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The Susceptibility of FPSO Vessel to Green Water in Extreme Wave Environment

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ABSTRACT

The Floating Production, Storage and Offloading (FPSO) vessels in harsh environment are often vulnerable to green water. Green water is the unbroken waves which overtop the bow, side or stern part of the deck of the floating offshore structure. It occurs when the relative motion between the vessel and the wave exceeds the freeboard. Green-water occurrence could lead to deck flooding and damage to deck-mounted equipment. It is therefore necessary to consider the vulnerability of the floating vessel to green water in the design stage. The objective of this research is to determine the optimal principal dimensions of FPSO vessel necessary to prevent or mitigate the effects of green water even in extreme wave environmental conditions. In order to achieve this, the effects of extreme environmental loads on the vessel have been evaluated in terms of the maximum responses in heave and pitch modes of motion. Furthermore, an interactive programme, the ProGreen has been designed to optimise the principal particulars based on the response and freeboard exceedance analyses for the required storage capacity of the FPSO. This design technique helps to prevent or reduce the green water occurrence, ensures good performance during operation and increases the level of safety and operability of the vessel even in extreme wave conditions.

KEY WORDS: FPSO, principal dimensions, green water, responses.

NOMENCLATURE

ProGreen: Programme for Green Water Analysis
B Breadth, Wave spectral parameter
a_3 Water particle vertical acceleration
T_z zero up-crossing period
E_i Freeboard exceedance of each FPSO vessel
ρ Density of sea water
g Acceleration due to gravity
RAO_R Response amplitude operator of the relative motion
Mbbls Million barrels of oil
z_m Draught to Depth ratio

1.0 INTRODUCTION

Green water is the flow of the unbroken waves which overtop the bow, side or even stern part of the deck of a ship or floating offshore structure. It depends on the relative motion between the vessel and the waves, velocity, freeboard, and the harshness or flow intensity of the wave. It occurs when the relative motion exceeds the freeboard. The bow is most susceptible to green water occurrence especially for a turret-moored offshore unit due to its weathervaning characteristics, although it sometimes occurs at the stern [1]. This problem is a very important design issue because of its great potential to cause damage to deck-mounted equipment. It poses a tremendous threat to both crew and deck facilities such as accommodation, watertight doors, walk-way ladders and cable trays [2, 3]. Also, it may lead to deck flooding which is hazardous and constitutes a threat to the workforce and could result in downtime depending on its severity.

The FPSOs in the North Sea are highly vulnerable to green water. Between 1995 and 2000, about seventeen green water incidents on twelve FPSOs in UK waters of the North Sea have been reported [4, 5].

Problems associated with green water and wave slamming at the bottom of the bow which are directly related to the freeboard and flare have remained unresolved by most of the available software, although they have been quite helpful in design and analysis of ships and offshore floating structures. Most of the available software cannot account for the influence of freeboard and flare which are essential geometric characteristics responsible for deck wetness and water impact forces on deck equipment.

Because of the criticality of these phenomena, this study will analyse and discuss ways of addressing the challenges of the green water susceptibility of a Floating Production Storage and offloading Vessel and predict the required principal dimensions with respect to a given storage capacity for a specified wave environment. In other words, the objective of this research is to determine the optimal principal dimensions of FPSO vessel necessary to prevent or mitigate these undesirable effects of green water.

The influence of geometric changes upon the behaviour of a ship or a moored floating offshore vessel (such as FPSO or Floating Storage Unit, FSU) in sea wave is very imperative. The parameters may be categorized as follows:

(i) Displacement, Principal Dimensions (L, B, T, D), and the Block Coefficient.

(ii) The Coefficients which define the hull form details. These are the Waterplane Area Coefficient, the Longitudinal Centres of Buoyancy and Flotation (LCB and LCF). For simplicity, a rectangular form is considered in this paper.

2.0 THEORETICAL ANALYSIS

2.1 The Principal Dimensions of the FPSO

There are three major factors that greatly influence the size and arrangements of these different parts of the Floating Production, Storage and Offloading system and its process plants. These are: (i) Provision of sufficient oil storage capacity, (ii) Provision of enough topside area or space for process plants, accommodation, helideck and other required topside equipment and (iii) Provision of displacement and ballast capacity. These factors are directly related to (or functions of) cubic number, length-breadth (x_b) and breath-depth (y_d) ratios (as variables in the analyses) respectively. The cubic number is the overall volume of the vessel and it is directly proportional to the required storage capacity. With the knowledge of the oil storage efficiency, the cubic number and the preliminary evaluation of the principal dimensions can made. The overall volume or the cubic number C_n is given by:

$$C_n = \mathrm{LBD} = \frac{L^3}{{x_b}^2 \times y_d} = \frac{B^3}{[y_d/x_b]} = \frac{\mathrm{D}^3}{[x_b \times {y_d}^2]^{-1}} = \frac{\nabla}{(T/\mathrm{D})} = \left(\frac{S_c}{C_f \times E_s}\right) \quad (1)$$

From eqn. (1), it follows that:

$$\text{The Length, L} = aC_{nr} \quad (2)$$
$$\text{Breadth, B} = bC_{nr} \quad (3)$$
$$\text{Depth, D} = (\mathrm{ab})^{-1}C_{nr} \quad (4)$$
$$\text{Draught, T} = z_m\mathrm{D} \quad (5)$$

Where: The cubic number, C_n in m^3; and the cube root of the cubic number is given by: $C_{nr} = (C_n)^{1/3} = \left(\frac{S_c}{C_f \times E_s}\right)^{1/3}$

∇ is the displacement; and the new dimensionless factors are: $\mathrm{a} = [{x_b}^2 \times y_d]^{1/3}$; $b = [y_d/x_b]^{1/3}$; $z_m = \nabla/C_n$

S_c: Required oil storage capacity in barrel (bbl); E_s: Oil storage Efficiency; and Conversion factor, $C_f = 6.28981077; 6.28981077bbl = 1m^3$.

2.2 The Wave Environment

In offshore structural design, it is convenient to describe the wave environment in spectral form. The general form of the wave spectrum model is given by:

$$S(\omega) = A\omega^{-p}\exp(-B\omega^{-q}) \quad (6)$$

The parameters (A, B) of the Spectrum are solved in terms of the significant wave height and the wave period (which are in common use in wave description) for specified values of p and q (For Pierson-Moskowitz spectrum, p=5 and q=4). The n^{th} moment of the spectrum which is very useful in obtaining the wave characteristics is expressed as:

$$m_n = \int_0^\infty \omega^n S(\omega)d\omega = \frac{A}{q}\left[\frac{\Gamma[(p-n-1)/q]}{B^{[(p-n-1)/q]}}\right] \quad (7)$$

The zeroth moment (n=0, m_n=m_0) or the variance of the wave elevation is defined as the area under the Spectral curve. The mean wave frequency $\bar{\omega}$ is the ratio of the first moment to the zeroth moment. The zero-crossing frequency ω_z is the square root of the ratio of the second moment to the zeroth moment. The spectral peak frequency can be obtained by differentiating $S(\omega)$ with respect to the wave frequency,ω and equating the result to zero.

By substituting the expressions for A and B, the modified version of the wave spectrum is therefore obtained as:

$$S(\omega) = 124\frac{{H_s}^2}{{T_z}^4}\omega^{-5}\exp[-496.1(\omega T_z)^{-4}] \quad (8)$$

The rectangular-shaped floating production, storage and offloading vessel with length L, Beam B and draught T, (which are evaluated based on the required storage capacity as given in eqns. 1-5) is be operated in the North Sea of 100-year Return Period storm; the zero up-crossing period and significant wave height are 17.5s and 16.5m respectively.

The equation of motion of this vessel is given by:

$$(M_{jk} + A_{jk})\ddot{\eta}_k + d_{jk}\dot{\eta}_k + C_{jk}\eta_k = F_j \quad (9)$$

Where: M_{jk} are the elements of the generalized mass matrix for the structure; A_{jk} are the elements of the added mass matrix; d_{jk} are the elements of the linear damping matrix; C_{jk} are the elements of the stiffness matrix; $F_j$are the amplitudes of the wave exciting forces and moments, j and k indicate the directions of fluid forces and the modes of motions; η_k represents responses; $\dot{\eta}_k$ and $\ddot{\eta}_k$ are the velocity and acceleration terms; and ω is the angular frequency of encounter.

2.3 Heave Force and Response

Assuming the vessel has a constant mass density, zero forward speed and moored in deep sea, with a sinusoidal wave propagating along the negative x-axis (head sea),the velocity potential is:

$$\phi = g\frac{\zeta_a}{\omega}e^{kz}\cos(\omega t + kx) \quad (10)$$

The vessel is divided into strips of equal sizes and the force acting on each strip (dF_3) is the sum of the pressure force and the added mass force. These forces are integrated across the length of the vessel to obtain the heave excitation force.

$$dF_3 = pBdx + A_{33}^{(2D)}a_3dx = \left(-\rho\frac{\partial\phi}{\partial t}\right)Bdx + A_{33}^{(2D)}\left(\frac{\partial^2\phi}{\partial z\partial t}\right)dx$$
$$= \zeta_a\left(\rho gB - A_{33}^{(2D)}kg\right)e^{-kT}\sin(\omega t + kx)\,dx$$

$$F_3 = \zeta_a\left(\rho gB - A_{33}^{(2D)}kg\right)e^{-kT}\int_{-\frac{L}{2}}^{\frac{L}{2}}\sin(\omega t + kx)\,dx$$

$$= 2\zeta_a\left(\frac{\rho gB}{k} - A_{33}^{(2D)}g\right)e^{-kT}\sin\left(\frac{kL}{2}\right)\sin(\omega t)$$

Where $A_{33}^{(2D)}$ is the 2-D added mass in heave, while the amplitude of the heave force is given by:

$$F_{3a} = 2\zeta_a\left[\frac{\rho gB}{k} - A_{33}^{(2D)}\mathrm{g}\right](\mathrm{e}^{-\mathrm{kT}})sin\left(\frac{kL}{2}\right)$$

$$= \rho g\zeta_a\left[\left(\frac{\mathrm{B}\lambda}{\pi}\right) - c_v\pi\left(\frac{B}{2}\right)^2\right](\mathrm{e}^{-\mathrm{kT}})\sin\left(\frac{\mathrm{kL}}{2}\right) \quad (11)$$

Therefore, the Heave Response Amplitude Operator, RAO_3, defined as the heave amplitude per wave amplitude, is:

$$RAO_3 = \frac{F_{3a}Q_3}{C_{33}\zeta_a}$$

$$RAO_3 = \frac{\rho gQ_3}{C_{33}}\left[\left(\frac{\mathrm{B}\lambda}{\pi}\right) - c_v\pi\left(\frac{B}{2}\right)^2\right](\mathrm{e}^{-\mathrm{kT}})\sin\left(\frac{\mathrm{kL}}{2}\right) \quad (12)$$

Q_3: Dynamic magnification factor in heave; λ: wavelength; c_v: virtual added mass coefficient in heave; ζ_a: wave amplitude; and wave number, $k = 2\pi/\lambda$.

$$F_3 = \zeta_a\left(\rho gB - A_{33}^{(2D)}kg\right)e^{-kT}\int_{-\frac{L}{2}}^{\frac{L}{2}}\sin(\omega t + kx)\,dx$$

$$= 2\zeta_a\left(\frac{\rho gB}{k} - A_{33}^{(2D)}g\right)e^{-kT}\sin\left(\frac{kL}{2}\right)\sin(\omega t)$$

Where $A_{33}^{(2D)}$ is the 2-D added mass in heave, while the amplitude of the heave force is given by:

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$$= \rho g\zeta_a\left[\left(\frac{\mathrm{B}\lambda}{\pi}\right) - c_v\pi\left(\frac{B}{2}\right)^2\right](\mathrm{e}^{-\mathrm{kT}})\sin\left(\frac{\mathrm{kL}}{2}\right) \quad (11)$$

Therefore, the Heave Response Amplitude Operator, RAO_3, defined as the heave amplitude per wave amplitude, is:

$$RAO_3 = \frac{F_{3a}Q_3}{C_{33}\zeta_a} = \frac{\rho gQ_3}{C_{33}}\left[\left(\frac{\mathrm{B}\lambda}{\pi}\right) - c_v\pi\left(\frac{B}{2}\right)^2\right](\mathrm{e}^{-\mathrm{kT}})\sin\left(\frac{\mathrm{kL}}{2}\right) \quad \ldots\ (12)$$

Q_3: Dynamic magnification factor in heave; λ: wavelength; c_v: virtual added mass coefficient in heave; ζ_a: wave amplitude; and wave number, $k = 2\pi/\lambda$.

