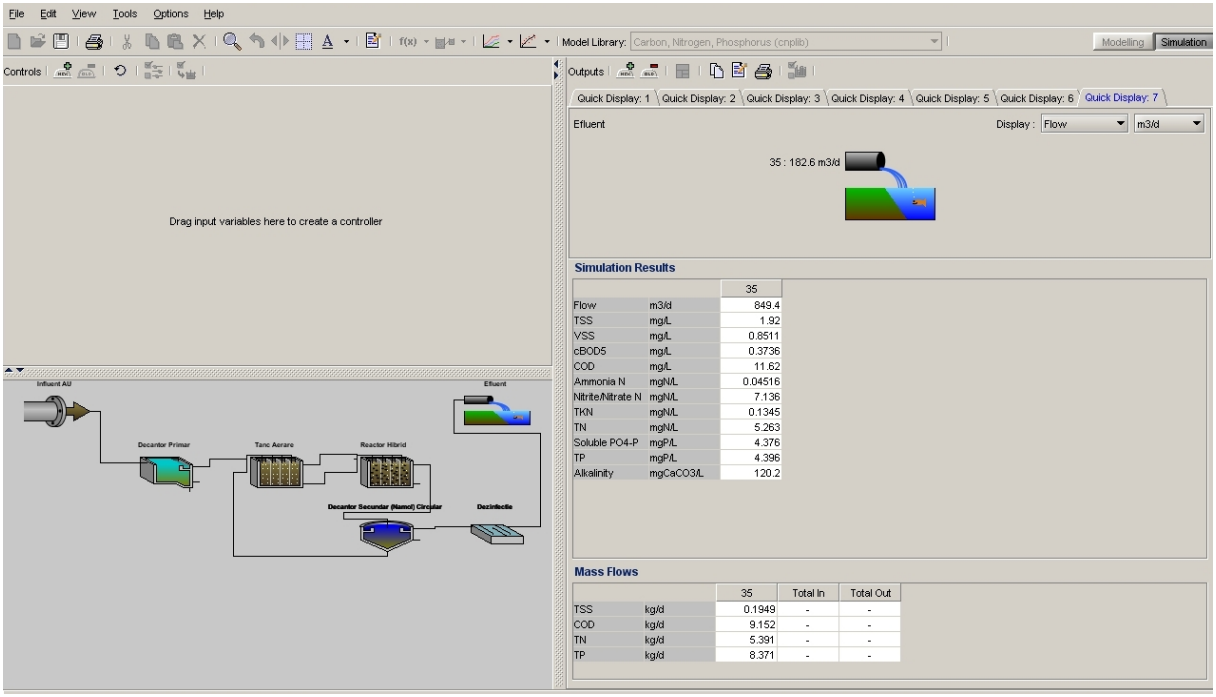

Figure 9 The results of simulation before evacuation

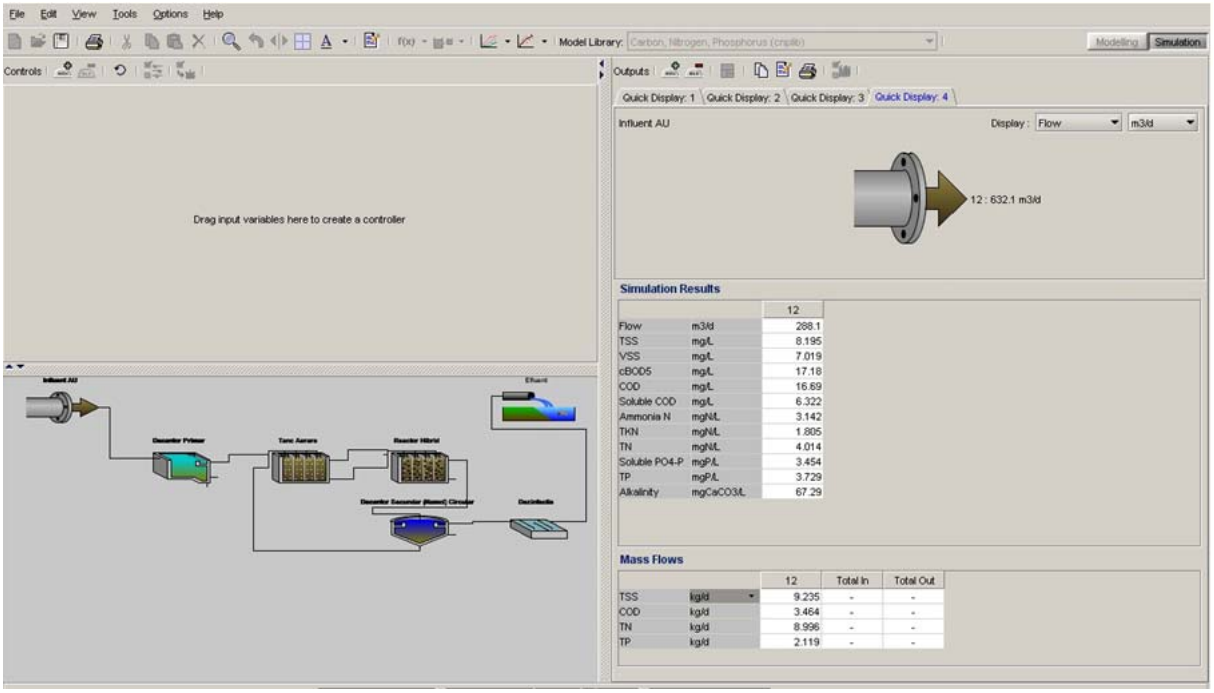

Figure 10 Results for influent

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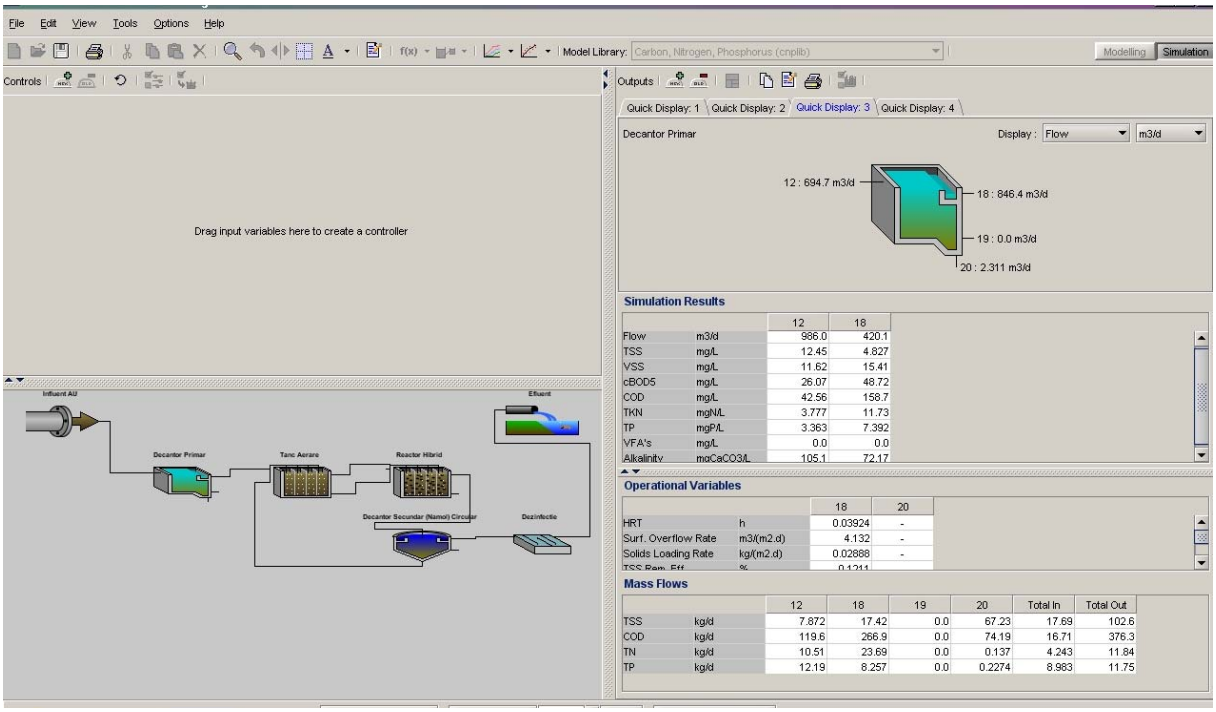

Figure 11 Primary settler tank

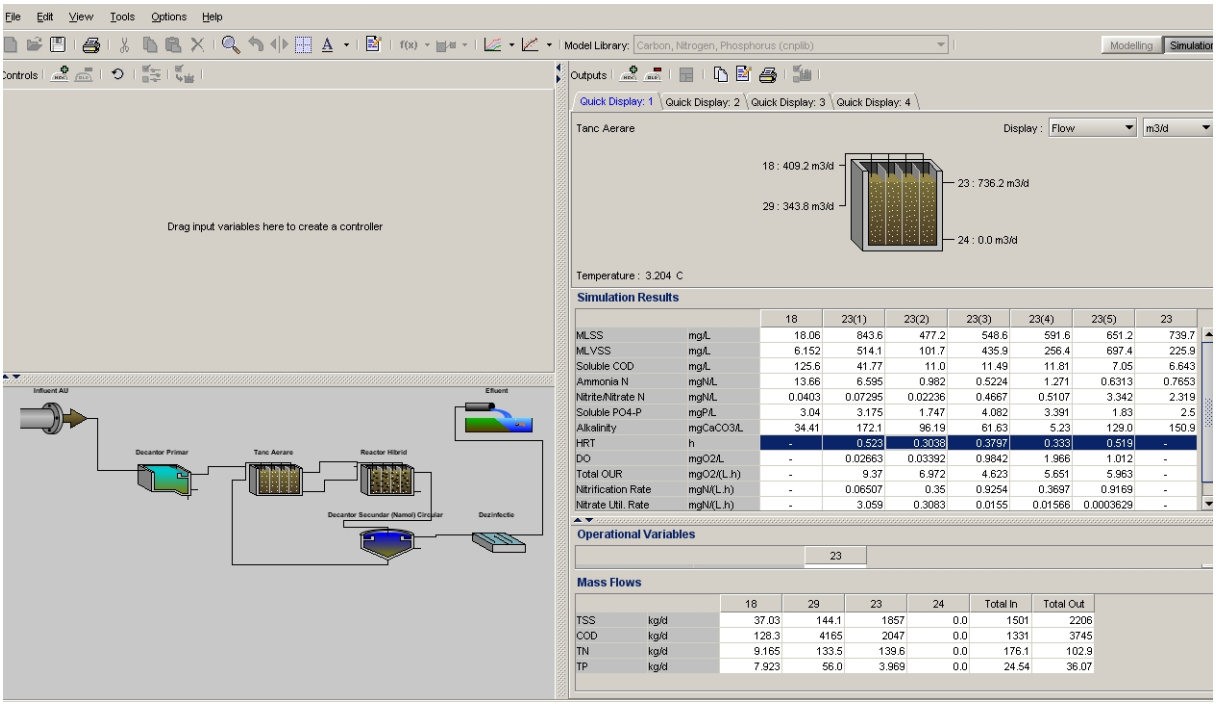

Figure 12 Aeration tank

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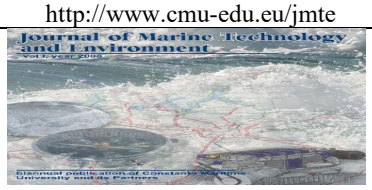

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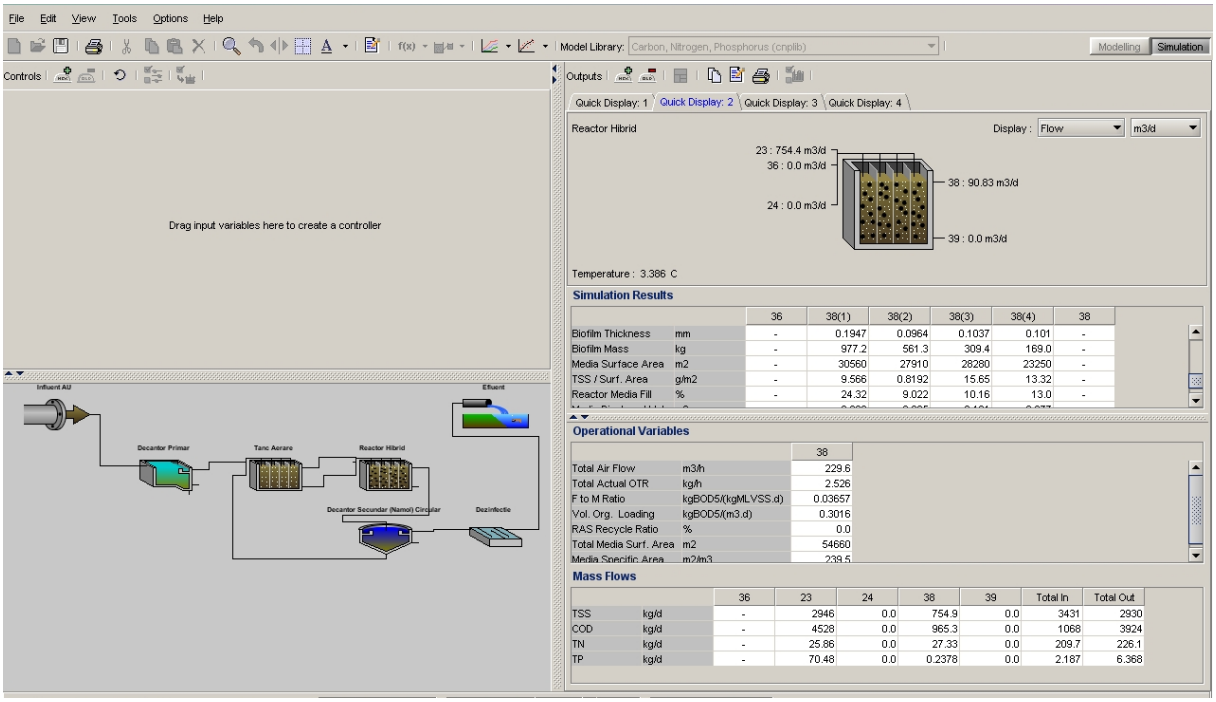