2.4Pitching Moment and Response

The amplitude of the pitching moment has also been obtained following similar procedure and it is given by:

$$F_{5a} = \rho g\zeta_a\left[\left(\frac{\mathrm{B}\lambda}{\pi}\right) - c_v\pi\left(\frac{B}{2}\right)^2\right](\mathrm{e}^{-\mathrm{kT}})\frac{1}{k}\left[\frac{kL}{2}\cos\left(\frac{kL}{2}\right) - sin\left(\frac{kL}{2}\right)\right] \quad \ldots\ (13)$$

So, the Pitch Response Amplitude Operator, RAO_5, defined as the pitch response amplitude per wave amplitude, is:

$$RAO_5 = \frac{F_{5a}Q_5}{C_{55}\zeta_a}$$

$$= \frac{\rho gQ_5}{C_{55}}\left[\left(\frac{\mathrm{B}\lambda}{\pi}\right) - c_v\pi\left(\frac{B}{2}\right)^2\right]\frac{1}{k}\left[\frac{kL}{2}\cos\left(\frac{kL}{2}\right) - sin\left(\frac{kL}{2}\right)\right] \quad (14)$$

$Q_5$is the dynamic magnification factor in pitch motion.

2.5 Relative Motion

The wave profile and heave motion at any point, x are respectively given by expressions:

$$\zeta_a\sin(\omega t + kx)\text{and}\eta_3 - x\eta_5$$

Therefore, the relative motion between wave and vesselat the bow is:

$$\eta_{3R} = \eta_3 - \frac{L}{2}\eta_5 - \zeta_a\sin\left(\omega t + \frac{kL}{2}\right)$$

$$= \eta_{3a}\sin(\omega t) - \frac{L\eta_{5a}}{2}\cos(\omega t) - \zeta_a\sin\left(\omega t + \frac{kL}{2}\right)$$

$$= \eta_{3a}\sin(\omega t) - \frac{L\eta_{5a}}{2}\cos(\omega t) - \zeta_a\left[\sin(\omega t)\cos\left(\frac{kL}{2}\right) + \cos(\omega t)\sin\left(\frac{kL}{2}\right)\right]$$

$$= \left[\eta_{3a} - \zeta_a cos\left(\frac{kL}{2}\right)\right]\sin(\omega t) - \left[\frac{L\eta_{5a}}{2} + \zeta_a\sin\left(\frac{kL}{2}\right)\right]\cos(\omega t)$$

So, the amplitude of the relative motion between the bow and the wave is:

$$\eta_{3Ra} = \left\{\left[\eta_{3a} - \zeta_a cos\left(\frac{kL}{2}\right)\right]^2 + \left[\frac{L\eta_{5a}}{2} + \zeta_a\sin\left(\frac{kL}{2}\right)\right]^2\right\}^{1/2}$$

$$\frac{\eta_{3Ra}}{\zeta_a} = \left\{\left[\frac{\eta_{3a}}{\zeta_a} - cos\left(\frac{kL}{2}\right)\right]^2 + \left[\frac{L\eta_{5a}}{2\zeta_a} + \sin\left(\frac{kL}{2}\right)\right]^2\right\}^{1/2}$$

$$RAO_R = \left\{\left[RAO_3 - cos\left(\frac{kL}{2}\right)\right]^2 + \left[\frac{LRAO_5}{2} + \sin\left(\frac{kL}{2}\right)\right]^2\right\}^{1/2} \quad \ldots\ (15)$$

These responses in regular waves are modified to account for the irregularities. Hence, for more realistic irregular waves, spectral analyses are adopted to obtain the most probable maximum responses. Let the most probable maximum amplitude of the relative motion be R. Consequently, the maximum allowable draftis required to be greater than thismaximum relative motion ($T > R$) in orderprevent the bow from exiting the water (bow slamming). Furthermore, a minimum freeboard, equivalent to R is needed to avoid green water on the deck.

The most probable maximum amplitude of the relative motion between the wave and the vessel at the bow is:

$$R = 3.72\sqrt{\int_0^\infty (RAO_R)^2 S(\omega)d\omega} \quad (16)$$

2.6 Freeboard Exceedance

The freeboard exceedance is the difference between the most probable relative motion and the freeboard. For each of the vessels being analysed (where i represents each of the vessels), it is given by:

$$E_i = R_i - (D_i - T_i) = R_i - (1 - z_m)(\mathrm{a}_i\mathrm{b}_i)^{-1}\left(\frac{S_c}{C_f \times E_s}\right)^{\frac{1}{3}} \quad (17)$$

These analyses are integrated in one computer program called the ProGreen. The ProGreen is a program which utilizes this method to effectively determine the susceptibility of various designs of FPSOs to green water. All the designs and analyses of the various FPSOs for a specified storage capacity are carried out and the freeboard exceedances are computed. The optimal design is then selected.

3.0 RESULTS AND DISCUSSIONS

To determine the optimal design point, it is necessary to examine the peak of the response amplitudes of motions, and the corresponding freeboard exceedances.

Figures- 1 and 2 show the response amplitude operators for the heave, pitch and relative motions. As the B/D and L/B ratios increase the peaks of the pitching and relative motions shift rightwards (on the graph of RAOs) approaching the critical period. A good example of critical period is the natural period of the vessel. The critical period is defined as the period at which the actual response is maximum (and it occurs when $\frac{L}{\lambda}$ tends to unity).

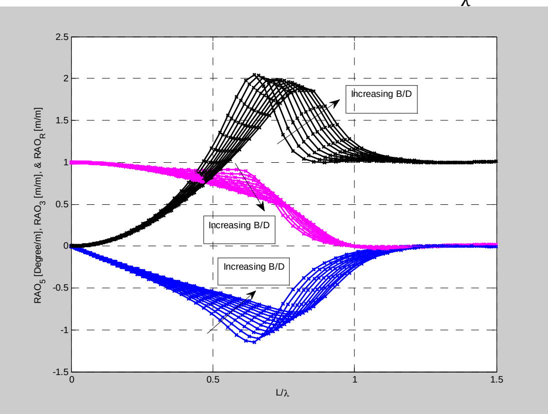

Figure 1: The Heave, Pitch, and Relative Motion Response Amplitude Operators for various B/D Ratios

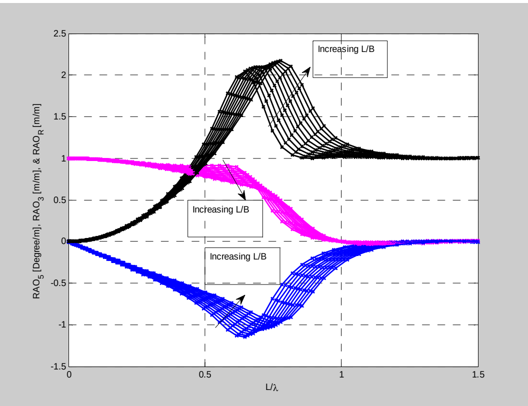

Figure 2: The Heave, Pitch, and Relative Motion Response Amplitude Operators for various L/B Ratios

As the B/D (and hence the "b" of eqn. 17) increases, the peak of the RAO_R decreases. Conversely, as L/B (and hence the "a" of eqn. 17) increases, the peak of the RAO_R also increases. In both cases, the freeboard exceedances increase (see Figs. 4 and 6).

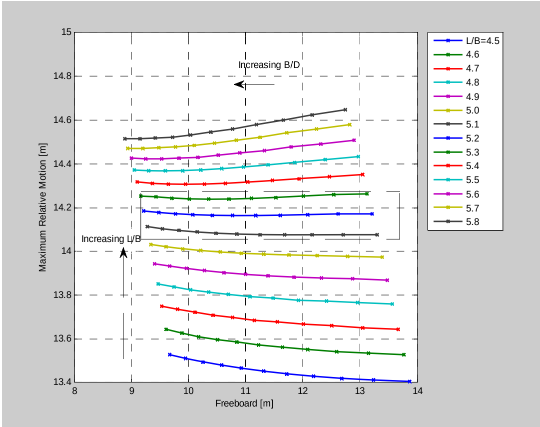

Figure 3: Effects of Freeboard on the Most Probable Maximum Relative Motion for given L/B

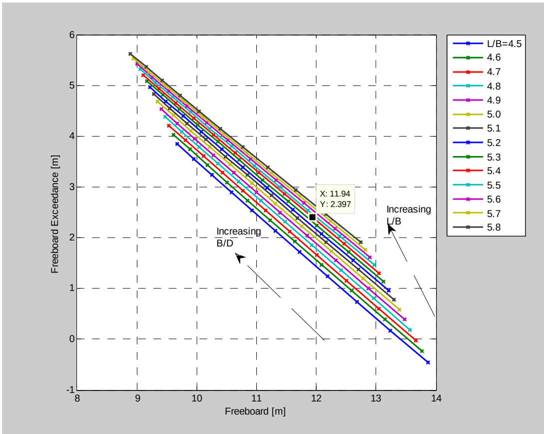

Figure 4: Effects of Freeboard on the Exceedance for given L/B

Figures 3 and 4 show the variations of the most probable maximum relative motion R, (between the bow and the wave) and the exceedance with freeboard for given L/B ratios (ranging from 4.5 to 5.8). For L/B ratios of 5.1, 5.2 and 5.3, R flattens out and nearly remains constant for all values of B/D.

The B/D has greater influence on the freeboard. The freeboard decreases more rapidly with increase in B/D (Figure 3), and slowly with increase in L/B (Figure 5).

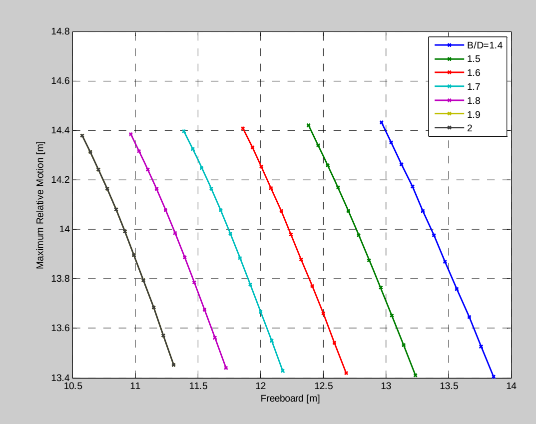

Figure 5: Effects of Freeboard on the Most Probable Maximum Relative Motion for given B/D

Generally, the exceedance is directly proportional to the pitch, heave and relative motions but inversely proportional to the freeboard. So, in order to avoid the vulnerability of the vessel to green water, the exceedance must be less or equal to zero.

$$L_a, B_a, D_a, T_a = L, B, D, T(E_i \leq 0) \quad (18)$$

Where the subscript, 'a' represents "avoidance of green water". The optimal design is obtained when the green water avoidance criterion is met with minimum heave and pitch motions.

$$L_o, B_o, D_o, T_o = L_a, B_a, D_a, T_a(\eta_{3max} \equiv \min(\eta_{3max})) \quad (19)$$

Where the subscript, 'o' represents "optimal design" of the ProGreen.