Figure 13 Hybrid bioreactor

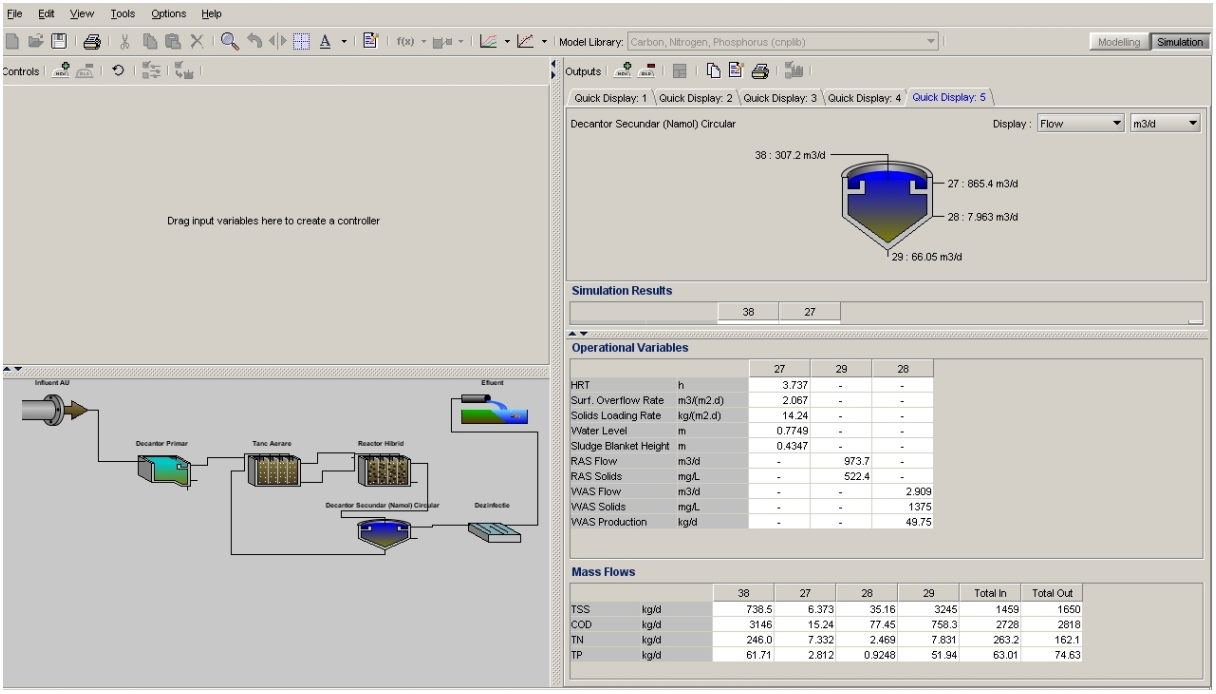

Figure 14 Secondary settler tank

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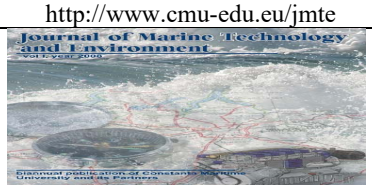


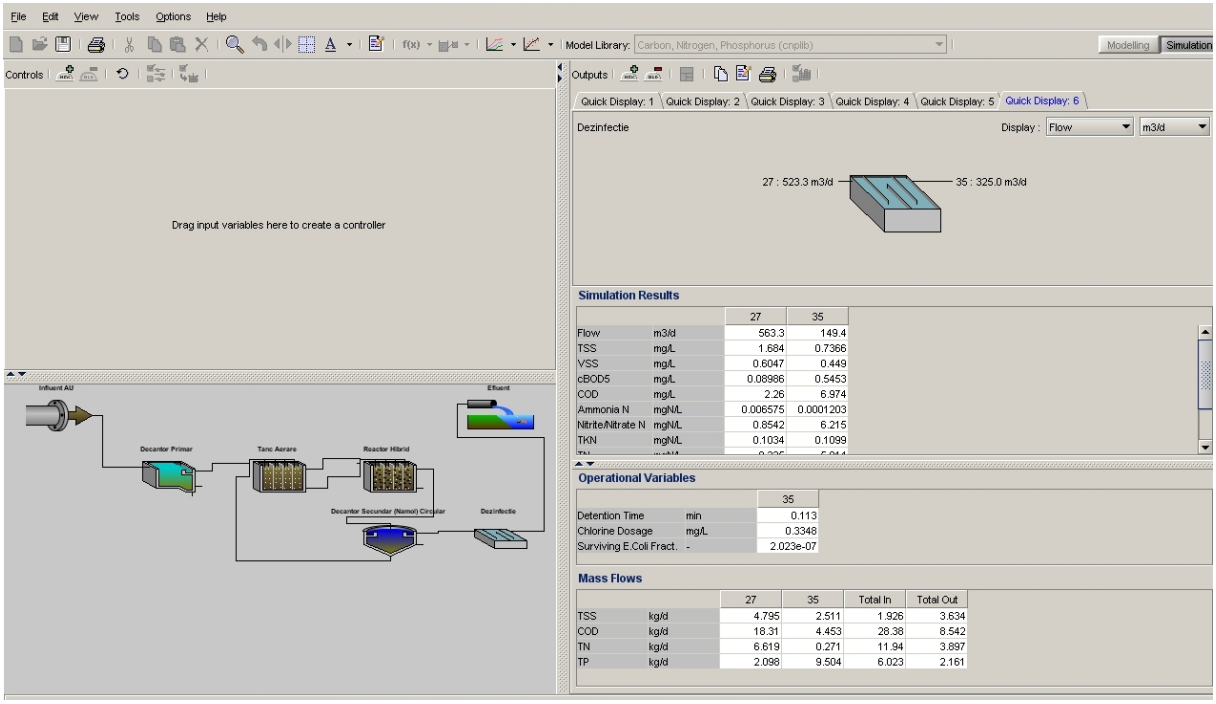


Figure 15 Disinfection

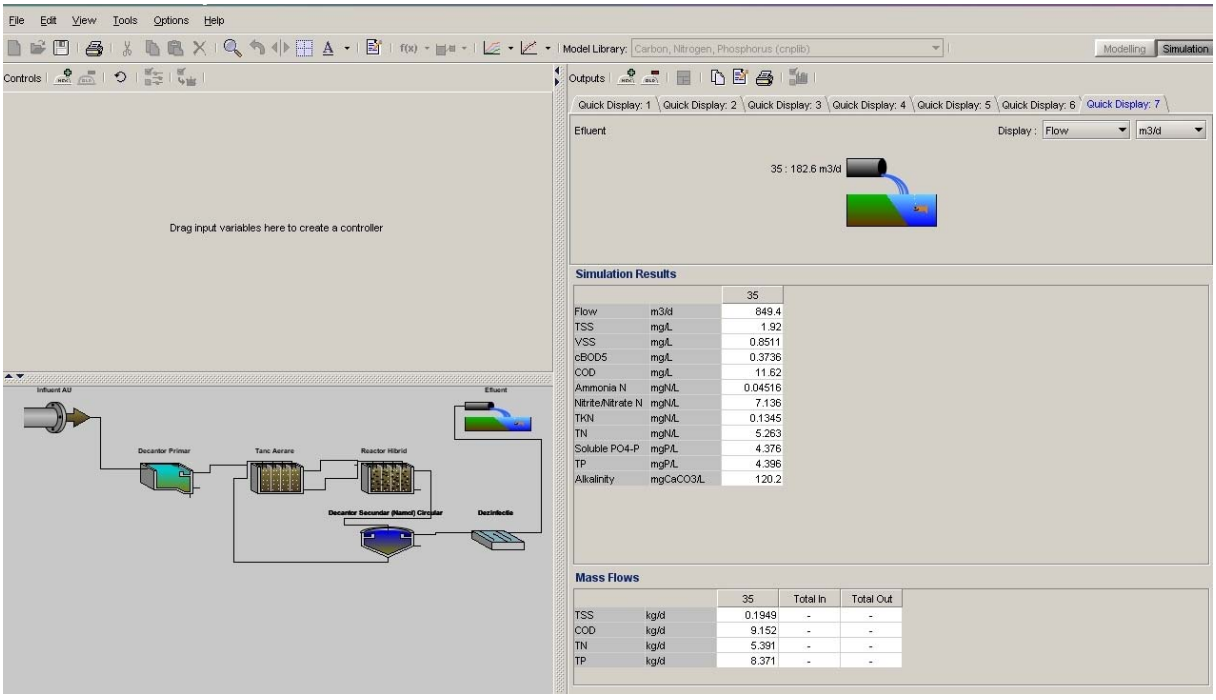
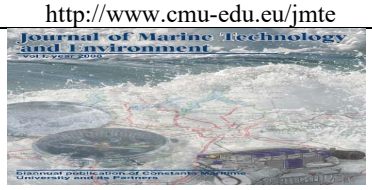


Figure 16 Efluent discharge in the natural emissary



4. CONCLUSIONS

The economic development of the last decades, materialized by industrialization, urbanisation and the chemistry of agriculture, has brought problems related to the impact on the natural environment, through increased consumption (over the autogeneration rate of the circuit Biogeo-Chemical) of natural resources, but also the introduction of factors (alogens), disrulators, pollutants.

This paper can be seen as the values of the analyzed parameters of wastewater treatment, at the evacuation in the natural receiver the values are reduced compared to those established at the entrance to the purification plant, thus being possible to evacuate the purified water according to the standards in force.

Using complex software tools such as GPS-X is a real help in validating the behavior of the simulated process, obtaining graphs of the parameter variation.

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ENERGY EFFICIENCY DESIGN INDEX ASSESSMENT FOR INLAND OIL TANKER OF BANGLADESH

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Abstract: Energy Efficiency Design Index (EEDI) was introduced since 2013 for new ships as a measure to improve energy efficiency of sea going ships. This factor already has created a great influence on global maritime industry. However, any requirement related to the energy efficiency of inland vessels does not exist. This paper attempts to evaluate EEDI for inland oil tankers of Bangladesh. According to the results of this analysis, which has been based on 90 existing inland oil tankers, EEDI that was introduced for seagoing ships cannot be applied B for proper evaluation of inland oil tankers due to limitation of carrying capacity and installed main engine power. So, the main objective of this paper is to provide EEDI reference line for inland oil tankers of Bangladesh.

Key words: Inland Oil Tanker, CO_2 emission, IMO, Reference line, Energy Efficiency Design Index (EEDI).

1. INTRODUCTION

According to IMO, ships engaged in international trade in 1996 contributed about 1.8% of the total world's CO_2 emissions which is approximated as 2.7% in 2007 and this percentage could go two or three times higher by 2050 if present trend continues [1]. In order to reduce CO_2 emission, Marine Environment Protection Committee (MEPC) at its 62nd session adopted Resolution MEPC.203 (62) [2] which includes amendments to MARPOL Annex VI. It introduces new chapter 4 which intends to improve energy efficiency for ships through a set of technical performance standards. The amendments, which entered into force on 1 January 2013, require that every ship has the International Energy Efficiency (IEE) Certificate on board. In order to obtain the IEE Certificate a ship has to comply with the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). The EEDI is mandatory for all new ships and SEEMP for all ships of 400 GT and above engaged in the international shipping. The EEDI is a simple formula that estimates CO_2 output per ton-mile at one design condition.

Due to geographical advantages, waterways are the cheapest mode of transport for transporting passengers and cargoes in Bangladesh. Although, there are more than 300 oil tankers plying all the year round in Bangladesh, but performance of these ships in terms CO_2 emission is not known and any regulations related to the energy efficiency for inland oil tankers still does not exist. Several attempts have made to establish a reliable tool for seagoing vessels with respect to energy efficiency that can be found in various papers & reports but there are no suggested benchmarks that could be used for assessment of the energy efficiency of inland oil tankers for Bangladesh. A. Simic [3] has proposed a reliable tool for benchmarking energy efficiency and carbon emissions of inland waterway self-propelled cargo ships for UK, which should be similar to already accepted approach for seagoing ships. Having in mind the significance of energy efficiency benchmarking, which already has a huge influence on the global marine shipbuilding industry, this study has been performed based on available data of 90 existing inland oil tankers of Bangladesh. From this perspective, this research will seek to review the present scenario of inland oil tankers in terms of EEDI, analyze the results and propose some reliable tool for benchmarking energy efficiency and carbon emission of inland oil tankers considering existing socio-economic and technical factors in Bangladesh. Originally, existing ships are not been targeted in EEDI regulation however, this study has been presented in order to investigate the conformity of existing designs with the new regulation for illustration purposes and take precautions for adopting EEDI methodology to new designs.

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2. FORMULATION OF THE GUIDELINES OF EEDI FOR INLAND OIL TANKERS IN BANGLADESH

2.1. Outline of the methodology

Primary data and information about different types of inland vessels of Bangladesh has been collected through interacting with structured, unstructured and open ended questionnaires from Department of Shipping (DOS), Mercantile Marine Department (MMD), Bangladesh Inland Water Transport Corporation (BIWTC), Chittagong Port Authority (CPA), Mongla Port Authority (MPA) and from various private shipyards. Secondary data and information has been collected from both external and internal means such as journals, reports, thesis, books, electronic and print media, ship owner associations, enlisted ship designing houses, related private organizations, web sites and other internet sources. Based on collected information a data base has been developed for more than three thousand ships. In case of missing information of the collected data, simple assumption and calculation has been required to adjust for missing data.

In order to establish EEDI reference lines for inland oil tankers of Bangladesh 100% of deadweight has used as capacity for other vessels as suggested by IMO. The calculation of EEDI has to be performed for 75% of MCR of engine and with corresponding evaluated ship speed and the value of MCR has to be obtained from power speed curve supplied by engine manufacturer. Adopted value of carbon emissions factor (CF) for diesel fuel was 3.2 t CO_2/t fuel, as recommended in [4].

In Bangladesh, inland vessels use new and old engines and most of these vessels' engine power is around 200 to 1000KW. Specific fuel consumption (sfc) of these new engines as well as old ones has to be collected from engine manufacturer. The value of sfc for engines used for inland vessels has to be cross checked by taking log-book data of actual fuel consumption in different routes.