In this study, 154 vessels have been analysed as described above (using the ProGreen). The optimal design of FPSO of 2Mbbls of storage capacity for the North Sea has been determined as shown in tables 1 and 2. However, if a different design is preferably selected due to other factors, then the process deck should be raised to account for the estimated freeboard exceedance. In figure 4 for instance, the FPSO with L/B of 5.4, and B/D of 1.6 has a freeboard of 11.5m and exceedance of 2.4m. Therefore, the topside/process deck is required to be raised 2.4m above the main deck.

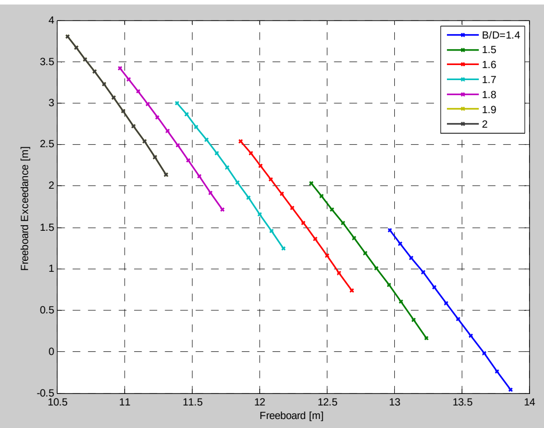

Figure 6: Effects of Freeboard on the Exceedance for given B/D

Table 1: Green Water Susceptibility of 2Mbbl North Sea FPSOs

S/No	L/B	B/D	L	B	D	Freeboard	Constraint	Exeedance
			[m]	[m]	[m]	D-T	D-T-R>0	E=R-(D-T)
1	4.5	1.4	249.5586	55.4575	39.6125	13.8644	0.4608	-0.4608
2	4.5	1.5	255.3643	56.7476	37.8318	13.2411	-0.1701	0.1701
3	4.5	1.6	260.9175	57.9817	36.2385	12.6835	-0.7364	0.7364
4	4.5	1.7	266.2438	59.1653	34.8031	12.1811	-1.2485	1.2485
5	4.5	1.8	271.3651	60.3034	33.5019	11.7257	-1.7147	1.7147
6	4.5	1.9	276.3001	61.4	32.3158	11.3105	-2.1417	2.1417
7	4.5	2	281.0648	62.4588	31.2294	10.9303	-2.5348	2.5348
8	4.5	2.1	285.6733	63.4829	30.23	10.5805	-2.8985	2.8985
9	4.5	2.2	290.1376	64.475	29.3068	10.2574	-3.2367	3.2367
10	4.5	2.3	294.4687	65.4375	28.4511	9.9579	-3.5522	3.5522
11	4.5	2.4	298.6759	66.3724	27.6552	9.6793	-3.8479	3.8479
12	4.6	1.4	253.2422	55.0526	39.3233	13.7632	0.2369	-0.2369
13	4.6	1.5	259.1336	56.3334	37.5556	13.1445	-0.3893	0.3893
14	4.6	1.6	264.7687	57.5584	35.974	12.5909	-0.9511	0.9511
15	4.6	1.7	270.1737	58.7334	34.5491	12.0922	-1.4589	1.4589
16	4.6	1.8	275.3706	59.8632	33.2573	11.6401	-1.9209	1.9209
17	4.6	1.9	280.3784	60.9518	32.0799	11.228	-2.3439	2.3439
18	4.6	2	285.2135	62.0029	31.0015	10.8505	-2.7333	2.7333
19	4.6	2.1	289.8899	63.0195	30.0093	10.5033	-3.0936	3.0936
20	4.6	2.2	294.4202	64.0044	29.0929	10.1825	-3.4284	3.4284
21	4.6	2.3	298.8152	64.9598	28.2434	9.8852	-3.7408	3.7408
22	4.6	2.4	303.0845	65.8879	27.4533	9.6087	-4.0335	4.0335
23	4.7	1.4	256.8992	54.6594	39.0424	13.6649	0.0199	-0.0199
24	4.7	1.5	262.8757	55.931	37.2873	13.0506	-0.6012	0.6012
25	4.7	1.6	268.5922	57.1473	35.717	12.501	-1.1582	1.1582
26	4.7	1.7	274.0752	58.3139	34.3023	12.0058	-1.6614	1.6614
27	4.7	1.8	279.3471	59.4356	33.0198	11.5569	-2.119	2.119
28	4.7	1.9	284.4273	60.5164	31.8508	11.1478	-2.5379	2.5379
29	4.7	2	289.3322	61.56	30.78	10.773	-2.9233	2.9233
30	4.7	2.1	294.0762	62.5694	29.7949	10.4282	-3.2799	3.2799
31	4.7	2.2	298.6718	63.5472	28.8851	10.1098	-3.6112	3.6112
32	4.7	2.3	303.1303	64.4958	28.0417	9.8146	-3.9204	3.9204
33	4.7	2.4	307.4613	65.4173	27.2572	9.54	-4.21	4.21
34	4.8	1.4	260.5303	54.2772	38.7694	13.5693	-0.1901	0.1901
35	4.8	1.5	266.5913	55.5399	37.0266	12.9593	-0.8059	0.8059
36	4.8	1.6	272.3886	56.7476	35.4673	12.4135	-1.3577	1.3577
37	4.8	1.7	277.9491	57.9061	34.0624	11.9218	-1.856	1.856
38	4.8	1.8	283.2956	59.0199	32.7888	11.4761	-2.309	2.309
39	4.8	1.9	288.4475	60.0932	31.628	11.0698	-2.7235	2.7235
40	4.8	2	293.4217	61.1295	30.5648	10.6977	-3.1048	3.1048
41	4.8	2.1	298.2328	62.1318	29.5866	10.3553	-3.4575	3.4575
42	4.8	2.2	302.8934	63.1028	28.6831	10.0391	-3.7852	3.7852
43	4.8	2.3	307.4149	64.0448	27.8456	9.7459	-4.091	4.091
44	4.8	2.4	311.8071	64.9598	27.0666	9.4733	-4.3775	4.3775
102	5.4	1.6	294.6393	54.5628	34.1018	11.9356	-2.3965	2.3965
154	5.8	2.4	353.7343	60.9887	25.4119	8.8942	-5.62	5.62

Table 2: Optimal Design for North Sea FPSO using ProGreen

L_o [m]	B_o [m]	D_o [m]	T_o [m]
256.8992	54.6594	39.0424	25.3776

4.0 CONCLUSIONS

(i) The most probable maximum relative motion is greatly influenced by selected L/B ratio while the freeboard is highly influenced by the B/D ratio.
(ii) The freeboard exceedance increases with both L/B and B/D ratios.

(iii) The optimal design is favoured by larger depths (or lower L/B and B/D ratios) which ensure that there are both sufficient freeboard and disparity from the critical wavelength.
(iv) Theoptimal design of FPSO for oil field development in extreme wave environment such as the North Sea is necessary to avoid green water on deck and its adverse effects.
(v) The optimal dimensions for 2Mbbls of oil storage capacity FPSO are: Length is 3.139 of C_{nr} (or 256.9m); Beam of 66.8% of C_{nr} (or 54.7m); and Depth of not less than 47.7% of C_{nr} (or 25.4m). That is, L/B and B/D ratios of 4.7 and 1.4 respectively.

ACKNOWLEDGEMENTS

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Integration System of Automatic Identification System (AIS) and Radar for Port Traffic Management

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ABSTARCT

In Vessel Traffic System (VTS), AIS can detect a larger number of targets without considering the shadow effect and can provide more voyage information for port center. For radar system can detect target actively even buoys or rock no matter ship size or fitted equipment. But even radar can detect all targets, it is cannot give full information as AIS. AIS can give full information such as types of ship, size, name, MMSI number and etc. AIS and radar system is very important in the VTS to control ship in and out at the port area. They have to use two different computers, which is one computer for AIS and another computer is for radar systems.By integrating AIS and radar, the officer can control port with more accurate and systematic. This paper will focus on integration of AIS and Radar for managing the movement of vessels in port for safety purpose by taking Port Tanjung Pelepas (PTP) as a case study.

KEYWORD: *Automatic Identification System (AIS); Radar; Integration.*

NOMENCLATURE

AIS	Automatic Identification System
PTP	Port TanjungPelepas
VTS	Vessel Traffic System
IMO	International Maritime Organization

1.0 INTRODUCTION

In vessel traffic management (VTS), they are using AIS or known as an Automatic Identification System and radar systems to control ship in and out at the port area. The function of AIS is used to identify and locating the vessel by electronic exchange data either with nearby ships or VTS stations. Besides that, AIS also can detect a larger number of targets without considering the shadow effect and can provide more voyage information for Port traffic Management.

Even though AIS can give full information to VTS, but still the AIS cannot replace radar system. The radar is for vessel which is not fitted AIS in their vessel. The benefit of a radar system is can detect targets actively even buoys or rock no matter ship size or fitted to any equipment (Bin Lin, Chih Hao Huang, 2006). Even though the radar system can detect all targets, but radar system cannot give full information such as size of ship, name, MMSI and IMO number.

Therefore, the port traffic management required to use both of this system to prevent the ship from collision, including a ship colliding with a fishing boat. This is because fishing boats also are using a port area that obstructs ship moving and increases navigation risk. From AIS information, these kinds of situation cannot be found so that the port traffic management officer cannot sound collision warning to the related ships.

In effect of that, it is difficult for port traffic officers to look out AIS and radar system in two different computers at the same time. It is can be attributed to human error on navigational faults due to incorrect judgment of ship movement by the port officer (Bin Lin, Chih Hao Huang, 2006). By integrating of AIS and radar system, it is much easier for port officers to look out and control the situation in the port area.

The port area for this project is focused on Port Tanjung Pelepas (PTP), which is located in the Strait of Malacca and the most important channel in the world that connecting the Indian Ocean with South China Sea and the Pacific Ocean. In PTP, they are still using Automatic Identification System (AIS) and radar system with separate computer. Therefore, this study focuses on the combination of AIS and radar system for safety and improvement of vessel movement in and out of the port marine transportation system. In this project also was proposed the system and tested at PTP as a study case.

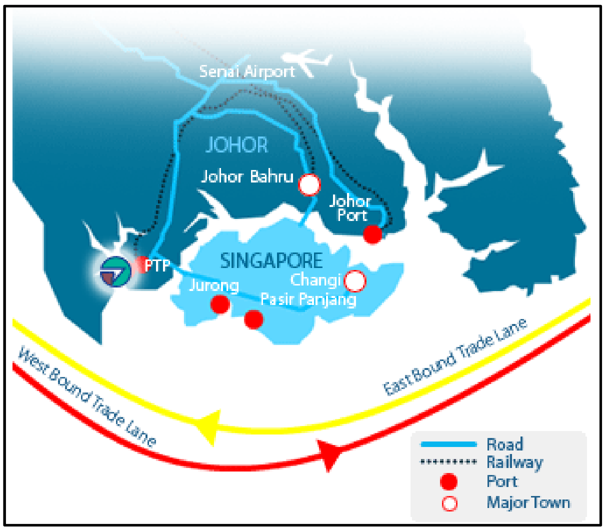

Figure 1: Port Tanjung Pelepas (PelabuhanTanjung Pelepas, 2009).