2.2. Establishment of the reference line regression model

In this study the reports of MEPC 60 were used as the basis for the calculations. MEPC 60 has been working on the mandatory treaty text for implementing the EEDI method on new building vessels within MARPOL Annex VI. Based on all collected data, values of EEDI of analyzed inland waterway vessels have obtained according to the equation introduced by IMO:

$$EEDI_{attained} = \frac{CO_2\,Emission}{Transport\ work} = \frac{Power \times Specific\ Fuel\ Consumption \times CO_2\,Conversion\ Factor}{Capacity \times Speed} = \frac{Emission\ from\ Main\ Engine + Emission\ from\ Auxiliary\ Engine + Emission\ for\ running\ shaft's\ motor - Efficient\ Tech.Reduction}{Capacity \times Reference\ Speed} =$$

$$\left[\left(\prod_{j=1}^{n} f_j\right) * \left(\sum_{i=1}^{nME} P_{ME(i)} * C_{FME(i)} * SFC_{ME(i)}\right) + \left(P_{AE} * C_{FAE} * SFC_{AE}\right) + \left(\left(\prod_{j=1}^{n} f_j * \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} P_{AEeff(i)}\right) * C_{FAE} * SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} * P_{eff(i)} * C_{FME} * SFC_{ME}\right)\right] * \frac{1}{f_i * f_c * Capacity * V_{ref} * f_w} * \left(\frac{gCO_2}{Tonne * knotical\ mile}\right) \quad (1)$$

The Average Index Values are used as the basis for calculating an exponential regression line. The regression line expresses the baseline value, which can then be calculated by using the following formula:

$$\text{Reference line value} = a \times b^{-c} \quad (2)$$

From Figure 1 we observe that the value of a is 950.93 and c is 0.406 where b indicates capacity. The reference line is based on the vessel database of Department of Shipping (DOS) in Bangladesh.

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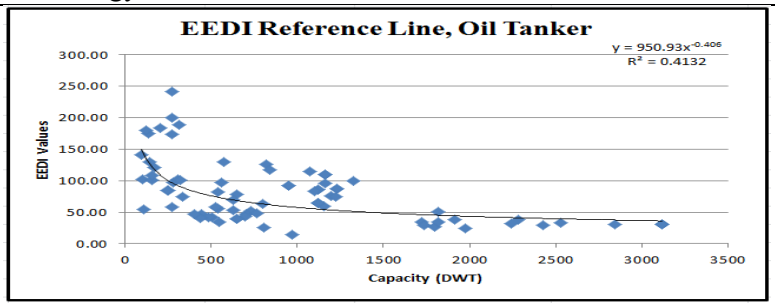

Figure 1 EEDI Reference line for Inland Oil Tanker of Bangladesh

Here R^2 describes the correlation of the baseline value. A correlation close to 1 or -1 represents a high degree of correlation. Outliers which are more than two standard deviations from the regression line are removed, and a new regression line is calculated. This ensures that special ships and erroneous data are excluded from the calculation. From figure 1 it has been observed that the number of oil tankers smaller than 3000 DWT. A group of ships in the 200-1200 ton DW range have relatively index values around 80. These ships would fit in much better in the figure showing EEDI values of oil tanker. It has been also observed that the correlation of the regression line is low and more scatter points would be one of the reasons for that. Arbitrary engine selection of oil tankers is one of the reasons to get more scatter points.

2.3. Reduction of EEDI reference line value

The Energy Emission Design Index adopted by the IMO in 2011 will affect most of these new ships. Time period for phase 1 is from 1st Jan 2015 to 31st Dec 2019, for phase 2 is from 1st Jan 2020 to 31st Dec 2024 and for phase 3 is from 1st Jan 2025 to onwards. Phase 1 indicates the reference line value whereas phase 2 and 3 will force an EEDI reduction of respectively 20% and 30% relative to the reference line for the ship type. The design of the new buildings in the different phases must take the EEDI into account – this will affect the whole chain from naval architects to the ship owners to the yards. The attained EEDI shall be as follows:

Attained EEDI ≦ Required EEDI = (1-X/100) × Reference line value

Where X is the reduction factor for the required EEDI compared to the EEDI reference line.

This attained EEDI must be less than the reference EEDI or reference line.

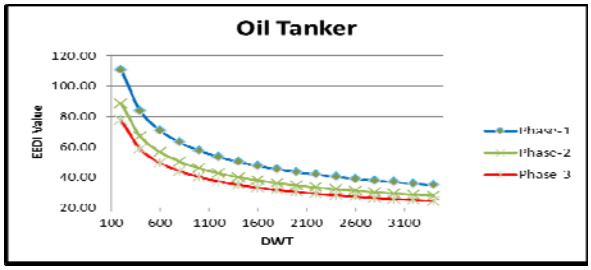

Figure 2 Phase wise EEDI Reference line reduction value for inland oil tankers

From figure 2, we have seen that phase 2 and 3 has much more restriction on EEDI reference line values. For example, a 1000 DWT oil tanker is designed for phase 1 should have required EEDI value 57.56 $gmCO_2$/tonne.mile. Whereas for phase 2 the required EEDI value will be 46.05 $gmCO_2$/tonne.mile and for phase 3 the required EEDI value will be 40.29 $gmCO_2$/tonne.mile.

2.4. Comparison between various countries inland cargo vessels EEDI reference lines

European countries have for a long time been concerned about the actual energy efficiency of ship designs, well before it was considered as a way to mitigate CO_2 emissions. The Netherlands Ministry of Transport, Public Works and Water Management are deeply involved in the development of the EEDI. Supported by maritime experts, the Dutch delegation contributes to the preparation of legislation in the regular and intersessional meetings of MEPC working group on green house gas emissions from ships. To gain insight into the effects of the EEDI on the Dutch fleet, the Ministry of Transport, Public Works and Water Management has tasked the foundation Centre for Maritime Technology and Innovation (CMTI) with this study. The main task in that study was to determine the EEDI values for ships within the Netherlands fleet and ships designed and built in the Netherlands between 1978 and 2008 [5]. Furthermore, in 2nd session of Intersessional meeting of the greenhouse gas working group in 4th February, 2009, energy efficiency design index baselines

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was submitted by Denmark [6]. In this paper Denmark & Netherlands formulated EEDI reference lines have been compared with the EEDI reference line of Bangladesh.

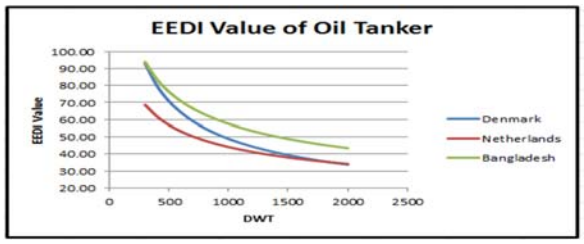

Figure 3 various countries inland vessels EEDI reference lines, Oil Tanker

From figure 3, it has been observed that EEDI reference lines for oil tankers of Bangladesh lies much above than Denmark & Netherlands. For example, a 1000 DWT oil tanker is designed for Denmark should have required EEDI value 48.88 $gmCO_2$/tonne.mile. Whereas for Netherlands the required EEDI value will be 44.09 $gmCO_2$/tonne.mile and for Bangladesh the required EEDI value will be 57.56 $gmCO_2$/tonne.mile. One of the main reasons behind this is inappropriate engine selections and inaccurate hull parameters selection that leads to higher EEDI value.

2.5. Verification of Reference line formula

The verification of mathematical model with capacity as independent variable data is shown in table 1. In this mathematical model the attained EEDI has been calculated using equation 1 and required EEDI has been formulated using equation 2. It has been observed from Table 1 that, the difference is within the permitted range between reference line value and actual EEDI value, so this reference lines formula can provide a reference for EEDI calculation of inland oil tankers of Bangladesh.

Table 1. Validation of mathematical model with capacity as independent variable.

Ship Name	Capacity (DWT)	Attained EEDI	Required EEDI	Difference
OT New Sea Queen	652	78.31	68.48	-14.4%
OT Meghoboti	1153	60.46	54.34	-11.3%
MT City-36	2528	33.94	39.5	14.1%
MT Mercentile-1	1914	38.49	44.23	13.0%
OT Queen of Joyoti	539	83.1	73.96	-12.4%
OT Al Fateh	280	98.1	96.57	-1.6%
OT Veola	1815	51.16	45.19	-13.2%
OT Totiri	798	64.06	63.09	-1.5%
OT Sarjil	629	69.69	69.46	-0.3%
OT Sea Sky	2284	38.81	41.16	5.7%

It has been observed from table 1 that, the difference is within the permitted range between reference line value and actual EEDI value, so this reference line formula can provide a reference for EEDI calculation of inland oil tankers of Bangladesh.

3. PRESENT STATUS OF INLAND VESSELS OF BANGLADESH WITH RESPECT TO EEDI

More than four years have been passed since IMO regulations regarding the required energy efficiency of seagoing ships became mandatory. These regulations introduced massive application of already existing technologies, which were neglected without proper incentives, and also initiated development of new solutions for reduction of unnecessary energy dissipation during ship navigation. As it turned out, in some cases even simple (well known) solutions in combination with already existing technologies can provide significant increase of energy efficiency of a ship. Moreover, the absence of appropriate energy and emissions benchmarks for inland vessels is a large impediment to performance improvements of these ships. In this paper, a considerable effort has been devoted to this matter; so far there are no suggested benchmarks that could be used for assessment of inland oil tankers efficiency during design stage or for comparison of existing ships with respect to energy and emission efficiency. In this study, phase 1, 2 and 3 has been applied to assess the present status of inland oil tankers of Bangladesh. It has been observed that in phase-1, 40% vessels have been passed in terms of EEDI and 60% vessels have been failed. In phase-2, 17% vessels have been passed in terms of EEDI and 83% vessels have been failed. In phase-3, 9% vessels have been passed and 91% vessels have been failed.

3.1. Present status of EEDI with respect to vessel's length

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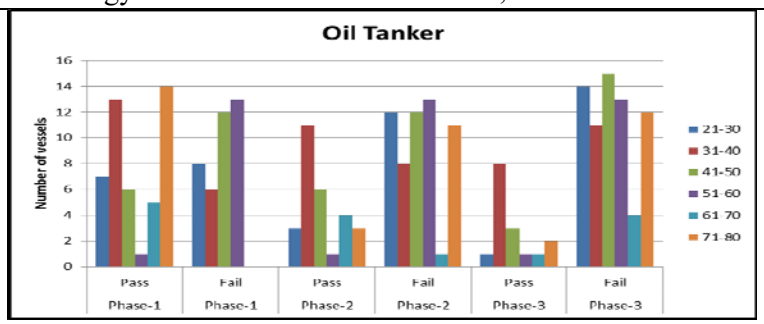

Figure 4 Present status on EEDI with respect to vessel's length

From figure 4 it has observed that in Bangladesh most of the inland oil tankers length is between 31to 40m. In this range there are presently 19 vessels out of them 13 vessels pass in terms of EEDI and the rest of the vessels EEDI exceed the required value in phase 1. As the phase increases more vessels exceed the required EEDI value. In vessel's length between 51 to 60m, most of the vessels EEDI exceed the reference line. It has been also observed that larger length vessels EEDI lies below the reference line. In this case in vessels length range between 61 to 80m, there is no such vessel which meets EEDI reference line.

3.2. Present status of EEDI with respect to vessel's Capacity

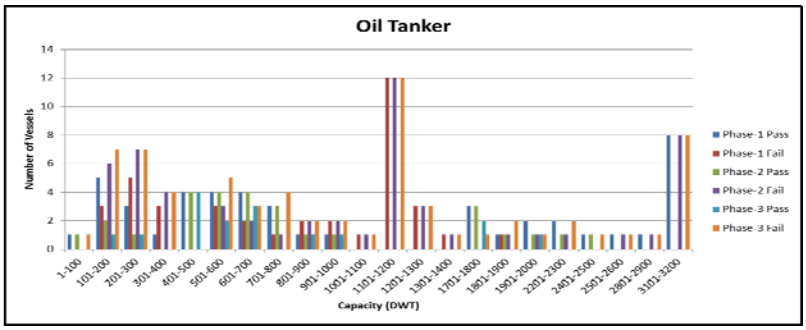

Figure 5 Present status on EEDI with respect to vessel's Capacity

3.3. Present status of EEDI with respect to vessel's Main engine power

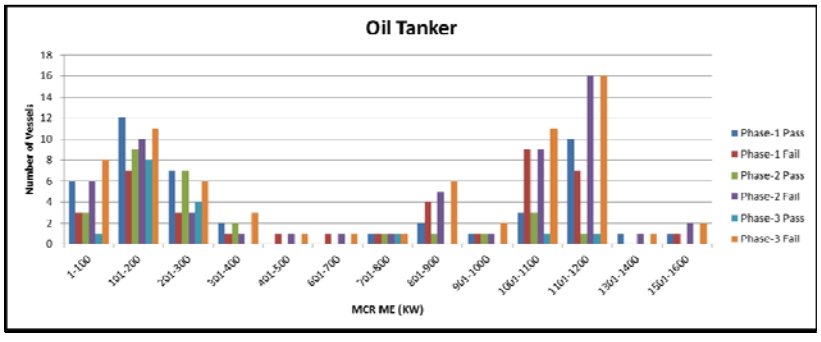

Figure 6 Present status on EEDI with respect to vessel's Main Engine Power

From Figure 6 it has observed that in Bangladesh most of the vessels EEDI exceed the reference line. It has been also observed that smaller main engine power vessels EEDI lies below the reference line.

4. CASE STUDY OF EXISTING INLAND VESSELS WITH RESPECT TO EEDI

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According to the EEDI, the energy efficiency of ships is defined as the ratio of the mass of CO_2 emissions from main, auxiliary engines and additional shaft per unit of transport work for a particular ship design. Therefore detailed design data, such as speed, engine power, fuel oil consumption, deadweight etc., are required in order to calculate the correct EEDI values which are closely related to the economic performance of the ship. The price of fuel has been the primary driver for improved efficiency and reduced fuel consumption on commercial ships. The highly competitive nature of the maritime industries meant that efforts to bring down fuel consumption were cost effective solutions, leading to overall optimization of the transport system. The IMO is developing the Energy Efficiency Design Index (EEDI) for new ships, which is a gauge of a ship's CO_2 efficiency. During the design stage of the vessel, for known demands, hull form should be determined at the beginning. Based on principal ship parameters, it is possible to estimate the attained EEDI and to compare it with the required value.

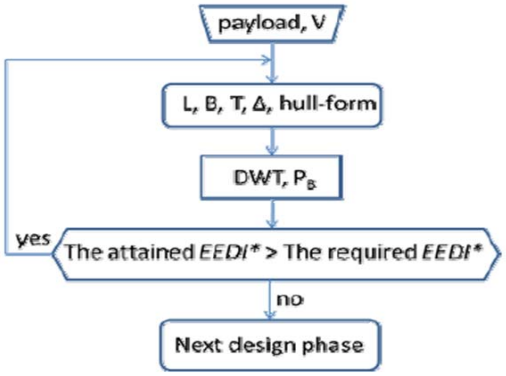

Figure 7 Procedure for evaluation of energy efficiency of a new ship during design stage [3]

If a criterion described in Figure 6 is fulfilled, something should be changed (improved) within the project, otherwise it is allowed to proceed to the next design stage. Naturally, results should be confirmed during the speed trials as is recommended to be done for the seagoing ships.

Sample Ship (Oil Tanker):

Sensitivity of EEDI has been exemplified through a set of calculations for a case oil tanker. For demonstration purposes, an existing 2774 dwt oil tanker design has been used as an example.

Principal particulars of the Sample Case Ship:

Table 2. Ship Specifications of 2774 DWT Oil Tanker

Length (O.A)	78.85m	DWT	2774
Length (B.P)	76.30m	Main Engine (Cummins-QSK60M)	2X1492 KW@100% MCR
Breadth (mld)	12.50m	SFC (ME)	165 g/KWh
Depth (mld)	6.50m	Main Generator	2X443KW
Draft	5.00m	SFC (AE)	185 g/KWh

For calculation of EEDI for the sample Ship, exact and ship specific model test data has been used and the calculation has been made according to the latest calculation guidelines as described in IMO MEPC.1/Circ.68 [7]. In this study, resistance has been calculated using Holtrop and Mennen's method. Calculated EEDI for the Case ship is 50.84 gCO_2/tnm. According to the formulated oil tanker baseline, the requirement for 2774 dwt oil tanker is 38.04gCO_2/tnm, thus the Case Ship is about 33.64% above the baseline. However actual EEDI of the case ship would need to be improved by 33.64% to match with the requirement.

The relative high power of the installed shaft generator (P_{PTO}) has a huge impact on the EEDI value. If the ship is equipped with a large shaft generator that has to supply power to other systems on top of the power for the basic auxiliary systems, will decrease the EEDI value to great extent. It should be considered that, by installing a higher powered shaft generator, we are actually reducing P_{ME} and thus EEDI is getting decreased, as P_{ME} is the numerator in the EEDI equation. If we decrease P_{ME} by increasing installed shaft generator would mean that, V_{REF} is also decreased. V_{REF} being a denominator in the EEDI equation will try to increase EEDI. Thus, it can be said that, installing higher power shaft generator is not favorable; rather, optimum effect of P_{PTO}, P_{ME} and V_{REF} on EEDI should be analyzed for the best design.

Change in Length of the vessel:

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Table 3. Optimization of ship's length with respect to EEDI (oil tanker)

Condition	Length (m)	Breadth (m)	Draft (m)	Cb	Displacement (T)	P_{ME} (kW)	MCR_{ME} (KW)	Total Resistance (KN)	EEDI (Attained)
Basis	76.3	12.5	5	0.857	4086	2217	2956	189.67	36.35
5% less	72.485	13.16	5	0.857	4086	2368	3158	202.59	38.83
10% less	68.67	13.88	5	0.857	4086	2662	3550	227.77	43.66
5% more	80.12	11.9	5	0.857	4086	2111	2815	180.6	34.6
10% more	83.93	11.36	5	0.857	4086	1998	2664	170.93	32.7

When increasing vessels length, the relative increase in power will generally be smaller than the relative increase in length, other factors being equal and keeping the capacity same as basis ship. This suggests that increasing the vessels length will tend to improve the EEDI because the EEDI is particularly sensitive to the service speed, as the required power increases by roughly the cube of the variation in service speed ($P \propto V^3$). From table 3, it has been observed that EEDI (attained) decrease with the increase of length at 12.5 knot speed, but increase with the increase of length at higher speeds. The reason behind it is the wave resistance that increases at high speed. So at higher speed, longer vessels are performing well. From this table it has been also observed that, Total resistance and Main engine power (P_{ME}) decreases with the increase of length.

Change in Breadth of the vessel:

Table 4. Optimization of ship's breadth with respect to EEDI (oil tanker)

Condition	Length (m)	Breadth (m)	Draft (m)	Cb	Displacement (T)	P_{ME} (kW)	MCR_{ME} (KW)	Total Resistance (KN)	EEDI (Attained)
Basis	76.3	12.5	5	0.857	4086	2217	2956	189.67	36.35
5% less	80.31	11.875	5	0.857	4086	2106	2808	180.15	34.53
10% less	84.77	11.25	5	0.857	4086	1970	2627	168.5	32.3
5% more	72.66	13.125	5	0.857	4086	2359	3145	201.78	38.67
10% more	69.36	13.75	5	0.857	4086	2591	3455	221	42.49

From table 4, it has been observed that EEDI (attained) increases with the increase of breadth at 12.5 knot speed and keeping the displacement same as basis ship. From this table it has been also observed that, Total resistance and Main engine power (P_{ME}) increase with the increase of breadth.

Change in Speed of the vessel:

Table 5. Optimization of ship's speed with respect to EEDI (oil tanker)

Condition	Speed (Knot)	P_{ME} (KW)	MCR_{ME} (KW)	Total Resistance (KN)	EEDI (Attained)
Basis	12.5	2217	2956	189	36.35
5% less	11.875	1958	2611	176	33.8
10% less	11.25	1355	1807	128	24.7
5% more	13.125	2851	3802	232	44.5
10% more	13.75	4575	6100	355	68.2

From table 5, it has been observed that EEDI (attained) increase with the increase of speed. It has been also observed that, Total resistance and Main engine power (P_{ME}) increase with the increase of speed. It can be decided easily that low speed gives the better performance in terms of EEDI.

Change in block coefficient of the vessel:

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Table 6. Optimization of ship's block coefficient with respect to EEDI (oil tanker)

Cordition	Length (m)	Breadth (m)	Draft (m)	Cb	Displacement (T)	$P_{MC\ (KW)}$	MCR_{ME} (KW)	Total Resistance (KN)	EEDI (Attained)
Basis	76.3	12.5	5	0.857	4086	2217	2956	189.67	36.35
5% less	76.3	13.16	5	0.814	4086	1744	2326	149.2	28.6
10% less	76.3	13.88	5	0.77	4086	1573	2098	134.63	25.8
5% more	76.3	11.9	5	0.89	4086	3776	5034	323	61.9
10% more	76.3	11.77	5	0.91	4086	4632	6176	396	75.9

From table 6, it has been observed that EEDI (attained) increase with the increase of block coefficient. It has been also observed that, Total resistance and Main engine power (P_{ME}) increase with the increase of block coefficient. It can be decided easily that, at any speed it is better to have small block coefficient.

Change in engine of the vessel:

Table 7. Optimization of ship's engine with respect to EEDI (oil tanker)

Engine Name	SFC (g/Kwh)	Price (USD)	EEDI (Attained)
Cummins	165	950000	36.35
Yanmar	190	810000	41.82
Weichai	200	630000	44
Nigbo CSI	210	600000	38.04

From table 7, it has been observed that EEDI (attained) increase with the increase of specific fuel consumption value. It has been also observed that, the price of engine increase which has low sfc value. It can be decided easily that low sfc gives the better performance in terms of EEDI. But considering the economic factor in Bangladesh, if the EEDI values between two engines are nearer then the engine which has high sfc would be used. Here in this study, the ship building cost has been taken into consideration but not the increase in the operating cost (fuel cost) during ship life cycle.

5. HULL FORM OPTIMIZATION

In the process of ships, the determination of hull lines is complicated and pivotal, in respect that ships main performance of the rapidity (resistance and propelling), maneuverability and seakeeping would be influenced directly. However to obtain the hull shape of the minimum resistance is the primary goal of designers. In order to increase competitiveness and ability of ship form development in international market, an optimization design method of excellent hull lines with the resistance performance and to development of program of ship lines of optimal design with the independent intellectual property is in urgent need.

The principal particulars of the existing oil tanker are shown in table 8.

Table 8. Ship Specifications of Oil tanker

Length (O.A)	62m	DWT	1350
Length (B.P)	58.8m	Main Engine (Nigbo CSI)	2X720 BHP@100% MCR
Breadth (mld)	10.10m	SFC (ME)	210 g/KWh
Depth (mld)	5.7m	Main Generator	2X200KW
Draft	4.0m	SFC (AE)	230 g/KWh

According to the specifications, we have found that the EEDI value for this vessel is 62.98 g CO_2/ton mile and the maximum EEDI value for this vessel is 50.9 g CO_2/ton mile. So, this vessel exceeds it's EEDI value and needs the optimization of hull form.

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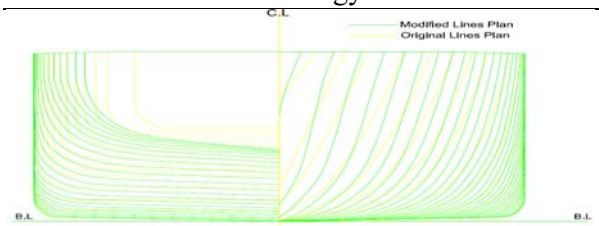

Figure 8 The comparison of body plans between the original hull form and the modified hull form (Oil tanker)

The comparisons of body plans between the modified hull form and the original hull are shown in figure 8 and in this figure yellow line shows the original body plan & green line shows the modified body plan. In this comparison ship's hull has been optimized by keeping it's principal parameters (e.g. length, breadth, draft and cargo carrying capacity same). In original model the displacement is 2136 T but in improved model the displacement is 2135T.

Resistance Vs Speed graphs:

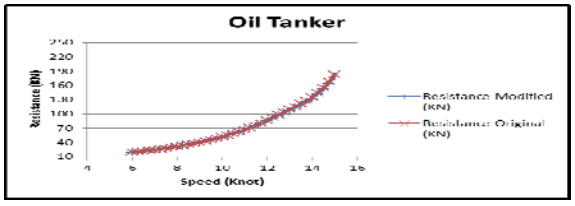

Figure 9 Resistance Vs Speed Graph (Oil tanker

From figure 9, we have seen that whereas in original lines plan resistance have found 52.2KN but in modified lines the resistance value is 50.5KN at 10 Knot service speed.so, the modified lines has given less resistance than the original one.

Power Vs Speed graphs:

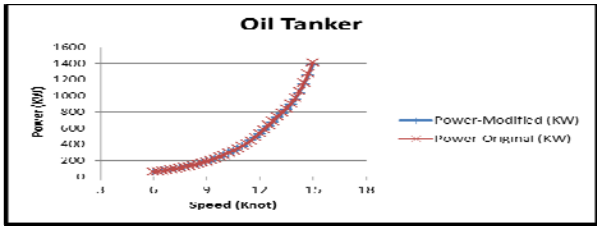

Figure 10 Power Vs Speed Graph (Oil tanker)

From figure 10 we have seen that whereas in original lines plan required main engine power is 800KW but in modified lines the required power is 770KW. By original lines plan we have found the EEDI value for the vessel is 81.69 g CO2/ton mile but the modified lines plan we have found the EEDI value 79.69 g CO_2/ton mile. Though originally 1045 KW power has been provided in this vessel but this vessel needs 800KW. So, we can say that a better and smooth hull design gives lesser resistance and hence gives better EEDI values.

7. CONCLUSIONS

Having in mind the significance of energy efficiency benchmarking, which already has a huge influence on the global marine shipbuilding industry, this study has performed, based on available data of existing inland oil tankers in Bangladesh and the following could be concluded:

- the EEDI introduced by IMO for evaluation of energy efficiency of oil tankers can't be used for proper evaluation of energy efficiency of inland oil tankers. The reason for this is the limitation of carrying capacity and installed main engine power for inland waterways vessels. For that reason a reference line formula has been proposed in this paper which would be used to calculate required EEDI value of inland oil tankers in Bangladesh.
- formulated baseline equations for EEDI of Bangladesh lies much above than other countries like Denmark & Netherlands and one of the reasons for that is inappropriate engine selection of most of the inland oil tankers in Bangladesh. For example, oil tanker's EEDI reference line value of Bangladesh lays 18% above Denmark's reference line value and 31% above Netherlands reference line value.
- comparatively longer vessel is favorable from the EEDI point of view. A slender hull form, which will create a smaller pressure difference between bow and stern, is favorable.
- Lower main engine power vessels are more effective in terms of EEDI.
- A better and smooth hull design gives lesser resistance and hence gives better EEDI values.

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EFFICIENT DESIGN OF THE GEAR UNIT WITH A ONE-SPEED GREARBOX WITH COMPUTER PROGRAM

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Abstract: By introducing international standards and local rules and Normalization was a lavish a production version based machines Field organs, thus creating interchangeability -the opportunity Machines bodies, with huge implications for maintenance and machine reliability. Technological evolution implies a great flexibility of production capabilities with strong influences on changing design concepts.

The emergence of personal computers is also favored by a tendency to globalize design rules through specialized design programs. The overall picture of design processes is changing very quickly and is determined by the emergence of modern means that designers have at their disposal today. Computer problem solving has been a strong motivation, so that later hardware development and PC development have led to the emergence of software dedicated to mathematical problems.

For over 20 years, Mathcad is the recognized standard in designing, documenting and collaborating with computers, calculation methods and algorithms in design.

This paper proposes the design of the gear unit for a single speed gear using the mathcad program.

Key words: speed reducer, gearing, mathcad program.