2.0 AUTOMATIC IDENTIFICATION SYSTEM (AIS)

In this research, data was extracted from the AIS station of International research on safety and environment (SERC). They have seven locations of AIS as showed in figure 2 which is as follows:

1. Station A (P23, UTM),
2. Station B (Belakang Padang),
3. Station C (Batu Ampar),
4. Station D (Politek Batam),
5. Station E (Karimun),
6. Station F (Bintan) and
7. Station G (Bengkalis) (ISOMAse, 2014).

For this paper, the AIS was focused at station A, P23, Faculty Mechanical, UTM, Universiti Teknologi Malaysia.

The AIS system consist of an antenna, AIS receiver CYPHO-150, TP-Link and Personal Computer (PC) computer as shown in Figure 4.

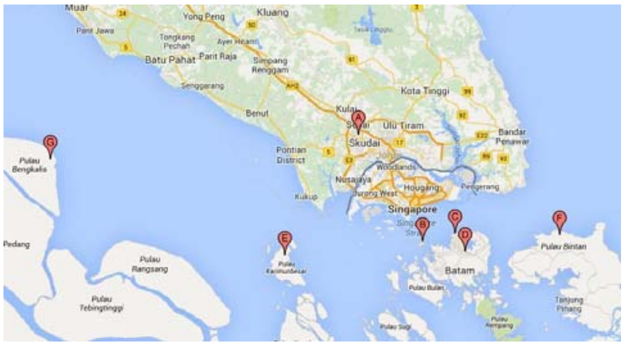

Figure 2: Location of AIS receiver (ISOMAse, 2014).

Figure 3: AIS antenna installed in P23, Faculty Mechanical, UTM, Universiti Teknologi Malaysia.

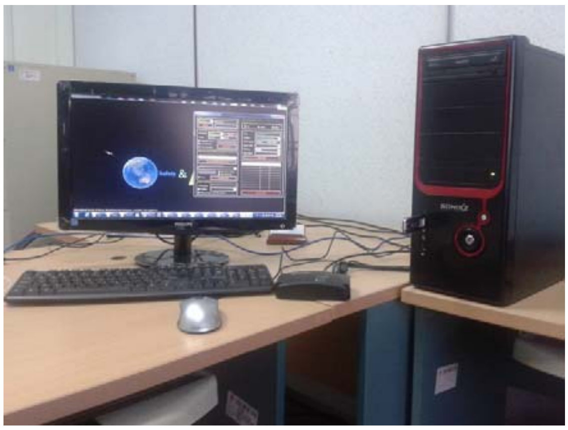

Figure 4: AIS System in P23, Faculty Mechanical, UTM, Universiti Teknologi Malaysia.

This AIS Marine Safety and Environment simulation developed using Microsoft Visual Basic 2010 as showed in figure

5.The primary data of ships which is obtained from AIS receiver was consists of date, time, MMSI number, IMO number and position of the ship (longitude and latitude). The data collected from AIS receiver is simultaneously stored and update in a hard disk on the PC. Ships details such as names of ships, types of vessel, and other data was extracted from free ship database such as Marine Traffic and Vessel Tracker. The raw data was recorded in every one minute which depends on setting up.

Firstly in this safety and environment system is choosing the location of AIS. For this paper the AIS was focusing on station A. Then, the file is uploaded from AIS to the server and required to select port serial and periodwith connect to server. The period is the data was save depend on setting up either one minutes, five minutes, ten minutes or one hours. In control panel, it is required to select the location and types of map. It has several types of mapping such as roadmap, satellite, terrain and hybrid. For this paper, the location is used Strait of Batam-Singapore because of the location of PTP near with this strait and mapping is using satellite map.

Figure 5: The AIS Marine Safety and Environment Simulation.

This system can be used for navigation tracking and collision prevention using GPS and AIS. The marine navigation tracking system will show the position of a ship on the map which is linked to a Google map and denoted with yellow color as show in figure 6. The full detail of ship can be identified in the ship database.

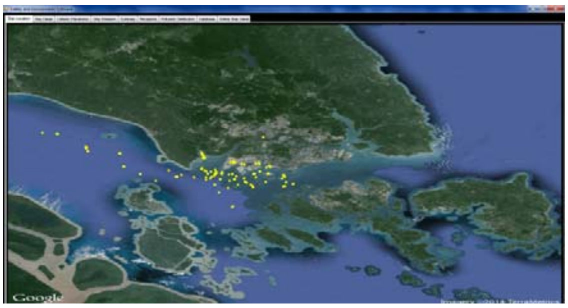

Figure 6: AIS data linked to a satellite map.

3.0 RADAR

RADAR stands for Radio Detecting and Ranging, which is using a radio wave to detect an object. It can be used in air, water and land. Radar is very important in marine for navigation.Radar system also is used in port management. It is to detect all moving or stationary targets in the area of the port. In the port area, any target should be acquired and maintain tracking in at least 5 out of every 10 scans average over a period of 2 minutes (Bin Lin, ChihHao Huang, 2006).

Radar for this project is located at PTP. The radar data was getting from the PTP marine operation. In this radar system they are using Linux system which is one of the operating system. This radar system also same like AIS system, it is can detect and scan target in that area but just showed in symbol. By using this symbol, the longitude and latitude is showed. In this project, the data are given from PTP in the raw data and only consist oflongitude and latitude. Figure 7 shows the radar system which is located at PTP.

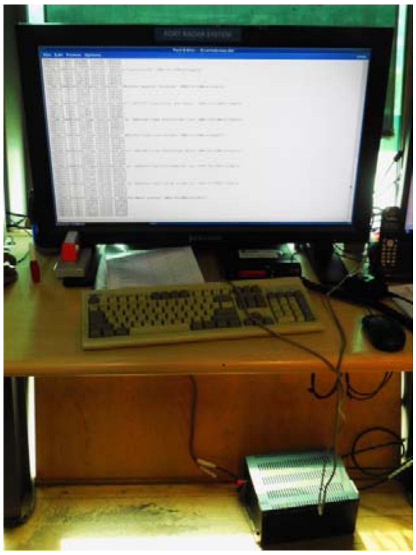

Figure 7: Port Radar System.

In figure 8 showed radar data in the Marine Safety and Environment system. The denoted with red color represent the target at the Strait of Batam-Singapore.

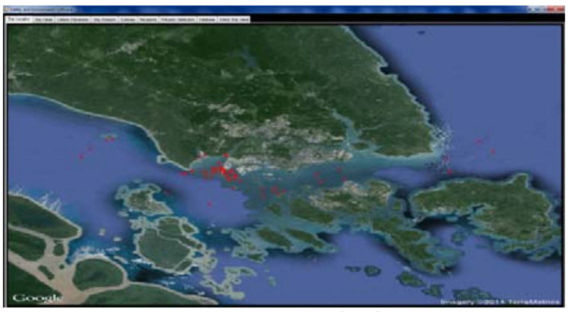

Figure 8: Radar data

4.0 INTEGRATION OF AIS AND RADAR

This integrated system was used to integrate AIS and radar system by using AIS Marine Safety and Environment simulation developed using Microsoft Visual Basic 2010. The study framework is started from collecting of AIS raw data such as name of ship, types, MMSI number, position of the ship, received date and received time and speed of ground. This AIS data is simultaneously updated and stored in the hard disk on the Personal Computer (PC). Besides that, the data need always updated in the data based. These ship data bases were extracted from free ship data based such as Marine Traffic and Vessel tracker.

After collecting AIS data, next step is collecting radar data. This radar data were collected at PTP in the raw data which is consists of longitude and latitude. After collecting AIS and radar data is integrating this AIS and radar data in the system. Figure 9 show the flow of integration AIS and radar system.

Figure 10 show an example data of integration system. Based on this result, the ship that have AIS and target detected from radar can see clearly. The denoted with yellow color represent the AIS data and red color represent the radar data.

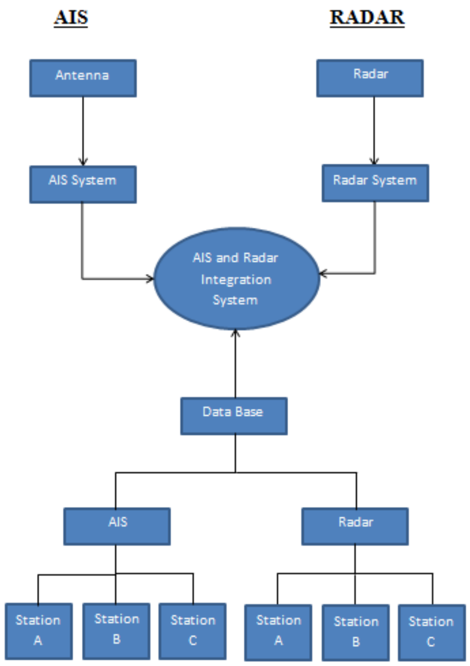

Figure 9: The integration AIS and Radar system

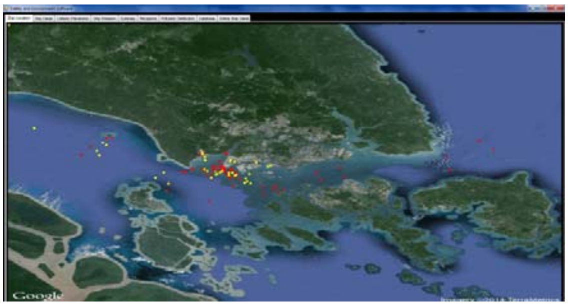

Figure 10: The integration of AIS and radar data.

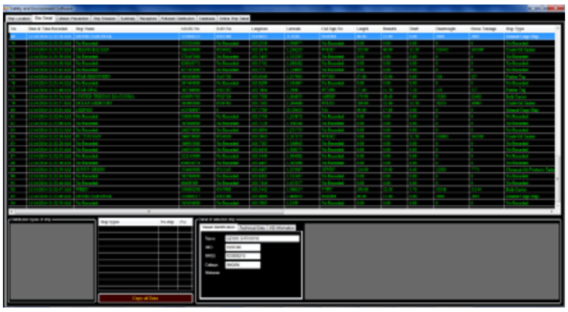

Figure 12: AIS data

In this integrated system, the vessel detected from AIS can know the detail in ship details. It will show the name of the ship, MMSI number, IMO number, length, beam, draft and flag as shown in figure 12. Radar target only appearson the map and did not have any detail information. So, VTS officer can see clearly the position of the vessel or any target in this integrated system.

5.0 CONCLUSION

The AIS and radar is very important in the port traffic management. It is because both of this AIS and radar can give accurate position detected target ships. By integrating AIS and radar, it can reduce the ship collision and prevent from the human error on navigational faults. It is because one of the major purposes of VTS is to prevent from collision occurring at the port area.

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Potential Threat to Ship and Port Security-Case Study

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ABSTRACT

Potential threats range from piracy and terrorism to theft, stowaways, rescues at sea and fraud. They can occur in port, at anchorage or on the high seas. They may involve violence, crime, disease or politically-charged incidents. This has been a major issue in global maritime security. The international ship and port security code (ISPS code) have been developed after the 9/11 Attacks which makes standardized frame work to assess risk and also develops set of rules to enhance maritime security. In this paper a few incidents which had constantly raised alarms to maritime security has been discussed. There are so many incidents which had occurred in the past all over the world. The case study helps us to analyze what are the reasons for such a threat and also how we can improve our security measures to avoid or minimize such incidents in future.

KEY WORDS: *Piracy at sea, Hijacking, Robbery at sea, Terrorism*

NOMENCLATURE

ISPS	*International Ship and Port Facility Security Code*
SOM	Straits of Malacca
MSPA	Maritime Security Patrol Area
GPS	Global Position System
AIS	Automatic Identification System

1.0 INTRODUCTION

The International Ship and Port Facility Security Code (ISPS Code) is a comprehensive set of measures to enhance the security of ships and port facilities developed in response to the perceived threats to ships and port facilities in the wake of the 9/11 attacks in the United States. The purpose of the Code is to provide a standardized, consistent framework for evaluating risk, enabling Governments to offset changes in threat with changes in vulnerability for ships and port facilities through determination of appropriate security levels and corresponding security measures. In essence, the Code takes the approach that ensuring the security of ships and port facilities is a risk management activity and to determine what security measures are appropriate, an assessment of the risks must be made in each particular case [1].

Piracy at sea is a worldwide phenomenon which has affected not only the coasts of Africa, but also Indonesia, Malaysia, the Philippines, Yemen and Venezuela. It involves boarding of unauthorized people coming in small high speed boats. There are various threats a ship can have when at sea like hijackings, robbery, kidnap etc. The pirates who come onboard are armed with knives and other automatic weapons, mortars, and rocket-propelled grenades. They are also often equipped with cell phones and other tech gadgets to keep in contact with organizers who feed them information about ships and their locations. The pirates demand huge ransom of money from the company or national government to release the ships.

2.0 SEVERAL CASE STUDIES

2.1 Case Study-1 Mumbai attacks (26/11/08), India.

This incident was one of the most tragic terrorist attacks which occurred on 26th November, 2008 in a city called Mumbai which is also a commercial and port capital of India. There were a series of 13 bomb blast in tourist and busy public areas which includes explosion in 'Hotel Taj' which is one of the best five star hotels in the region and it also hosts many local as well as international delegates. There was also an explosion in Mumbai port area. This raises security concern in both national and marine security.

According to the investigation made it was found that 10 men in inflatable speed boats came ashore in two different locations near colaba. The investigators also found that attackers travelled by sea from Karachi, Pakistan across the Arabian Sea, hijacked the Indian fishing trawler, killed the crew of four, and then forced the captain to sail to Mumbai. After murdering the captain, the attackers entered Mumbai on a rubber dinghy [2]. This case clearly shows that a threat comes without warning. It has raised security concerns in all the coastal regions. These incidents can only happen if proper security measures are not followed. According to the ISPS code there are three security levels. Security level1 which is normal security, Security level 2 which is heightened security and Security level 3 which has a high risk. After this incident special measures are used to enhance port security. CC TV cameras and other surveillance devices are fitted in and around the port area. The Indian coast guard patrol vessels are provided at all times.

(a.)

2.1 Font Format

(b.)

Figure 1: [a] shows the building before attack; [b] shows the building after attacks.

2.2 Case Study-2 MAERSK Alabama hijacking, (8-12 April, 2009)

Piracy is a biggest threat to ship and port security. It is very popular in the coast of Somalia and various other locations. This incident occurred around coast of Somalia. The Maersk Alabama hijacking was a series of events involving piracy that began with four Somali pirates seizing the cargo ship MV Maersk Alabama 240 nautical miles southeast of the Somali port city of EYL [3].It was the sixth vessel in a week to be attacked by pirates who had previously extorted ransoms in the tens of millions of dollars. The crews of the ship were trained for anti-piracy and they performed regular drills so they knew to deal with such situation. This event ended after a rescue effort by the U.S. Navy on 12 April 2009.It was the first successful pirate seizure of a ship. This case shows that if the crew has proper training and follow ship security plan as mentioned by ISPS then we can minimize the risk of such incidents though the pirates managed to board the vessel.

Figure 2- Pirates attacking the ship

2.3 Case study-3 Robbery at sea, Malaysia (9,June 2013)

The Straits of Malacca (SOM), situated between Indonesia and Malaysia, is considered to be the world's most dangerous waters for pirate attacks. Six pirates armed with guns and long knives, in a speed boat, approached and boarded the underway tug approximately 30nm east of Kerteh, Terengganu. They took hostage all crew members, cut off the cables to the VHF communication system and stole crew and ship cash and property.

Another event took on the same day to Singapore-flagged tug which was boarded approximately 6 nm off Terengganu while underway from Thailand to Indonesia; six robbers armed with guns and choppers, boarded the tug boat and forced the crew to pump-out fuel oil from the tug boat to an unknown fishing boat. The robbers also took the crew's belongings before leaving the tug boat [4].

Figure 3- Pirates attacking crew and forcefully asking ship cash and property.

2.4 Case study-4 Tanker Hijackings Raise Piracy Concerns in Seas around Singapore, November, 2013.

There has been this new trend of hijacking tankers, taking away their cargo and selling in the black market which has been reported near Singapore. Two tanker hijackings in about a month in the South China Sea and Malacca Strait, a route for about a quarter of sea borne oil trade, This shows that piracy of these tankers is rising and potentially driving up ship insurance premiums. On November 7, 2013 pirates hijacked a tanker carrying marine gasoil in the strait near Pulau Kukup, Malaysia, and stole its cargo before the ship and crew were released. It was the second hijacking in waters around Singapore this year after an attack on a Thai-registered tanker laden with gasoil near Pulau Aur, Malaysia, in the South China Sea on Oct. 10. The ship was released after its cargo was transferred to another tanker.

The attacks follow three similar ship hijackings and gasoil thefts in 2011 and 2012. In these kind of hijacking it has been observed that pirate groups work in a team over different areas involving the seizure of tug boats and barges for resale on the black market and the seizure of tankers so that their cargo, often marine gasoil, can be transferred and sold on the black market, The tanker hijacked was the 3,254 deadweight tonne (dwt) which was operated by Singapore firm Global Unique Petroleum, according to anti-piracy sources and ship tracking data. One ship broker estimated the gasoil cargo was worth more than $2.7 million if the Panama-flagged ship was fully loaded and all cargo stolen. Previous tanker hijackings and cargo thefts have involved gangs gaining access to information on routings, what the vessel was carrying, origin and destination and possible locations where the oil transfer could be carried out Attacks by gangs armed with guns and knives on shipping passing through the Malacca strait have been running at 12 to 20 a year over the last three years [5].

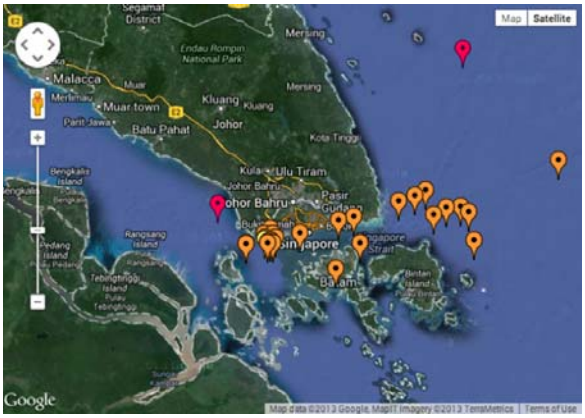

Figure 4: IMB's Live Piracy Map for 2013 shows two hijacking in Red and many boardings in Orange.

3.0 ANTI-PIRACY PLAN

As per ISPS to enhance maritime security anti-piracy plan has to be made. Strengthen and Encourage the Use of the Maritime Security Patrol Area (MSPA) [6].Updating Ships' Security Assessment and Security Plans. Encourage all vessels to use appropriate non-lethal measures such as netting, wire, electric fencing, long-range acoustical devices, and fire hoses to prevent boarding. It also includes risk assessment plan. The risk management concept will be embodied in the Code through a number of minimum functional security requirements for ships and port facilities.

For Ships:
- Ship security plans.
- Ship security officers.
- Company security officers.
- Certain on-board equipment

For Ports:
- Port facility security plans.
- Port facility security officers.
- Certain security equipment.

In addition the requirements for ships and for Port Facilities include:
- monitoring and controlling access.
- monitoring the activities of people and cargo.
- ensuring security communications are readily available [7].

Figure-5 Security Watch.

4.0 SECURITY SYSTEMS

In order to minimize the risk of potential threats some techniques can be introduced which might help to detect and control the situation.
- Video Surveillance
- Radar and Sonar
- Cargo / Container Screening Systems
- Mass Notification
- Other Systems

These security systems have been used in only limited ports so the technology has to be distributed to other nations as well. A long-range vision detection system mounted onboard the vessel should be used which Detects and tracks small vessels that may pose a collision or pirate threat, providing crucial response time for the ship's crew to take necessary action that can be integrated with GPS transponder, radar, AIS and other navigational sensors [8].

Figure 6: Video Surveillance.

5.0 CONCLUSION

Based on the case studies we have found that threat can come without a warning. There is a need to identify people, cargo, and equipment brought into ports or aboard ships while allowing for free movement through these facilities. Piracy is a global issue and should not be neglected. We should implement guidelines given by ISPS in order to minimize the risk of such threats. There are various security systems which can be used so that some action can be taken in emergencies.

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Application Low Cost Air Drying Model in Indonesian Traditional Shipbuilding

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ABSTRACT

Indonesian traditional ship is a product of an indigenous technology developed long before the advent of western culture along the Coast of Sulawesi Island. The ships are built traditionally in both method and equipment without any sketches or calculations. Advancement in science and technology, and abundant information available on the World Wide Web has caused unprecedented changes in many areas of human Endeavour. However, Indonesian traditional ship builders have not taken full advantage of available technology and information particularly in the preparation of lumber which remains one of the critical and most unpredictable stages in construction. This study addressed the issue of delays which is always one of the critical issues confronting the construction of traditional ship in Kepulauan Riau. A low cost air drying model was proposed. The model was tested by comparing the air drying time of lumber in two specific conditions. Four different samples of lumber were used to test the efficiency of both the air drying model and the natural air drying technique. In conclusion, the proposed model having applied and compared with the traditional method clearly show a better method.

KEY WORDS: *Lumber Drying Process; Traditional Ship Production; Kepulauan Riau-Indonesia.*

NOMENCLATURE

EMC	Equilibrium Moisture Content

1.0 INTRODUCTION

Indonesian traditional ship is a product of an indigenous technology developed long before the advent of western culture along the Coast of Sulawesi Island. The ships are built traditionally in both method and equipment without any sketches or calculations. The building expertise is passed down from generation to generation, a knowledge that is further honed through daily practice with the help of each builder's instincts and natural gift. Still built by hand in the traditional manner, these majestic sailing ships are a living spirit from the golden age of sail, which ended in the West in the early twentieth century, but still thrives in the waters of Indonesia.

The beauty and efficiency is not a product of technical science, they are a product of the spiritual nature of these people and their culture. They are at one with their environment and they follow a path of least resistance in their lives and in their work. This philosophy contributes to the beauty and efficiency of their ship designs, and it comes from a basic and simple understanding of the world in which they live. This philosophy based nature and balance allowed the peoples of the Indonesian islands to produce solutions to practical challenges long before the societies of Europe were able to.

In as much as one would like to appreciate the people and their philosophy, it is also good to mention that a mix of local craft and beliefs plus modern and scientific ways of doing things will go a long way in transforming the practice of ship building in Indonesia. Advancement in science and technology, and abundant information available on the World Wide Web has caused unprecedented changes in many areas of human endeavour. However, Indonesian traditional ship builders have not taken full advantage of available technology and information particularly in the preparation of lumber which remains one of the critical and most unpredictable stages in construction. They have failed to explore outside the ancient method of wood preparation other possible ways of making lumber ready for use in shipyards. Nofrizal et al, 2012 has raised the drying lumber issue in traditional shipbuilding in Kepulauan Riau, Indonesia as shown in Figure.1.

Figure.1: Drying lumber issue in traditional ship production in Kepulauan Riau, Indonesia.

It is in the light of the above statement that this study will like to identify from literature different ways of preparing lumber for use in traditional shipyards and proposed a low cost model that may help in impacting the practice of traditional ship building in Indonesia positively.