1. INTRODUCTION

Mathcad is a unique, powerful way to work with equations, numbers, text, and graphs. Unlike any other math software, Mathcad does math the same way you do. That's because it looks and works like a scratchpad and pencil. Mathcad's onscreen interface is a blank worksheet on which you can enter equations, graph data or functions, and annotate with text - anywhere on the page. And instead of forcing you to use a programming-like syntax, Mathcad lets you use the language of mathematics.

The only difference is that Mathcad's equations and graphs are live. Change any data, variable, or equation, and Mathcad recalculates the math and redraws the graphs - instantly. With Mathcad, you can solve a wide range of technical problems - from the simple to the very complex - numerically or symbolically. You can also visualize equations and data with 2D and 3D graphing. With Mathcad Electronic Books you also get a wealth of mathematical knowledge and reference material - all live and ready to be dragged and dropped into your worksheets.

Most important, Mathcad gives you all the power you need to get the job done - from start to finish. With Mathcad you can truly do it all – explore problems, formulate ideas, analyze data, model and test scenarios, select the best solution . . then document, present, and communicate the results. Using Mathcad's connections to the Worldwide Web, you can also share your Mathcad worksheets with colleagues and other professionals. This means you can collaborate easily during any phase of a project - and you can do it in the rich and powerful language of mathematics.

2. GEAR CALCULATION

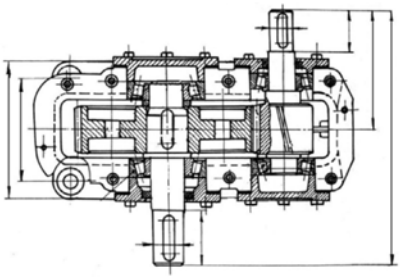

Figure 1 Overall drawing of a reducer

2.1. Selection of the materials

The gears in general are heavy loaded machine elements. The main loads for which the calculation will be conducted are bending stress affecting the dedendum

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(σ_F) and the contact stress (σ_H), both being dynamic and variable in time after a pulsating cycle.

As a consequence when designing gears one have to know many details of the material behavior as ultimate strength, yielding strength, hardness etc., and the fatigue strength for the above mentioned stresses (σ_{Flim} and σ_{Hlim}), which are experimentally determined.the steels to be used for gears are rolled steels, forged steels, cast steels, non-ferrous like bronzes, aluminum, etc. For reducers one use rolled or forged steels.

There are two groups of steels to be used:

• The tempered steels with the Brinell hardness less than *350HB*

• Hardened steels via quenching and heat treated or thermo-chemically treated with the Brinell hardness greater than *350HB*

The first group of steels will result in bigger sizes of hears than those made out of the second group of steels working in the same conditions. The first group renders the gear cost cheaper so that whether the size of the gear is not an issue; the first group of steels is advisable to be used.

For reducers since the tendency is to have smaller sizes, the second group is then recommendable.

I'll choose the allied steel 41 MoCr11.

2.2. Pre-dimensioning of the helical cylindrical gear

The first thing to do when pre-dimensioning is to calculate the center distance *a*, the normal module m_n, the inclination helix angle on the pitch cylinder *β,* and the profile displacements distances.

a) The center distance a,

By using the relation demonstrated during the course we have:

$$a \geq (1+u)\sqrt[3]{\frac{K_A K_V K_{H\beta} M_{t\,pinion}}{2u\Psi_a}\cdot\left(\frac{Z_M Z_H Z_\varepsilon}{\frac{\sigma_{H_{lim}}}{S_H}K_{HN}Z_R Z_W}\right)^2} \quad (1)$$

where:

$$u = \frac{z_{mare}}{z_{mic}} = i_{RD} = 3{,}15$$

u = i_R for reducers (from the design specification),
u = is the ratio (*u* > 1);
KA = 1
K_A –is the factor taking into account the functioning regime in order to consider the external dynamic over-loads to be developed during functioning of the transmission, and being a function of the engine type, the actuated mechanism, the loading characteristics like uniform loads, moderate shocks or big shocks, etc. ;
K_v = 1,21
K_v –is the factor taking into account the dynamic loads due to the machining/fabrication errors of the gears, the elastic deformations of the gear and the assembly where it is mounted during functioning, etc.;
$K_{H\beta}$ =1,18
$K_{H\beta}$ –is the factor taking into account the unevenness of the load distributed on the contact teeth width due to the fabrication errors of the gear, mounting errors inside the cases, on the shafts etc.;
$M_{t\,pinion} = M_{tI}$ – is the moment loading the driving gear (pinion).

For both gears the moment is:

$$M_{t_{M(I,II)}} = 955\cdot 10^4 \cdot \frac{P_{M(I,II)}}{n_{M(I,II)}}\ [Nmm] \quad (2)$$

$$M_{tI} = \frac{955\cdot 10^4 \cdot 37}{4095} = 862.88Nmm \quad (3)$$

$$M_{tII} = \frac{955\cdot 10^4 \cdot 37}{1300} = 271.808Nmm \quad (4)$$

$\Psi_a = 0.5$
Ψ_a is the gear width coefficient
$\Psi_a = b/a$ (where b is the width of the gear)

Z_M= 271 N/mm²
Z_M – material factor.

$$Z_M = \sqrt{0{,}35\cdot E} \quad (5)$$

$$\frac{1}{\mathrm{E}} = \left(\frac{1}{\mathrm{E}_1}+\frac{1}{\mathrm{E}_1}\right)\cdot\frac{1}{2} \quad (6)$$

where E_1, E_2, E, are the Young modulus for the gears and E is the equivalent modulus.

Z_H = 1,77
Z_H – point roll factor; the predimensioning will take
Z_ε = 1
Z_ε – Is the contact zone factor;
$\sigma_{H\,lim}$ – is the limit fatigue pressure

$$\sigma_{Hlim} = (1.8\cdot HB + 200) = 686N/mm^2$$

S_H = 1,25
S_H – is the safety factor for contact stress
K_{HN} =1
K_{HN}– the number odd cycles factor for contact stress
Z_R =1
Z_R – roughness factor
Z_w =1
Z_w – flank hardness factor

$$a \geq (1+3{,}15)\cdot\sqrt[3]{\left(\frac{1\cdot 1{,}1\cdot 1{,}15\cdot 1{,}18\cdot 135904}{2\cdot 3{,}15\cdot 0{,}5}\right)}\cdot\sqrt[3]{\left(\frac{271\cdot 1{,}77\cdot 1}{\frac{686}{1{,}25}\cdot 1\cdot 1\cdot 1}\right)^2} = 4{,}15\cdot\sqrt[3]{49198{,}42} = 147{,}11\ mm. \quad (7)$$

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The center distance is standardized and is given in Figure 2. We'll choose the next superior value but whether the calculated value is less than 5% than the lower one, we may choose the lower one.

We'll take ***a=160 mm.***

b) The normal module m_n calculation

This normal module is calculated from the condition of even resistance to the dedendum bending stress. We may use the relation:

$$m_n \geq \frac{M_{t\,pinion}\,(1+u)K_A K_V K_\alpha K_{F\beta} Y_F Y_\beta}{\Psi_a \cdot a^2 \cdot \frac{\sigma_{F_{lim}}}{S_F} \cdot K_{FN} Y_s Y_{Fx}}. \quad (8)$$

Standard modules [mm]

I	II	I	II
1			4,5
	1,25	5	
1,25			5,5
	1,375	6	
1,5			7
	1,75	8	
2			9
	2,25	10	
2,5			11
	2,75	12	
3			14
	3,5	16	
4			18

Standard center distances [mm]

I	II
40	40
	45
50	50
	56
63	63
	71
80	80
	90
100	100
	112
125	125
	140
160	160
	180
200	200
	225
250	250
	280
315	315
	355

Figure 2 Standard module and center distances (mm)

Where:

$\boldsymbol{K_a = 1}$

K_a −Factor to count for the frontal load distribution

$\boldsymbol{K_{F\beta} = 1,15}$

$K_{F\beta}$ −Factor to count for the longitudinal distribution of the load for dedendum bending calculation;

$\boldsymbol{Y_F = 2,25}$

Y_F −Shape factor

$\boldsymbol{Y_\beta = 1}$

Y_β − Inclination angle factor

a = 160 mm – center distance.

$\boldsymbol{\sigma_{F\,lim} = 250\ N/mm^2}$

$\sigma_{F\,lim}$ − Selected from Table 4.1 is the fatigue limit stress to the dedendum

$\boldsymbol{S_F = 1,5}$

S_F −Safety factor for dedendum bending loading,

$\boldsymbol{K_{FN} = 1}$

K_{FN} −The number of circles factor for dedendum loading

$\boldsymbol{Y_s = 1}$

Y_s −Stress concentrator factor,

$\boldsymbol{Y_{Fx} = 1}$

Y_{Fx} −Dimensional factor,

The other factors (Ψ_a, K_A, K_V) are the same as previously mentioned.

$$m_n \geq \frac{135904 \cdot (1+3,15) \cdot 1 \cdot 1,1 \cdot 1 \cdot 1,15 \cdot 2,25 \cdot 1}{0,5 \cdot 160^2 \cdot \left(\frac{250}{1,5}\right) \cdot 1 \cdot 1 \cdot 1} = 0,752\ mm. \quad (9)$$

The calculated value of the normal module will be compared to the ones mentioned in Figure 2.

If the value under 1 mm then m_n is selected 1 mm.

Thus $m_n = 1\ mm$.

As a principle for other modules, we'll adopt the next superior value but we can consider the inferior one if the calculated module is not bigger than 5%.

c) The inclination helix angle on the pitch cylinder β

It is recommended that the helix angle β to be inside the range 80º…200º. Specifically:

- β = 15º (or 12º) if the gears are made out of tempered steels with the HB hardness of the flank HB<350
- β =10º if the gears are made out of steels with surface hardness $HB\ flank \geq 350$.

We'll choose β =15º

d) Establishing the number of teeth from the driving gear

The maximum number of teeth is calculated taking into account the center distance and the normal module:

$$z_{1max} = \frac{2 \cdot a \cdot \cos\beta}{m_n \cdot (1+u)} = \frac{2 \cdot 160 \cdot \cos 15^0}{1 \cdot (1+3,15)} = 74,481. \quad (10)$$

The final number of teeth z1 is calculated considering:

- z_1 must be inferior to the z_{1max} calculated above;
- $z_1 \geq 14$. If this last condition is not met then the center distance is selected as the next standardized above the initial one and the normal module is calculated again and finally the new z_{1max}

If the calculated $z_1 \in [14; 17]$

We'll choose a positive profile displacement

- If out of calculation the number of teeth is big $z_{1max} = 24 \ldots 50$ (in our case is 80), then z_1 is selected as follows:

$$-z_1 = z_{max}\ if\ z_{1max} < 25$$
$$-z_1 = 24 \ldots 27\ if\ z_{1max} = 25 \ldots .35$$
$$-z_1 = 27 \ldots 30\ if\ z_{1max} = 35 \ldots .45$$
$$-z_1 = 30 \ldots 35\ if\ z_{1max} = 45 \ldots .80\ and\ more$$

We'll choose $\mathbf{Z_1 = 34}$.

e) The final selection of the normal module m_n and the number of teeth z_1 and z_2

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We'll recalculate the normal module m_n:

$$m_n = \frac{2 \cdot a \cdot \cos(\beta)}{z_1 \cdot (1+u)} = \frac{2 \cdot 160 \cdot \cos(15)^0}{34 \cdot (1+3{,}15)} = 2{,}191\ mm \quad (11)$$

The new module now is used as basis to select a new module as shown at Paragraph b) above.
We'll chose $\boldsymbol{m_n = 2{,}25\ mm}$

With this new value one may recalculate the number of teeth:

$$z_1 = \frac{2 \cdot a \cdot \cos(\beta)}{m_n \cdot (1+u)} = \frac{2 \cdot 160 \cdot \cos(15)^0}{2.25 \cdot (1+3{,}15)} = 34{,}265 \quad (12)$$

The new selected number of teeth is now $\boldsymbol{z_1 = 34}$ identical with the preliminary selected one (it may be different).

With z_1 final we may calculate the number of teeth for the driven gear:

$$z_2 = u \times z_1 = 3{,}15 \times 34 = 107{,}1\ . \quad (13)$$

We'll choose $\boldsymbol{z_2 = 107}$

f) The final actual transmission ratio

$$i_{ef} = \frac{z_2}{z_1} = \frac{107}{34} = 3{,}147\ . \quad (14)$$

Now, once the main parameters are calculated, we'll check how different the new actual transmission ratio is in report to the one given by the design specification. This difference is supposed to be less than 3%.

$$\Delta_1 = \frac{|i_{ef} - u|}{u} \cdot 100 = \frac{|3{,}147 - 3{,}15|}{3{,}15} \cdot 100 = 0{,}01\% < 3\%\ . \quad (15)$$

If the above condition is not met one change the teeth number calculated in Paragraphe).

g) The profile displacement calculation

The purpose of profile displacement is to increase the loading capacity of the teeth, avoiding undercut and increasing the engagement factor. The profile displacement is reducing the center distance so that it will be standardized.

Usually we use gears with extended center distance(x > 0) which is increasing the teeth dedendum width and the tooth become sturdier.

In order to calculate the profile displacement coefficient x the following stages will be:

❖ The reference center distance is calculated:

$$a_0 = \frac{m_n \cdot (z_1 + z_2)}{2 \cdot \cos(\beta)} = \frac{2.25 \cdot (34+107)}{2 \cdot cos(15)^0} = 164{,}221\ mm. \quad (16)$$

The reference center distance a_0 has to meet the requirements:

- $a_0 < a_{standard}$ Chosen in Paragraph1 and that's for having space for extended center distance 164,732>160 mm).
- The difference $a_{standard} - a_0$ to be inside the range $(0{,}4m_n \ldots 1{,}3m_n)$ for the positive profile displacement to have beneficial effects and the pointing of the addendum not to be exaggerated.

$$a_{standard} - a_0 = 160 - 164{,}732 = -4{,}732\ mm \quad (17)$$

$$0{,}4m_n = 0{,}4 \times 2{,}25 = 0{,}9\ mm \quad (18)$$
$$1{,}3m_n = 1{,}3 \times 2{,}25 = 2{,}95\ mm \quad (19)$$

If this requirement is not met (and it isn't) the number of teeth of the driven gear z2 is modified and/or the normal module chosen in Paragraph 3. Since in our case $a_{standart} - a_0$ has to be smaller then we'll take a_0 bigger and thus z2 has to be bigger. We'll take z2 =103.

All the calculations from Paragraph 6 and 7 has to be redone:

$$i_{ef} = \frac{z_2}{z_1} = \frac{103}{32} = 3{,}219 \quad (20)$$

$$\Delta_1 = \frac{|i_{ef} - u|}{u} \cdot 100 = \frac{|3{,}219 - 3{,}15|}{3{,}15} \cdot 100 = 2{,}19\% < 3\% \quad (21)$$

$$a_0 = \frac{m_n \cdot (z_1 + z_2)}{2 \cdot \cos(\beta)} = \frac{2{,}25 \cdot (34+104)}{2 \cdot cos(15)^0} = 157{,}23\ mm \quad (22)$$

$$a_{standard} - a_0 = 160 - 157{,}23 = 2{,}77\ mm \quad (23)$$

$$0{,}4m_n = 0{,}4 \times 2{,}25 = 0{,}9\ mm \quad (24)$$
$$1{,}3m_n = 1{,}3 \times 2{,}25 = 2{,}95\ mm \quad (25)$$

❖ We'll calculate now the frontal pitch pressure angle α_t:

$$\alpha_t = arctg\left(\frac{\mathrm{tg}(\alpha_n)}{\cos(\beta)}\right) = \mathrm{arctg}\left(\frac{\mathrm{tg}(20^0)}{\cos(15^0)}\right) = 20{,}64689^0 \quad (26)$$

Where α_n-is the normal pitch pressure angle
$\alpha_n = \alpha_0 = 20^0$($\alpha_0$ –is the standardized reference pressure angle)

❖ The pitch gearing normal angle α_{wt} *is*:

$$\alpha_{wt} = \arccos\left(\frac{a_{0 \cdot \cos(\alpha_t)}}{\alpha_{STAS}}\right) = \arccos\left(\frac{157.23 \cdot \cos(20{,}64689^0)}{160}\right) = 23{,}13959^0\ . \quad (27)$$

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❖ The profile displacement coefficient sum for both gears is:

$$inv(\alpha_{wt}) = \text{tg}(\alpha_{wt}) - \frac{\pi}{180}\cdot\alpha_{wt} = \text{tg}(23{,}13959^0) - \frac{\pi}{180}\cdot 23{,}13959^0 = 0{,}427 - 0{,}404 = 0{,}023 \quad (28)$$

$$[\![inv(\alpha]\!]_t) = \text{tg}[\![(\alpha]\!]_t) - \frac{\pi}{180}\cdot\alpha_t = \text{tg}(20{,}64689^0) - \frac{\pi}{180}\cdot 20{,}64689^0 = 0{,}3768 - 0{,}36035 = 0{,}0\,1644 \quad (29)$$

$$x_s = x_1 + x_2 = (z_1 + z_2)\cdot\frac{inv(\alpha_{wt}) - inv(\alpha_t)}{2\,\text{tg}(\alpha_n)} = (32 + 103)\cdot\frac{0{,}023 - 0{,}01644}{2\,\text{tg}(20)} = 1.217 \quad (30)$$

In order to distribute this sum on both gears we'll use the chart in figure 2. It is recommended that first to derive X_1 and then X_2.

From the chart we have

$X_1 = 0{,}4$ or $0{,}5$ depends on x_s so that $X_2 = 0{,}293$.

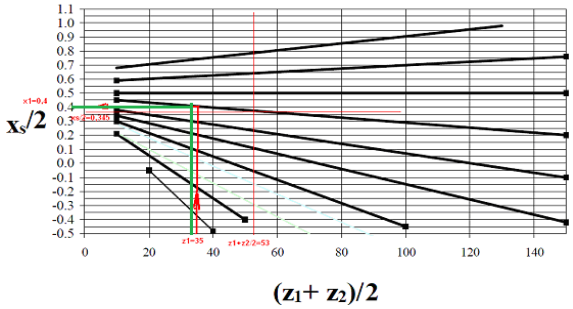

Figure 3 Profile displacement distribution

3. GEOMETRICAL ELEMENTS CALCULATION FOR GEARS

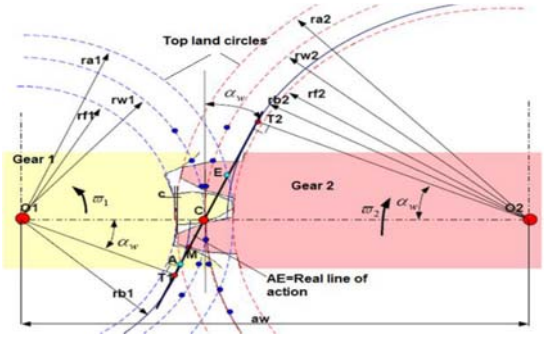

Figure 4 Geometrical elements for gears

We'll calculate the following elements:

❖ Normal pitch:

$$p_n = \pi\cdot m_n = 7{,}06\ mm. \quad (31)$$

❖ Frontal module:

$$m_t = \frac{m_n}{\cos(\beta)} = 2{,}329\ mm. \quad (32)$$

❖ Frontal pitch:

$$p_t = \pi\cdot m_t = 7{,}317\ mm \quad (33)$$

❖ Addendum:

$$h_{a1} = m_n\cdot(h_{0a}^* + x_1) = 2{,}25\cdot(1 + 0{,}4) = 3{,}15\ mm \quad (34)$$

$$h_{a2} = m_n\cdot(h_{0a}^* + x_2) = 2{,}25\cdot(1 + 0{,}293) = 2{,}959\ mm\,. \quad (35)$$

Where $h_{0a}^* = 1$

❖ Dedendum:

$$h_{f1} = m_n\cdot(h_{0f}^* + x_1) = 2{,}25\cdot(1{,}25 - 0{,}4) = 1{,}91\ mm\,. \quad (36)$$

$$h_{f2} = m_n\cdot(h_{0f}^* + x_2) = 2{,}25\cdot(1{,}25 - 0{,}293) = 2{,}125\ mm \quad (37)$$

Where $h_{0f}^* = 1{,}25$

❖ Whole depth:

$$h = m_n\cdot(h_{0f}^* + h_{0a}^*) = 2{,}25\cdot 2{,}25 = 5{,}06\ mm \quad (38)$$

❖ Pitch diameter:

$$d_1 = m_t z_1 = \frac{z_1 m_n}{\cos(\beta)} = 76{,}539\ mm \quad (39)$$

$$d_2 = m_t z_2 = \frac{z_2 m_n}{\cos(\beta)} = 237{,}596mm \quad (40)$$

❖ Top land diameter:

$$d_{a1} = d_1 + 2h_{a1} = 83{,}169\ mm \quad (41)$$

$$d_{a2} = d_2 + 2h_{a2} = 175{,}962\ mm \quad (42)$$

❖ Root diameter:

$$d_{f1} = d_1 - 2h_{f1} = 73{,}049\ mm \quad (42)$$

$$d_{f2} = d_2 - 2h_{f2} = 165{,}794\ mm \quad (43)$$

❖ Base circle diameter:

$$d_{b1} = d_1\cos(\alpha_t) = 71{,}932\ mm \quad (44)$$

$$d_{b2} = d_2\cos(\alpha_t) = 159{,}122\ mm \quad (45)$$

❖ Rolling diameter:

$$d_{w1} = d_1\frac{\cos(\alpha_t)}{\cos(\alpha_{wt})} = 76{,}869\cdot 1{,}0125 = 77{,}830mm \quad (46)$$

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$$d_{w2} = d_2 \frac{\cos(\alpha_t)}{\cos(\alpha_{wt})} = 172{,}170\ mm \quad (47)$$

- Gear width:

$$b_2 = a\Psi_a = 125 \cdot 0{,}5 = 62{,}5\ mm \quad (48)$$

The gear width for the driven gear is taken the calculated one but for pinion in order to compensate the mounting errors, is taken bigger with 2…5 mm. So that the pinion width will be $b_1 = 65mm$.

- The equivalent gear with pitch diameter:

$$d_{n1} = \frac{d_1}{cos^2(\beta)} = \frac{76{,}869}{cos^2(15)^0} = 82{,}388\ mm \quad (49)$$

$$d_{n2} = \frac{d_2}{cos^2(\beta)} = \frac{170{,}044}{cos^2(15)^0} = 182{,}253\ mm \quad (50)$$

- The equivalent gear teeth number:

$$z_{n1} = \frac{z_1}{cos^2(\beta)} = 35{,}37. \quad (51)$$

$$z_{n2} = \frac{z_2}{cos^2(\beta)} = 78{,}24. \quad (52)$$

With all the given dimension the **Solid Works 2016** Cad software is able to generate the gears.

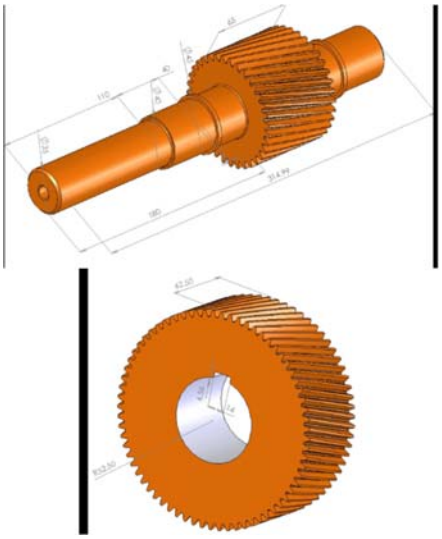

Figure 5 CAD generation of gears

4. FORCES CALCULATION IN GEARS

When two gear teeth in contact a normal force F_n will develop. This one will be decomposed in in three perpendicular components: the tangential force F_t, the radial force F_r and the axial component F_a. All these will act upon the pitch circle of the gears.

If we neglect the power losses due to the friction forces the force components may be calculated accounting on the moment to be transmitted by the pinion, and once calculated for the pinion, the driven gear will have identical but opposite forces as per the action-reaction principle.

The calculation equations are:

- Tangential components:

$$M_{tI} = \frac{955 \cdot 10^4 \cdot 18{,}5}{2464} = M_{tpinion} = 71702\ Nmm \quad (53)$$

$$F_{t1} = F_{t2} = \frac{M_{tpinion}}{d_1} = \frac{71702}{76{,}869} = 932{,}785\ N \quad (54)$$

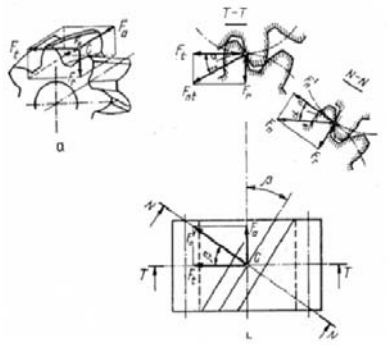

Figure 6 The force components

- The radial component:

$$F_{r1} = F_{r2} = F_{t1} \frac{\mathrm{tg}(\alpha_n)}{\cos(\beta)} = 351{,}48\ N \quad (55)$$

- The axial component:

$$F_{a1} = F_{a2} = F_{t1}\,\mathrm{tg}(\beta) = 249{,}94\ N \quad (56)$$

- The normal force:

$$F_n = \frac{F_{t1}}{\cos(\alpha_n)\cos(\beta)} = 1027{,}66\ N \quad (57)$$

We mention that the directions of the tangential and axial forces depend on the rotation direction of each gear, of the direction of the helical teeth, and the radial force always has the same direction pointing to the gear axis.

5. MATHCAD SOFTWARE APPLICATION FOR DESIGNING THE SCREW-NUT ASSEMBLY

The calculation program MATHCAD initial design data is entered. Enter formulas and standards chosen dates thereafter. The program calculates and generates results.

MATHCAD application program looks like this:

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Introduce your data in the yellow fields

Center distance a

u := 3,15

KA:= 1

KV := 1,21

KHβ := 1,18

PM := 30

nMI := 4095

nMII := 1000

$$MtI = 9550000 \cdot \frac{PM}{nMI}$$

MtI = 86288

$$MtI = 9550000 \cdot \frac{PM}{nMII}$$

MtII = 271808

ψa := 0,1

ZM := 271

ZH := 1,77

σHlim := 686

SH := 1,25

KHN := 1

ZR := 1

ZW := 1

Zε := 1

$$a\_preliminar := (1+u) \cdot \left[\left(\frac{KA \cdot KV \cdot KH\beta \cdot MtI}{2 \cdot u \cdot \psi a}\right) \cdot \left[\frac{ZM \cdot ZH \cdot Z\varepsilon}{\left(\frac{\sigma Hlim}{SH}\right) KHN \cdot ZR \cdot ZW}\right]^2\right]^{\frac{1}{3}}$$

a_preliminar = 147,311

a := 160

Normal module calculation mn

Kα := 1

KFβ := 1,15

YF := 2,25

Yβ := 1

σFlim := 250

SF := 1,5

KFN := 1

YS := 1

YFx := 1

$$mn\_preliminar := \frac{MtI \cdot (1+u) \cdot KA \cdot KV \cdot K\alpha \cdot KF\beta \cdot YF \cdot Y\beta}{\psi a \cdot a^2 \cdot \left(\frac{\sigma Flim}{SF}\right) \cdot KFN \cdot YS \cdot YFx}$$

mn_preliminar = 0,752

mn_provizoriu := 1

Teeth inclination angle

grade_β := 15

$$\beta := \frac{grade\_\beta \cdot \pi}{180}$$

β = 0,262

Teeth inclination angle

$$z1max := \frac{2 \cdot a \cdot cos\beta}{mn\_provizoriu \cdot (1+u)}$$

z1max = 74,481

z1_preliminar := 35

Final normal module

$$mn\_calculat := \frac{2 \cdot a \cdot cos\beta}{z1\_preliminar \cdot (1+u)}$$

mn_calculat = 2,191

mn := 2,25

$$z1\_recalculat := \frac{2 \cdot a \cdot cos\beta}{mn \cdot (1+u)}$$

z1_recalculat = 34,265

z1_nedeplasat := 35

$$z2\_calculat := u \cdot z1\_nedeplasat$$

z2_calculat = 107,1

z2_nedeplasat := 107

Actual transmission ratio

$$ief := \frac{z2\_nedeplasat}{z1\_nedeplasat}$$

ief = 3,147

$$\Delta i := \left(\frac{|ief - u|}{u}\right) \cdot 100$$

ief = 0,01

Profile displacement

$$a0\_initial := \frac{mn \cdot (z1\_nedeplasat + z2\_nedeplasat)}{2 \cdot cos\beta}$$

a0_initial = 164,321

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$\Delta a\_initial := a - a0\_initial$