2.0 LITERATURE REVIEW

The demand for traditional wooden ship in Indonesia is on the increase, this is evident from the high patronage especially among local fishermen. The ship building industry in Indonesia has survived many centuries ably supported by the activities of locally trained builders. Many of the builders acquired the required skill through biological descent or through apprenticeship schemes. Hence, it a common phenomenon to find men with minimal educational ability, narrow world view and limited exposure to the outside world in ship building industry **(**Risandi et al, 2012**)**.

Wood remains the major material and the role of wood in the traditional shipbuilding in Indonesia cannot be overemphasized. When wood is fallen down and sawn into various shapes and sizes, the sawn lumbers are usually allowed to dry before they are used in the construction of ship. However, the drying process is not usually controlled. The drying process most times takes place in open air and as such is exposed to elements of weather which makes the drying process and the drying time highly unpredictable.

Literature reviewed revealed that several studies have identified some of the specific issues central to traditional ship construction in Indonesia. Production issue of traditional shipbuilding in Kepulauan Riau, Indonesia was studied by Nofrizal et.al (2012). His research is proposed to collect data for ship production process and redraw the work flow required to pass through in order to construct the a traditional wooden ship and also identify the major problems exists in the process. Mufti et al, 2012, lamented the lack of blue print or formal sketches as well as calculations on performance during the design stage. The study stated that the traditional ship designs are derived from the replication of an existing ship that is serving its purpose well or from informal conversation between the ship builders and the client.

In another study, E. Prayetno et al, 2012, dwelt on quality control issues in traditional shipbuilding as shown in Figure.2. The study mentioned that there is no standard quality control measure in the choice of materials. The master builders depend heavily on their senses specifically visual assessment and on the job experience acquired over the years. There is no scientific approach to quality control.

Figure.2: Quality issues in traditional ship production.

Moreover, A. Deah et al 2012, addressed safety issue from the perspectives of occupational safety and policies. The study observed that at the construction stage most of the builders failed to take necessary precautions to arrest issues that can expose workers to fatal injuries and jeopardize their health. For instance workers are not provided the required safety wares that such as helmet, boot, hand gloves that can protect them from against injuries. Furthermore, the study highlighted non compliance to specified safety regulations at the point of ship building as laid down by government appointed regulatory agencies.

It is important to mention that some other studies have identified delivery as one of the critical issues in traditional ship building process. Surhan et al 2012, mentioned that traditional shipbuilding process follows a certain unique procedure, a procedure which been handed down from one generation to another generation. The study posited that the unique procedure adopted by the builders was often fraught with flaws. These observed flaws make it almost impossible to give a definite start or completion date for a given project.

One of the major flaws cited by Surhan et al 2012, centred on the refusal of the builders to take advantage of available knowledge in modern day science and technology. The preparation and processing of wood for construction till date still take place in open air. Consequently, wood air drying time remains dependent on prevailing weather conditions. Hence, it is difficult to estimate or project the time required to air dry a given quantity of wood needed to build a specific ship size.

Modern technology nowadays however, does allow wood drying to be carried out in diverse ways instead of just drying outside under the sun. This makes room for better and consistent results as the process can be partly or fully controlled. Not only that, it can also help in the projection of air wood drying time and also encourage the application of scheduling tools at the construction stage. Application of scheduling tools in return may be an advantage in the optimization of the overall ship production process.

The focus of this study is to discuss and address lumber air drying time, and also develop a model that can be used in air drying time calculation. The ultimate goal is to propose a low cost air drying model which may be used to predict the time required to prepare a specific needed quantity of lumber for a given size of ship. This study believes that the proposed model with the ability to predict time for air drying of lumber will eliminate non standardization of time which has been a familial and perennial problem and hence the optimization of the overall production process through the application of scheduling tools.

3.0 LOW COST LUMBER DRYING MODEL

Lumber used in shipbuilding must be seasoned, which means that the moisture from the green wood has to be removed in order to improve its serviceability. Air drying and kiln drying are the two methods used for lumber seasoning, and generally speaking, the air dried process is the best for shipbuilding woods. Most of the lumber available in advanced countries in the west is kiln dried but air drying method is still very rife in Indonesia which is equally acceptable if done properly. Lumber drying process has to be done with great care. If the process is either rushed (leaving too much moisture in the wood), or the lumber is "cooked" too long or at too high a temperature, (thereby removing too much of the moisture and making the wood brittle), the lumber will not be suitable for ship building.

For most ship building lumber, the ideal moisture content ratio to lumber weight after drying (regardless of the process) is approximately 15%, with a range of from 12% to 16% being acceptable (W. Simpson, 2004). When the wood is seasoned, it shrinks to some degree, and if during drying, too much moisture is removed, the wood will later absorb moisture and swell excessively once in use in the ship. On the other hand, if the wood is "green" or contains too much moisture after seasoning, the wood will tend to shrink and split while the ship is being built.

The moisture content of wood below the fiber saturation point is a function of both relative humidity and temperature of surrounding air. The EMC is the moisture content at which the wood is neither gaining nor losing moisture; this however, is a dynamic equilibrium and changes with relative humidity and temperature.

The Hailwood-Horrobin equation for two hydrates is often used to approximate the relationship between EMC, temperature (T), and relative humidity (h) (R. Baronas, 2001):

$$M_{eq} = \frac{1800}{W}\left[\frac{kh}{1-kh} + \frac{k_1kh+2k_1k_2k^2h^2}{1+k_1kh+k_1k_2k^2h^2}\right] \quad (1)$$

where;

$$W = 330 + 0.452T + 0.00415T^2$$

$$k = 0.791 + 4.63x10^{-4}T - 8.44x10^{-7}T^2$$

$$k_1 = 6.34 + 7.75x10^{-4}T - 9.35x10^{-5}T^2$$

$$k_2 = 1.09 + 2.84x10^{-4}T - 9.04x10^{-5}T^2$$

If the wood is placed in an environment at a particular temperature and relative humidity, its moisture content will generally begin to change in time, until it is finally in equilibrium with its surroundings, and the moisture content no longer changes in time. This moisture content is the EMC of the wood for that temperature and relative humidity.

The moisture content of wood is calculated by the following formula::

$$MC = \frac{m_g - m_{od}}{m_{od}} \quad (2)$$

where, m_g is the green mass of the wood, m_{od} is its oven-dry mass. The equation can also be expressed as a fraction of the mass of the water and the mass of the oven-dry wood rather than a percentage. For example, 0.59 kg/kg (oven dry basis) expresses the same moisture content as 59% (oven dry basis).

3.1 Construction of the Air Drying Model

The model was constructing by using an aluminum rectangular frame with 69 cm of length, 65 cm of with and 42 cm of height and a polythene sheet as shown in Figure.3. The polythene sheet was spread over the frame and held firmly to the frame by tape and screws. The purpose of the polythene is to serve as shed for some of the samples.

Figure.3: Constructing the Air Drying model.

Using the model, experiment was conducted for 7 days with detail as follows:

Day 1

- The low cost air drying model was constructed using a rectangular frame and a polythene sheet.
- The length of each of the Samples A, B, C, D, 1 and 2 of lumber pieces were recorded
- The initial weights of the samples were also recorded.
- The samples A, B, C, D, 1 and 2 were immersed in water
- The samples A, B, C, D, 1 and 2 were removed from water for about two and a half hours. The weights of the samples were recorded again.
- Samples A, B and 1 were placed inside the model.

- Samples C, D and 2 were placed outside the model in the open air (that is they were exposed to elements of weather condition).
- The following parameters time, temperature and relative humidity were recorded.
- The samples were kept outside for another ten hours and the changes in weight (that is loss in moisture content) were recorded.

Day 2- Day 7

- The samples were kept outside in two different specific conditions and their weights, time, temperature and relative humidity were steadily recorded at time interval of two hours for a given period of one week.
- Condition 1: samples A, B and 1 were spread out inside the model protected from elements of weather with a clear transparent polythene sheet.
- Condition 2: samples C, D and 2 were spread out in the open air unprotected from elements of weather.
- The data obtained were tabulated accordingly.

3.2 Immersion of Samples in Water and Sample Arrangement

The samples were immersed in water after taking their initial weights in order to confirm how dry or wet they were. They were immersed for a period of two and half hours. Their weights were also recorded and this is illustrated in figure.4 below.

Figure.4: Samples immersed in water

After immersion, the samples were laid apart in upright position in order to allow for direct effect of weather condition as shown in the Figure.5, Figure.6 and Figure.7.

The data were collected at different time interval. Day 1 data was collected at time intervals of two hours. This is only to find the patent of dryness of lumber. The time interval for day two and three is four hours and day four and above is six hours.

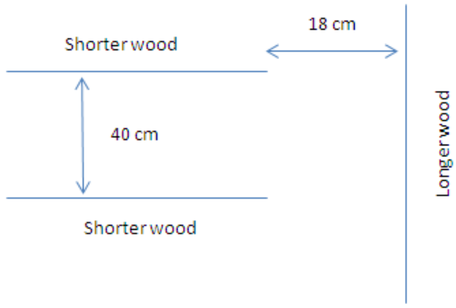

Figure.5: Samples arrangement.

Figure.6: Arrangement of the samples

Figure.7: Experiment under rain showers

3.0 REQUIRED DRYING TIME OF LUMBER

To determine the number of days required to dry lumber, this study applied EMC equation to determine the dryness of the lumber. In general, the moisture content of lumber below the fiber saturation point is a function of both relative humidity and temperature of surrounding air. The EMC is the moisture content at which the wood is neither gaining nor losing moisture; this however, is a dynamic equilibrium and changes with relative humidity and temperature.

Let assume that m is the mass of the lumber (with moisture) and m_{od} is the oven-dry mass of lumber (i.e. no moisture). If the lumber is placed in an environment at a particular temperature and relative humidity, its moisture content will generally begin to change in time, until it is finally in equilibrium with its surroundings. At that point, the moisture content no longer changes. This moisture content is the EMC of the lumber for that temperature and relative humidity. To estimate the EMC, Hailwood-Horrobin equation for two hydrates is often used to approximate the relationship between EMC, temperature (T), and relative humidity (h). The example below shows the application the Hailwood-Horrobin equation to calculate the EMC of sample A and sample C. The initial data obtained during the experiment for sample A is highlighted in the Table.1 below:

Table.1: The initial data for sample A after immersion.

Particular	Recorded Data
Initial Weight, m (Weight remove from water)	0.972 kg
Average Temperature, T	30.85 ^{0}C (87.53 F)
Fractional, H (Average Humidity)	83.16% (0.8)

From the calculation above, the drying weight for the sample A (inside the model) and sample C (outside the model) is 0.841 kg and 0.742 kg respectively. In the calculation, the Moisture Content is 15 percent (My Life: Kayu). By plotting the graph of sample A and sample C using the data from the experiment against recorded time. The total time required for the lumber to air dry from fully wet condition can be determined. The Comparison between the required times to air dry the samples (A and C) with both the proposed technique and traditional technique is showed in the figure.8.

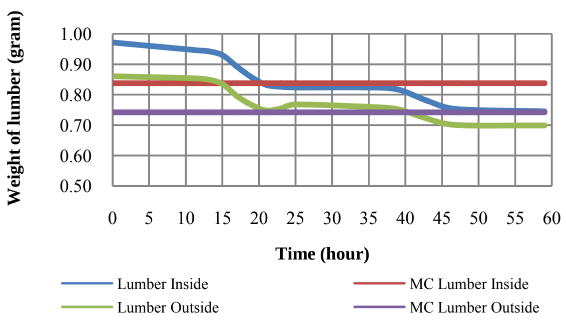

Figure.8: The air drying time of lumber in two specific conditions i.e drying time between proposed technique and traditional lumber drying technique.

According to figure 8, it is evident that the proposed technique proves to be more successful, drying the lumber in less than one day (20 hour). While the traditional method shows delay that is it takes almost two day (40 hour). The delay caused by the traditional technique as observed from the graph is because of rainfall the second day after the drying process started.

According to the rainfall data from Department of Irrigation and Drainage Malaysia, the amount of cumulative rainfall in Johor Bahru area on initial data collection day which is 7th July 2013 is as high as 10mm. The cumulative rainfall data provided by the Department of Irrigation and Drainage Malaysia is shown in figure.9.

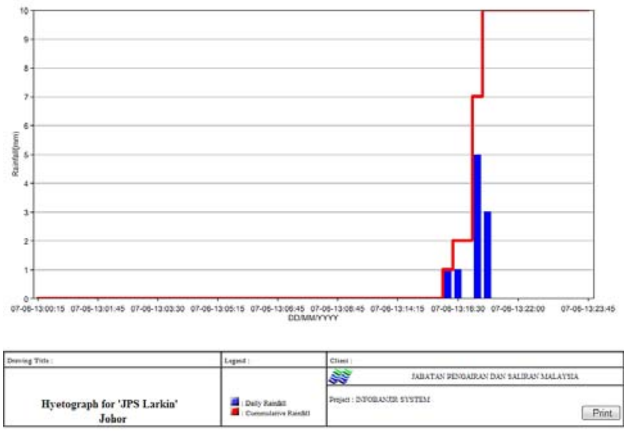

Figure.9: The cumulative rainfall for the month of June, 2013 by Department of Irrigation and Drainage Malaysia.

By comparing the cumulative rainfall data to the amount of the drying time, it can be assumed that for every 10 mm of rainfall, the air drying time of the lumber is elongated using traditional drying method. In other words, if there no rainfall the following day, the lumber air drying time by traditional technique can also be predicted to dry in one day.

3.1 Comparison between the Use of the Proposed Model and Traditional Method

From the experiment conducted, the lumber placed outside the model is exposed to rainfall therefore becomes wet when it rained and also difficult to work on because of the wet surface as shown in Figure.10. The wet surface would invariable translate to delay in the overall production process because it required more time to dry.

Figure 10: Effect of rainfall on drying of lumber using the proposed technique and traditional technique.

3.2 Effect of Air Drying on the Size of the Lumber

Also from the experiment, it is deduced that there was no noticeable change in the size of the lumber. Figure.11 shows the graph of the air drying time for different sizes of lumber. The result shows that the changes are negligible.

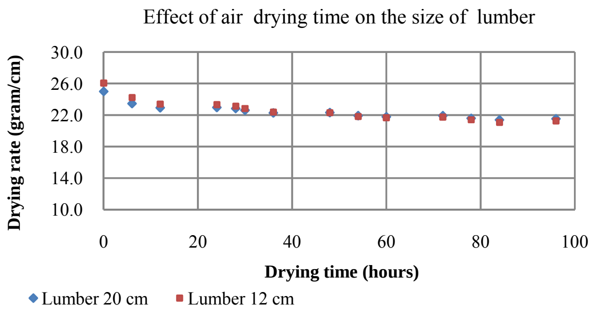

Figure.11: Effect of air dry time on the size lumber using the proposed technique.

5.0 CONCLUSION

The following conclusion is to answer the objective of the present study.

- The low cost lumber drying model is proposed in the present study.
- The low cost model was constructed using a rectangular frame and a polyethylene sheet.
- Experiment was conducted to determine required drying time of lumber using the proposed drying model and current technique which is applied by traditional shipyard in Kepulaun Riau, Indonesia.
- In the experiment, length of lumbers are as follows 31 cm, 20 cm and 12 cm. Width and thickness are the same in which 20 cm of width and 2 cm of thickness.
- The interval time is record
- The analysis of experimental results show that required drying time using the proposed model is shorter than the current technique.

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Prediction of CO2 Emission along the Ferry Routes Caused by Marine Transport

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ABSTRACT

Global warming and air pollution have become one of the important issues to the entire world community. Exhaust emissions from ships has been contributing to the health problems and environmental damage. This study focuses on the ferry routes from ferry terminal in Stulang Laut, Johor Bahru to Batam Island, Indonesia because it is one of the world's most congested straits used for international shipping where located on the border among three countries of Indonesia, Malaysia and Singapore. This study will identify and predict Carbon Dioxide (CO2) emission from the marine transport from ferry terminal in Stulang Laut, Johor Bahru along its routes to Batam Island, Indonesia.

KEY WORDS: *AIS, Carbon Dioxide, CO2, Emission, Distribution*

1.0 INTRODUCTION

The international shipping industry is responsible for the carriage of about 90% of world trade and is vital to the functioning of the global economy. Intercontinental trade, the bulk transport of raw materials and the import export of affordable food and goods would simply not be possible without shipping. It is the availability, low cost and efficiency of maritime transport that has made possible the major shift towards industrial production in Asia and other emerging economies (IMO 2006).

The Strait of Malacca remains as one of the world most congested straits used for international shipping which is a narrow stretch of water lying between the east coast of Sumatra Island in Indonesia and the west coast of Peninsular Malaysia, and is linked to Singapore at its southeast end. The Strait of Malacca varies in width from 200 miles to 11 miles with irregular depths from over 70 to less than 10 meters is one of the most important shipping channels in the world which is connecting the Indian Ocean with the South China Sea and the Pacific Ocean. (SJICL, 1998).

At approximately 805 kilometers long, the Strait of Malacca is the longest Strait in the world used for international navigation (Wikipedia, 2013). From the study by Jaswar (2013), it shows that daily 1500 vessels approximately pass through the Strait of Malacca which is 42 percent was under Singaporean flag. These consist of a wide spectrum of different types of vessels with 32 percent of Liquid bulk and 11 percent of container ships.

With this number of ship, it will leave environmental impact such as Greenhouse gas emission. Carbon dioxide emissions from shipping is estimated to be 4 to 5 percent of the global total, and estimated by the International Maritime Organization (IMO) to rise by as much as 72 percent by 2020 if no action is taken (Vidal, 2007). IMO (2009) study of greenhouse gas (GHG) shows total exhaust emission from shipping from 1990 to 2007 and can see that there are increases of exhaust emission every year.

2.0 AIS

Automatic Identification System (AIS) firstly has been used to comply with safety and security regulations, functioning as collision avoidance, vessel traffic services, maritime security, aids to navigation, search and rescue and accident investigation. The AIS is meant to be used primarily as a means of lookout and to determine the risk of collision rather than as an automatic collision avoidance system, in accordance with the International Regulations for Preventing Collisions at Sea (IMO, 1998).

Primary data of ships which obtained from an AIS receiver in the study are MMSI of the ship, IMO number, receive time, position of the ship (longitude and latitude), speed of ground (SOG) and COG. These all the data obtained from an AIS receiver installed in Marine Technology Laboratory (Marine Technology Center (MTC)), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia (UTM). Information of ships based on AIS is not complete to use as the basis for calculation. AIS only provides several initial data such as MMSI, IMO number, position of ships (longitude and latitude), Speed Over Ground (SOG), Centre of Gratify (COG) and true heading of the ship. Gross Tonnage (GT) data for calculation of emission rate as explained by Trozzi C. (2010) is obtained from other references such as marinetraffic.com, maritime-connector.com, equasis.org, vesseltracker.com and Equasis.org. The combination of all the data will make a complete database that can be used for the calculation.

3.0 CARBON DIOXICE (Co2)

Carbon dioxide (CO2) is a colorless, odorless, non-flammable gas that is a product of cellular respiration and burning of fossil fuels. It has a molecular weight of 44.01g/Mol (NIOSH 1976). Although it is typically present as a gas, carbon dioxide also can be a solid form as dry ice and liquefied, depending on temperature and pressure (Nelson 2000).

In a natural carbon cycle, carbon dioxide is re-absorbed by plants and trees. However, the rate in which the burning fuels is way too fast for trees and plants to absorb and convert into breathable air. In addition to that, many rainforests have been lost because of the cutting down of trees, which doesn't help in the already existing problem. The effect of all this extra carbon dioxide in the atmosphere is that the overall temperature of the planet is increasing, resulting to global warming. Carbon dioxide is not only a gas which affects the heat flow to and from the atmosphere of the earth, but is also a serious pollutant in its own right (Robertson, 2006). The concentration of this gas in the atmosphere is not known to have risen above 320 ppm over the last 40,000 years (Neftal et al, 1982).

Evidence demonstrates this to be the case for the past 420,000 years (Petit et al, 1999). Several researches suggest that carbon dioxides also give effect to the Physiological. Although the safe working level of carbon dioxide is presently set at 5000 ppm for an 8 h day 40 h working week, no human ever endures such a level of carbon dioxide in the atmosphere for 24 h a day, 365 days a year, for an entire lifetime nor has any human ever bred offspring under these conditions. This includes workers in breweries and the greenhouse industry, where the concentration of carbon dioxide in the atmosphere either commonly reaches or is set at a maximum of 900 ppm (Robertson, 2006).

4.0 CASE STUDY

The study was conducted on 27 August 2014 on a ferry from ferry terminal in Stulang Laut, Johor Bahru to Batam Island, Indonesia. According to Jaswar (2013) here are 813 marine transport detected by Automatic Identification system (AIS) in the area from ferry terminal in Stulang Laut, Johor Bahru to Batam Island, Indonesia that is include the marine transport in Singapore area as shown in figure 1.

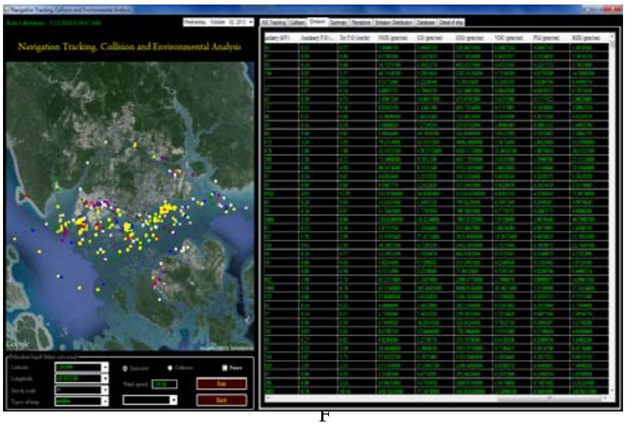

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Figure 1: Routes taken by ferry (Jaswar, 2013).

The purpose of the study is to identify and predict carbon dioxide emission from the marine transport along the ferry routes from ferry terminal in Stulang Laut, Johor Bahru to Batam Island, Indonesia.

Table 1: Number of marine transport (Jaswar, 2013)

Code	Type	Number of Ship
SB	Solid Bulk	49
LB	Liquid Bulk	372
GC	General Cargo	51
CO	Container	124
PC	Ro-Ro Cargo	3
PA	Passenger	12
HS	Highspeed ferries	1
TU	Tugs	138
FI	Fishing	1
OT	Other	62
Unknown		360
Total Number of Ship		1173
Total correspondent ship		813

From table 1, it is shown that the type of all 813 total number of marine transport. The highest of identify marine transport at the study area is Liquid Bulk ship that is 372 follow by Tug boat and container ship that is 138 and 124.

There is still higher number of unknown types of marine transport around the study area. 360 number of unknown ship has been recorded at the time of the study conducted. This number can be narrow down after another study with a completed Automatic Identification System (AIS) database.

Table 2 show 34 Latitude and Longitude within the routes taken by the ferry during the study conducted. From ferry terminal in Stulang Laut, Johor Bahru that is 1.47109N 103.7849E to ferry terminal in Batam Island, Indonesia that is 1.13151N 104.0561E.