Δa_initial = 3,873

$\Delta amin\_initial := 0{,}4 \cdot mn$

$\Delta amax\_initial := 1{,}3 \cdot mn$

z1 := 34

z2 := 107

$a0 := \frac{mn \cdot (z1 + z2)}{2 \cdot cos\beta}$

a0 = 157,23

$\Delta a := a - a0$

Δa = 2,77

grade_αn := 20

$\alpha n := \frac{grade\_\alpha n \cdot \pi}{180}$

β = 0,349

$\alpha t := atan\left(\frac{tan(\alpha n)}{cos\beta}\right)$

αt = 0,36

$grade\_\alpha t := \frac{\alpha t \cdot 180}{\pi}$

grade_αt := 20,647

$\alpha wt := acos\left(\frac{a0 \cdot cos(\alpha t)}{a}\right)$

αwt = 0,392

$grade\_\alpha wt := \frac{\alpha wt \cdot 180}{\pi}$

grade_αwt = 23,140

$inv\_\alpha wt := tan(\alpha wt) - \alpha wt$

inv_αwt = 0,023

$inv\_\alpha t := tan(\alpha t) - \alpha t$

inv_αt = 0,016

$xs := (z1 + z2) \cdot \frac{inv\_\alpha wt - inv\_\alpha t}{2 \cdot tan(\alpha n)}$

xs = 1,217

x1 := 0,682

x2 := 0,535

Geometrical elements

$pn := \pi \cdot mn$

pn = 7,069

$mt := \frac{mn}{cos\beta}$

mt = 7,317

$pt := \pi \cdot mt$

h0a := 1

$ha1 := mn \cdot (h0a + x1)$

ha1 = 3,15

$ha2 := mn \cdot (h0a + x2)$

ha2 = 2,959

h0f := 1,25

$hf1 := mn \cdot (h0f + x1)$

hf1 = 1,912

$hf2 := mn \cdot (h0f + x2)$

hf2 = 2,125

$h := mn \cdot (h0f + h0a)$

h = 5,063

$d1 := mt \cdot z1$

$d2 := mt \cdot z2$

d1 = 76,539

d2 = 237,569

$da1 := d1 + 2 \cdot ha1$

$da2 := d2 + 2 \cdot ha2$

da1 = 83,169

da2 = 175,962

$df1 := d1 - 2 \cdot hf1$

$df2 := d2 - 2 \cdot hf2$

df1 = 73,049

df2 = 165,794

$db1 := d1 \cdot cos(\alpha t)$

$db2 := d2 \cdot cos(\alpha t)$

db1 = 71,932

db2 = 159,122

$dw1 := d1 \cdot \left(\frac{cos(\alpha t)}{cos(\alpha wt)}\right)$

$dw2 := d2 \cdot \left(\frac{cos(\alpha t)}{cos(\alpha wt)}\right)$

dw1 = 77,830

dw2 = 172,170

$b2 := a \cdot \psi a1$

b2 = 62,5

b1 := 65

$dn1 := \frac{d1}{(cos\beta)^2}$

$dn2 := \frac{d2}{(cos\beta)^2}$

dn1 = 82,388

dn2 = 182,253

$zn1 := \frac{z1}{(cos\beta)^3}$

$zn2 := \frac{z2}{(cos\beta)^3}$

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zn1 = 35,37

zn2 = 78,24

Forces

$$Ft1 := \frac{Mt1}{d1}$$

Ft1 = 932

$$Ft2 := Ft1$$

Ft2 = 932

$$Fr1 := Ft1 \cdot \left(\frac{tan(\alpha n)}{cos\beta}\right)$$

$$Fr2 := Fr1$$

Fr1 = 351

$$Fa1 := Ft1 \cdot (tan\beta)$$

$$Fa2 := Fa1$$

Fa1 = 250

$$Fn := \frac{Ft1}{cos(\alpha n) \cdot cos\beta}$$

Fn = 1027

6. CONCLUSIONS

In contrast to spreadsheet programs where the equations are cryptically expressed and conversion between different systems systems is impossible, or programming languages accessible to programmers in particular, Mathcad is a much better way to design and manage engineering computers, these being easy to realize, understand, verify, communicate, and logically follow.

Mathcad offers a unique whiteboard intuitive design environment that allows engineers to work out, create documents, and quickly share engineering calculations, including product requirements, critical data, methods, equations and assumptions.

By introducing the Mathcad software in design of machine design is made interactive and easier data processing. In application created can be modified easily input data to obtain more rapid project results.

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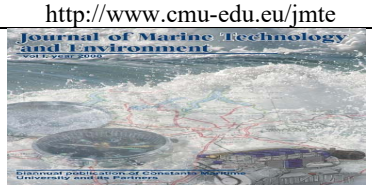

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CONCEPTUAL MODEL FOR EVALUATION OF SHORT SEA SHIPPING ENVIRONMENTAL PERFORMANCE

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Abstract: The present paper analyses the environmental performance of short sea shipping in terms of greenhouse gas emissions and its impact on the strategic development of shipping companies. The legal framework and policy issues at EU and international level are studied. A framework of parameters is developed for analysis of energy efficiency and CO_2 efficiency of short sea shipping. A conceptual model is proposed for evaluation of the environmental performance of short sea shipping based on a developed system of performance indicators. The proposed conceptual model serves as a basis for quantification of the environmental impact of shipping activities of the company and strategic decision-making as concerns investment in technologies, new-buildings and services restructuring for enhancement of environmental performance.

Key words: environmental performance, greenhouse gas emissions, performance indicators, maritime transportation, short sea shipping

1. INTRODUCTION

Maritime transportation is considered to have a high competitive advantage as concerns environmental issues. Traditionally, it has been receiving extensive governmental and international support for its development and efficiency increase. Being considered as an environmentally friendly transportation mode as concerns emissions of CO_2, the other types of emissions like SO_2, No_x and particles are measured as particularly high. The latter considerations apply at a higher extent to short sea shipping. EU policies and measures aiming at promotion of short sea shipping are to take into account the environmental impact of this type of organization of maritime transport. Although seagoing vessels are considered as being efficient in terms of bunker consumption per deadweight tonne this pattern cannot be applied to short sea shipping vessels, especially ro-ro type, feeder vessels and ro-pax vessels, therefore deeper analysis of short sea shipping environmental performance is needed.

The present article analyses the environmental performance of short sea shipping in terms of CO_2 emissions and its impact on the strategic development of shipping companies. The legal framework and policy issues at EU and international levels are studied. A conceptual model is proposed for evaluation of the environmental performance of short sea shipping based on an applied system of performance indicators. The proposed conceptual model serves as a basis for quantification of the environmental impact of the company's shipping activities and strategic decision-making as concerns investment in technologies, new-buildings and services restructuring.

2. SHORT SEA SHIPPING AND ENVIRONMENTAL ISSUES

European short sea shipping has had considerable attention during the last four decades, especially as concern the promotion of modal shift in moving cargoes from road transportation to sea transportation or to inland waterways. The main reason for such adopted policy measures and actions is based on the perception of short sea shipping as being efficient as concerns environmental impact (mainly energy use per tonne-km).

According to [1] maritime transportation is more energy efficient than road transport option (per tonne/km). The latter, however, is not entirely valid for unitized and containerized cargo carriage over short sea distances. The performance in terms of environmental impact of vessels typically engaged in short sea shipping (feeder container ships, general cargo vessels, ro-ro vessels and ro-pax vessels) differs substantially from the generally perceived environmental performance of maritime transportation.

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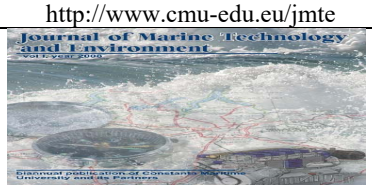

That is due mainly to the fact that these vessels are of smaller carrying capacity, operate at higher service speed and are generally involved in scheduled services (liner shipping, ro-ro shipments, ferry transportation) and have much lower lever of carrying capacity utilization. From operational point of view the underutilization of capacity is off-set by the better option of utilizing the back voyages whenever applicable thus leading to an acceptable average level of capacity utilization. There is also another issue to be considered as concerns container feeder transportation and ro-ro shipments - when calculating the average capacity utilization both the number of containers and/or vehicles and the weight of cargoes carried in containers/vehicles should be taken into consideration. The latter leads to the important assumption that the ratio between bunker fuel used for transportation and the capacity utilization is considerably lower than that for dry bulk vessels performing voyages on long hauls.

The international regulations concerning air emissions from ships were introduced in 2007 through Annex VI of the IMO Marpol convention and have been expanded at stricter level with the application of the Environmental Control Areas for SO_2 (SECAs) and/or NO_X (NOX-ECAs). The limitations in sulphur content of bunker fuels were set to 0.1% in SECAs as from 2015 and will be set to 0.5% as from 2020. As concerns the regulations for NO_X emissions these are introduced via the NO_X-code for ships' engines. As from 2016 in NO_X ECAs Tier 3 regulations apply representing a decrease of NO_X emissions of about 80% leading to slow-speed emissions of 3.4 g/kWh and no specific regulations for particle emissions are implemented for marine engines [5]. Figure 2 presents the CO_2 emissions from international shipping according to ship type.

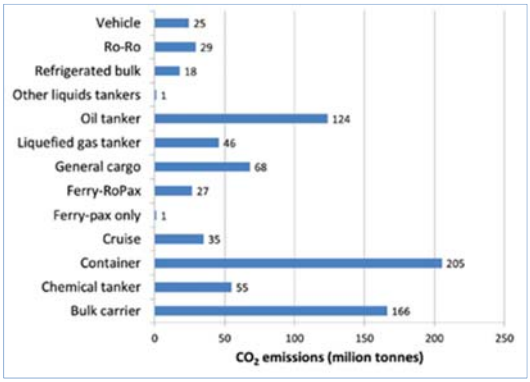

Figure 1 CO_2 emissions from international shipping according to ship types, 2012 [2]

3. CO_2 EMISSIONS AND ENERGY EFFICIENCY IN SHORT SEA SHIPPING

The transport efficiency of CO_2 emissions is metrified as CO_2/transportation work, i. e. the total mass of emission (in grammes) per tonne-kilometre. For the ship's operational period it is defined as follows:

$$CO_2 \text{ efficiency} = \frac{CO_2}{\text{tonne} * \text{km}}. \quad (1)$$

The above is based on the assumption that the mass of CO_2 emissions within the operational period for a ship are accounted for. Furthermore, the mass of CO_2 emissions is dependent on the load factor – the transportation work performed by the vessel and the capacity utilization. The same principle is valid for the definition of the Energy Efficiency Design Index (EEDI) and the Energy Efficiency Operational Indicator (EEOI).

The transportation work of a ship is calculated as the product of the specific cargo capacity of the vessel and the average capacity utilization degree. The latter is based on the number and duration of ballast legs, deliveries of cargoes to several ports against the obtainable average capacity utilization in laden legs. It should be noted that an average weight of containers (for container vessels) must be assumed as well as an average weight of vehicles per lane meter (for ro-ro vessels). According to [1] the loaded efficiency is the theoretical maximum efficiency when the ship is fully loaded at service speed at 85% load.

The efficiency ratios are based on assumed 50% capacity utilization irrespective of ship's type and age. The index is defined as per (2), whereas bunker consumption is given in g/h and vessel speed (V) in knots [1]:

$$\text{Efficiency index} = \frac{\text{Fuel consumption} * 3.09}{0.5 * \text{DWT} * \text{V}}. \quad (2)$$

There is a considerable potential for improvement of energy efficiency in short sea shipping. According to [1] CO_2 efficiency in shipping can be increased by 50% in average which would mainly be due to the increased energy efficiency.

Energy Efficiency Design Index (EEDI), developed by IMO, aims at designing and building of ships with optimal fuel efficiency and minimized emissions. EEDI constitutes a ratio between environmental performance costs and benefits for the environment. As from 2011, EEDI is an important element of the amended MARPOL Annex VI. It has been planned that EEDI will be valid for all new-building ships as from 2019. The established framework for maximum mass of greenhouse gas emissions (depending on type of the vessel, age, size, etc.) will undergo gradual reduction in order minimize the emissions. The Energy Efficiency Operational Index (EEOI) has been created for measuring efficiency of newly-built ships and ships in service in terms of operational efficiency. The index allows for realistic comparison of ships' performance of technically similar ships and serves as a valuable tool for application of operations efficiency measures.

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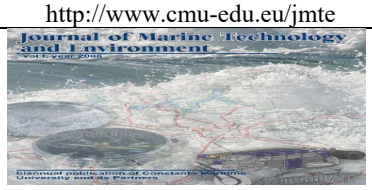

Another measure introduced by IMO is the Ship Energy Efficient Management Plan (SEEMP), to be mandatory as from 2019. The latter includes specific guidelines to owners as to the application of certain environmental measures for improved ship's efficiency (speed optimization, cargo handling optimization, applied weather routing, engine power optimization, etc.)

Table 1. Estimates of CO_2 efficiency for cargo ships [1]

Vessel type	Size	Average cargo capacity (tonne)	Average yearly capacity utilization	Average service speed (knots)	Transport work per ship (tonne-NM)	Loaded efficiency (g of CO_2/ tonne-km)	Total efficiency (g of CO_2/ tonne-km)
Bulk carrier	10,000–34,999 DWT	26,000	55%	14.3	1,268,561,872	5.3	7.9
Bulk carrier	0–9,999 DWT	2400	60%	11.0	68,226,787	22.9	29.2
General cargo	10,000 DWT	15,000	60%	15.4	866,510,887	7.6	11.9
General cargo	5,000–9,999 DWT	6,957	60%	13.4	365,344,150	10.1	15.8
General cargo	0–4,999 DWT	2,545	60%	11.7	76,945,792	10.9	13.9
General cargo	10,000 DWT	18,000	60%	15.4	961,054,062	8.6	11.0
General cargo	5,000–9,999 DWT	7,000	60%	13.4	243,599,799	13.8	17.5
General cargo	0–4,999 DWT	4,000	60%	11.7	120,938,043	15.5	19.8
Container	2,000–2,999 TEU	16,800	70%	20.9	1,480,205,694	18.3	20.0
Container	1,000–1,999 TEU	7,000	70%	19.0	578,339,367	29.4	32.1
Container	0–999 TEU	3,500	70%	17.0	179,809,363	33.3	36.3
Ro-Ro	2,000 lm	5,154	70%	19.4	368,202,021	45.3	49.5
Ro-Ro	0–1,999 lm	1,432	70%	13.2	57,201,146	55.2	60.3

According to the data in Table 1 ro-ro ships of capacity up to 1,999 lane meters have the highest efficiency in terms of CO_2/tonne-km, followed by container vessels with TEU capacity up to 999 TEU.

4. CONCEPTUAL MODEL FOR EVALUATION OF SHORT SEA SHIPPING ENVIRONMENTAL PERFORMANCE

Maritime transportation industry is highly energy extensive whereas the costs of fuel represents a large portion of total voyage costs – about 45% - 50% on the average. A typical operational measure includes reduction of service speed to enable savings on fuel consumption which involves extensive analysis of past data of fuel consumption and speed performance. In general, energy savings can be also achieved via decreasing of port stay (adjusting speed to ensure for timely arrival for direct berthing). Shipping companies develop specialised systems for enhanced operational performance – regular maintenance activities, evaluation of performance, etc. via various technical decisions. One of the major issues for continuous monitoring of ships' environmental performance is the absence of specific equipment on board. A significant factor for enhancing of vessel environmental performance is the development of special crew training to promote crew awareness and cooperation. The increase of energy efficiency of ships is a key point for companies' restructuring, in addition to applying measures for decrease of fuel costs. Presently, the energy efficiency issue is mainly induced by the policy measures of IMO other than by the developed company operational measures to reduce costs. According to the European Commission report, the operational measures should include solar energy, waste heat recovery, a speed reduction of 20% and Flettner rotors [3].

[4] have performed an in-depth study of several groups of operational measures. Table 2 presents a summary of these measures along with expected reduction of costs.

Table 2. Measures of operational efficiency [4]

Measures for operational efficiency	Gross potential for costs reduction
Slow steaming	10% - 20%
Optimization of voyage	0-10%
Reduced port stay time	0-10%
Ballast and trim optimization	< 5%
Employment of larger ships (economies of scale)	< 4%
Applied weather routing	0.1% - 4%
Energy awareness	N/A
Regular hull cleaning	1% - 10%

The form of ship's employment is also a significant factor as concerns control of vessel's energy efficiency. In general, time charterers are more perceptive than the voyage charterers of the concept of ships' energy

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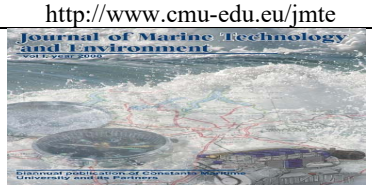

efficiency albeit both should develop better awareness of the performance quality. From a commercial point of view, cargo interests will be more informed about the service performance of the ship. Better ship performance will gain higher income for owners and better market position which is directly related to ship's energy efficiency. The composition of costs that are transferred to the cargo interests should be more balanced, i.e. the extent of the transfer of costs of fuel to the cargo owner should be reduced. [3] deduced that bunker costs are transferred to the cargo interests in 80% of all contracts on the average. Another issue is the company structure and the diversity of functions within the company which directly affect the leverage between maintenance costs and income. The latter can be improved via strategic decisions to outsource some of the activities despite the decreased control of those external activities.

At operational level companies need to develop procedures for control of emissions from ships, evaluation of vessel's energy efficiency and assessment of vessels' environmental performance. For development of strategies for CO_2 emissions reduction, the following actions are to be undertaken by the shipping companies:

- definition of scope, purpose and time frame for CO_2 emissions reduction strategy;
- assessment of the "as-is" status of CO_2 emissions of ships under operations;
- definition of achievable CO_2 emission reduction aim and the achievement deadline (reduction by a certain percentage within a certain time frame or reduction by a certain percentage per transportation work);
- development of business activity plan for measures to decrease the CO_2 emissions;
- control and monitoring of the measures application and reporting.

The present article introduces a conceptual model, describing the structure of the processes, the input parameters and output indicators for evaluation of vessel's performance. The following parameters are proposed to be included in the model:

- *average service speed and nominal speed*

This parameter presents the decrease of speed due to transiting of canals, manoeuvring, technical breakdowns and delays due to adverse weather. A reference percentage is adopted as a guideline value;

- *actual and planned voyage time*

As it is difficult to plan with certainty the duration of the voyage the analysis of this parameter is two-fold – portion of delayed voyages and duration of delays. For this reason, operators plan a time reserve as unforeseen delays and upon voyage completion same is compared with the planned values. Within the operational period the average duration of delays in voyages is further analysed in order to verify the factors causing such delays;

- *average duration of port stay*

This parameter can be defined either as total time per voyage or as a percentage of the total operational time. The lower the port stay time, the higher the efficiency of transportation;

- *consumed fuel (measured in monetary units per tonne-kilometre)*

Fuel efficiency depends on the service speed and vessel's capacity and varies according to the vessel age and type. As fuel efficiency affects the voyage costs and the total costs, this parameter is of significant importance. It should be noted that bunker consumption affects the greenhouse gases emissions. These data are also used for the calculation of energy efficiency and are the basis for evaluation of voyage and external costs;

- *CO_2 emissions (measured in grammes/tonne-kilometre)*

The specific mass of CO_2 emissions is different for every type of ship's engine but these can nevertheless be evaluated according to the technical specifications. The volume of greenhouse gases emissions is also directly related to the bunker quality (according to ISO standards) and the applied procedures and measures for decreasing of emissions. Therefore the direct costs involved for the decrease of the emissions are also included in the analysis, quantified and considered as part of the total costs (monetary units for grammes/tonne-kilometre). In addition to the emissions costs for the company, the external costs per tonne are to be identified as well.

- *capacity utilization (%)*

This parameter is obtained as a ratio between total carrying capacity and total number of units/quantity carried by the vessel during the operational period whereas average values are taken into account.

There are also direct costs against the transportation work carried out by the vessel (monetary units per tonne-kilometre). In view of the latter, the terms of the Protection and Indemnity cover for the operator have to be balanced against the actual past performance. However, keeping track of actual cargo losses/damages and arisen liabilities to third parties will enable evaluation of the overall losses in this respect which can also be measured as costs per tonne-kilometre. Thus the possibly incurred additional costs, for example deductibles, should be planned and added to the total costs of vessel's operations.

The above described parameters are dependent on the following variables: type of ship, size of ship, distance (in nautical miles), ship's engine type, type of fuel. The calculation of CO_2 emissions in mass during sea passages and at ports are performed basis relevant statistical analysis of past data as per vessel's engine type and type of fuel used. CO_2 efficiency of each ship is calculated as per (1).

Voyage costs are calculated basis costs for bunker consumed during the operational period, port costs and

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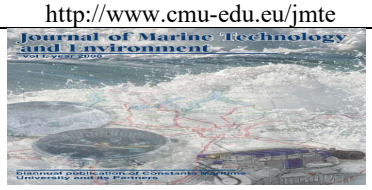


costs for canals transit. Running costs are calculated as per vessel's budget and are planned for the operational period only. As for external costs same include the cost of CO_2 emissions to the society and are quantified according to the current market price.

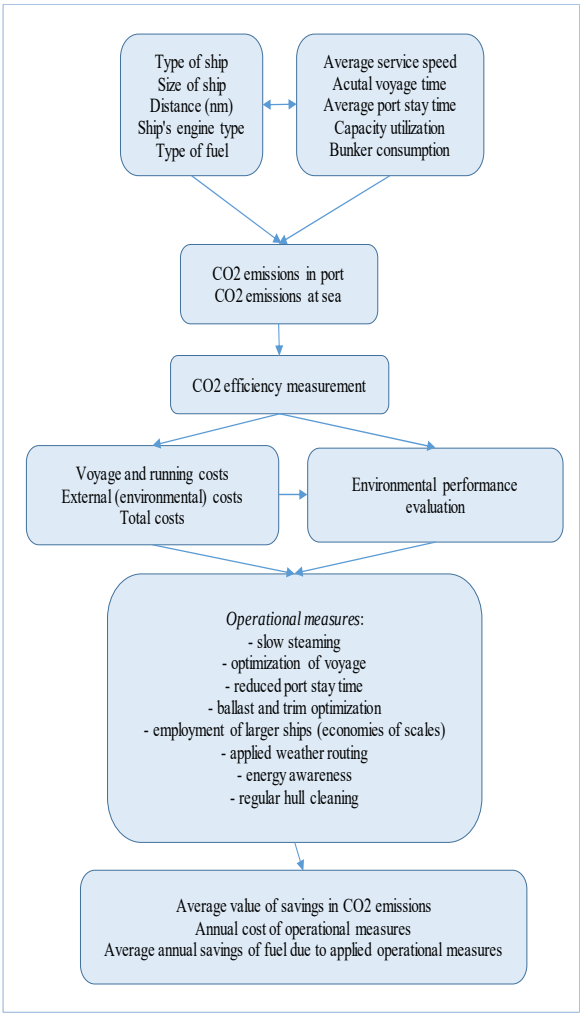


Figure 2 Conceptual model for environmental performance evaluation

Each specific operational measure to be applied by the company should have a preliminary assessment of its effect on costs. The operational measures typically applied include: slow steaming, optimization of voyage, reduced port stay time, ballast and trim optimization, employment of larger ships (economies of scales), applied weather routing, energy awareness, regular hull cleaning.

The assessment and control phase includes following evaluation approaches related to the output of the model:

- *average value of savings in CO_2 emissions* which can be presented as the product of average savings in CO_2 emissions and the current market price of CO_2;

- *average annual costs for the applied operational measures for reduction of CO_2 emissions* defined as the product of the average costs of such measures per voyage and the number of voyages within the operational period;

- *average savings per year for bunkering of the vessel per year* presented as the difference between the average annual current consumption costs per vessel and average annual fuel consumption costs with applied operational measures;

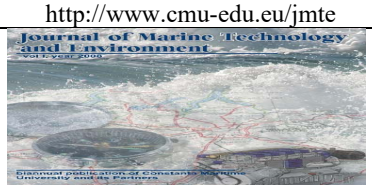
- *average energy efficiency of the ship for the operational period* presented as the product of the energy efficiency per voyage (defined as per (1)) and the number of voyages within the operational period.

The input parameters are based on statistical analysis of past data as concerns speed, voyage time, port stay time, capacity utilization and fuel consumption. By the application of the evaluation approaches for the measurement of CO_2 emissions (during sea passages and at ports) the CO_2 efficiency of the fleet can be measured and the external costs can be quantified. The costs of operational measures are direct costs and are included also in the total costs of vessel's operations. The results of the conceptual model application serve as a basis for strategic decisions as concerns fleet mix, investment in newly built ships and operational activities optimization.

5. CONCLUSIONS

Within a framework of international and European regulations for reduction of greenhouse gases emissions shipping companies seek new strategies to improve the environmental performance of ships. The latter is particularly valid for short sea shipping since same is energy intensive and requires special measures for environmental performance enhancement. The incentives for short sea shipping industry to reduce the CO_2 emissions are directly related to the energy efficiency of ships. Faced with difficult investment decision to invest in new ships which have higher energy efficiency, shipowners apply both specific operational measures to increase environmental performance and restructure their activities at a strategic level. The short-term improvement of environmental performance is achieved via application of new concepts for evaluation, monitoring and control of the environmental performance of ships. As the shipping market undergoes a downturn during the last decade such concepts are vital for the strategic development of the companies.

The present article has analysed the current issues of short sea shipping as concern its environmental performance. IMO policies and EU regulations have been analysed. It has been proved that CO_2 efficiency is directly related to energy efficiency of ships. The latter is dependent on the transportation work produced by the vessels.



A conceptual model has been developed based on parameters concerning vessels' type and size, service speed and fuel consumption. By integrating the external costs of short sea shipping environmental performance with the total costs, the model allows for quantification of the direct costs of application of operational measures for increase of environmental performance.

There are, however, certain barriers to the development and application of the policies and operational measures:

- lack of enough accuracy in estimating ships' energy efficiency due to external factors such as: adverse weather, quality of equipment, efficiency of internal system of monitoring, control and reporting. In view of the latter, statistical analysis of data is required to avoid errors in making assumptions and subsequent management decisions;
- lack of information for proving the effect of the expected bunker savings based on the application of particular operational measures;
- existing unpredictability of the potential fuel savings following the application of particular measures;
- uncertainty about the prices of fuel based on the forecast of world economic growth;
- shipping companies need to restructure its functional organization in terms of designating duties and responsibility to staff to perform environmental performance evaluation;
- the form of shipping contracts and the type of ships' employment influences directly the decisions which operational measure to apply. For example, under a time charter the charterers would not have a high incentive to slow-steam the ship due to the possible accrual of demurrage at ports for relet voyage. As discussed, a new scheme for distribution of bunker costs between charterers and cargo interests is to be applied;
- the costs of external services for ascertaining vessels' speed and fuel consumption. Such systems could provide data for the optimal speed against the planned arrival and berthing of the ships. The data can be further used in quantifying the potential saving in fuel and CO2 emissions. The process of data collection and metrification of savings should be in real time.

The proposed modelling approach for estimation of CO_2 efficiency allows for defining company's strategic goals for increasing the energy efficiency of the fleet. On the basis of the methodology proposed for the evaluation of ships' environmental performance, it would be feasible to develop more precise operational measures and policy guidelines. It is without doubt that the control and enhancement of environmental performance within a shipping company should be further extended to the entire shipping industry in an attempt to decrease also the external costs of emissions from shipping.

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