Table 2: Ferry routes.

No	Latitude	Longitude	No	Latitude	Longitude
1	1.47109	103.7849	18	1.13151	104.0561
2	1.47085	103.7926	19	1.42784	103.9119
3	1.47463	103.8142	20	1.42862	103.9255
4	1.46845	103.8409	21	1.42690	103.9458
5	1.45172	103.8651	22	1.42441	103.9843
6	1.43340	103.8880	23	1.41832	104.0002
7	1.42950	103.8967	24	1.39043	104.0101
8	1.42278	103.9596	25	1.38052	104.0239
9	1.40600	104.0060	26	1.36580	104.0386
10	1.36580	104.0386	27	1.34155	104.0607
11	1.30667	104.0694	28	1.30667	104.0694
12	1.25730	104.0672	29	1.25730	104.0672
13	1.23628	104.0635	30	1.23628	104.0635
14	1.22236	104.0617	31	1.19627	104.0566
15	1.19627	104.0566	32	1.16066	104.0631
16	1.16066	104.0631	33	1.13870	104.0586
17	1.13870	104.0586	34	1.13151	104.0561

The figure 2 below show the routes taken by the ferry from ferry terminal in Stulang Laut, Johor Bahru to ferry terminal in Batam Island, Indonesia. Along the routes, the ferry will pass through few places and area with high density number of marine transport such as Perlabuhan Pasir Gudang in Johor Bahru.

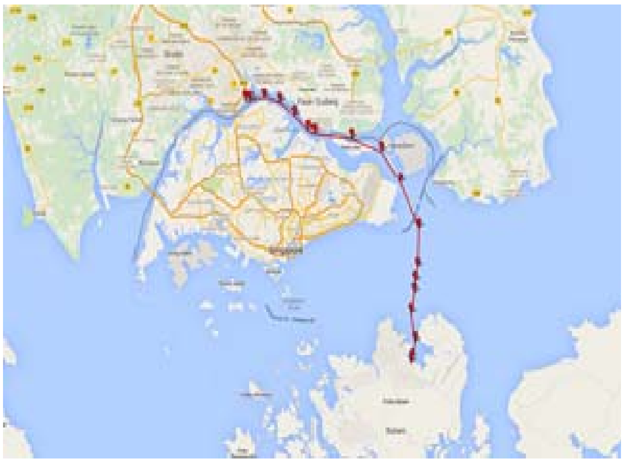

Figure 2: Routes taken by ferry.

In this study, carbon dioxide is measure in Parts per million (PPM). The measurement is taken for every minutes for one hour start from 6:55 PM and ended at 7:57 PM as shown in table 3 below.

Table 3: Carbon Dioxide (CO2) every 1 minute for 1 hour.

Time	CO2	Time	CO2	Time	CO2
6:55 PM	455	7:16 PM	461	7:37 PM	461
6:56 PM	451	7:17 PM	456	7:38 PM	461
6:57 PM	450	7:18 PM	453	7:39 PM	462
6:58 PM	451	7:19 PM	451	7:40 PM	463
6:59 PM	452	7:20 PM	451	7:41 PM	453
7:00 PM	453	7:21 PM	451	7:42 PM	449
7:01 PM	452	7:22 PM	451	7:43 PM	446
7:02 PM	453	7:23 PM	449	7:44 PM	445
7:03 PM	455	7:24 PM	449	7:45 PM	446
7:04 PM	457	7:25 PM	453	7:46 PM	448
7:05 PM	457	7:26 PM	458	7:47 PM	445
7:05 PM	457	7:27 PM	457	7:48 PM	445
7:07 PM	456	7:28 PM	457	7:49 PM	446
7:08 PM	455	7:29 PM	457	7:50 PM	438
7:09 PM	454	7:30 PM	457	7:51 PM	439
7:10 PM	455	7:31 PM	457	7:52 PM	458
7:11 PM	461	7:32 PM	457	7:53 PM	457
7:12 PM	478	7:33 PM	456	7:54 PM	458
7:13 PM	484	7:34 PM	456	7:55 PM	455
7:14 PM	488	7:35 PM	456	7:56 PM	449
7:15 PM	485	7:36 PM	458	7:57 PM	450

The data shown that within one hour period the carbon dioxide level is range from 438 PPM to the highest point that is 488PPM. Still this level is still above the normal outdoor carbon dioxide level that is between 300 PPM to 400 PPM.

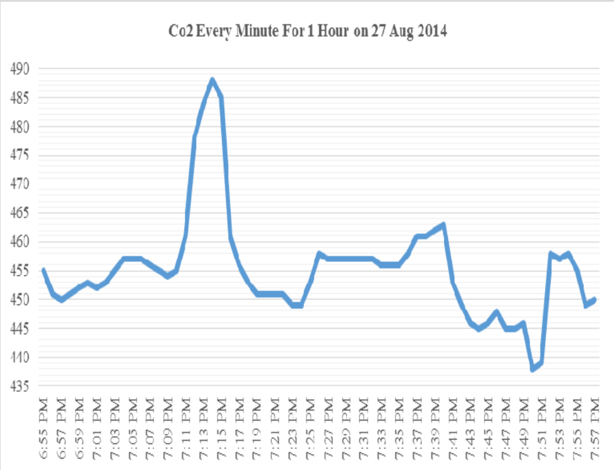

Figure 3: Carbon Dioxide level graph.

The highest level of carbon dioxide recorded is 488 PPM at 7:14 PM and the lowest level of carbon dioxide recorded is 438 PPM at 7:50 PM. The graph in figure 3 show that an increase of carbon dioxide concentration level from 7:11 PM to 7:14 PM.

As shown in figure 4 below, the highest level of carbon dioxide concentration recorded at Latitude and Longitude 1.42950E 103.8967N that is in the area of Pasir Gudang Port. From the Automatic Identification System data, there is known to be a lot of marine transport activities in the area of Pasir Gudang Port (Jaswar, 2013).

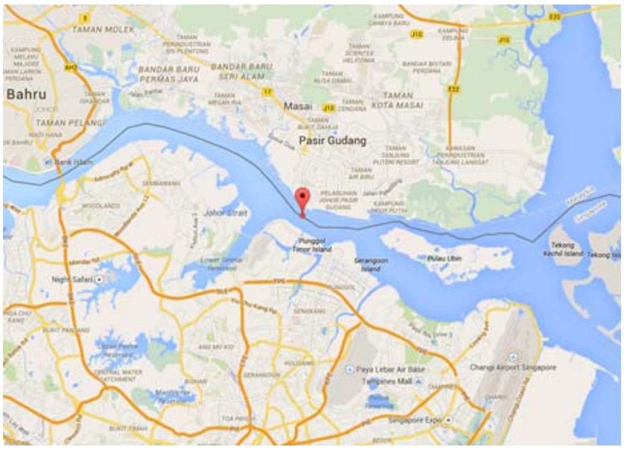

Figure 4: The highest Carbon Dioxide level recorded.

The data also shown that carbon dioxide concentration level most probably was contribute by the marine transport until further study will be conducted. The more activities by marine transport in the area, most probably the higher carbon dioxide concentration level will be recorded. Figure 5.1, 5.2, and 5.3, below also showing picture taken during the study. The high amount of marine transport can be sighted in the area where the highest carbon dioxide concentration level has been recorded.

Figure 5.1: Sighted marine transport.

Figure 5.2: Sighted marine transport.

Figure 5.3: Sighted marine transport.

In figure 6, latitude and longitude of 1.23628E 104.0635N show the location of the lowest carbon dioxide recorded in the study. From the Automatic Identification System (AIS) data also shown that there is less marine transport at the area (Jaswar, 2013).

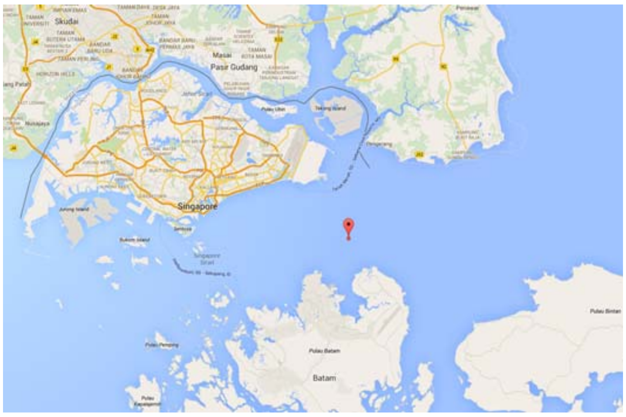

Figure 6: The lowest Carbon Dioxide level recorded.

Other than less activities of marine transport, the factor of natural carbon sinking by the ocean was probably another reason of the lowest carbon dioxide concentration recorded at the study area (Raven, 1999). Of all the area, it was located at the open sea far away from land and there also less activities of marine transport sighted (Takahashi, 2002).

5.0 CONCLUSION

In conclusion, this paper explained that marine transport do contribute to carbon dioxide pollutions. The highest level of carbon dioxide concentration was recorded on the area of high traffic of marine transport that is in the area of Pasir Gudang Port. Marine transport such as cargo ship still contribute low emission of carbon dioxide compare to other transport. This is because for equal weight and distance it is the most efficient transport method such as air freight.

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Collision Preventing System of Marine Navigation using AIS System

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ABSTRACT

Navigation safety has become one of the important issues to the entire world community. Automatic Identification System (AIS) firstly has been used to comply with safety and security regulations, functioning as collision avoidance, vessel traffic services, maritime security, aids to navigation, search and rescue and accident investigation. This paper presents marine navigation collision preventing system between ships and ships using AIS. In the system, the raw data from AIS is crossed with database based MMSI number to find detail information then, location of each ship was plotted on to Google Map. The safety distance is assessed based actual and stopping distance. The system was tested in the Batam and Singapore Channel.

KEY WORDS: *Marine Navigation; Collision Preventing System, Automatic Identification System; Safety Distance*.

1.0 INTRODUCTION

Safety on navigation between the vessels has become one of the important issues to the entire world community. Shipping accidents have occurred more frequently which is attributed to heavy traffic in the strait between Batam, Indonesia and Singapore. The incident highlights the risk that ships face when navigating increasingly crowded in the strait. Over 100,000 oil and cargo vessels travelled the strait in a year, each day carrying 3.23 million barrels of crude oil which is about 33 percent of global seaborne crude oil. It was recorded 476 casualties from 1975-1995. These involved collisions (21 %), fire and explosion (17 %), sinking (32 %), engine troubles (26 %) and other (4 %) (Jaswar, 2013).

Automatic Identification System (AIS) firstly has been used to comply with safety and security regulations, functioning as collision avoidance, vessel traffic services, maritime security, aids to navigation, search and rescue and accident investigation. The AIS system is meant to be used primarily as a means of lookout and to determine the risk of collision rather than as an automatic collision avoidance system, in accordance with the International Regulations for Preventing Collisions at Sea.

The AIS was developed as a collision avoidance tool to enable commercial vessels to 'see' each other more clearly. The AIS does this by continuously transmitting a vessel's identity, position, speed and course along with other relevant information to all other AIS equipped vessels and port authorities within range. AIS was made compulsory in 2002 for most large commercial ships in which ships over 300 gross tonnage engaged on international voyages and cargo ships over 500 gross tonnage not engaged on international voyages and passenger ships irrespective of size.

This paper discusses development of marine navigation collision avoidance system using AIS data for safety navigation. The system is applied in the strait between Batam, Indonesia and Singapore as case study. The safety is assessed based on stopping distance and actual distance.

2.0 MARINE NAVIGATION TRACKING USING AIS

Marine traffic in the strait between Batam, Indonesia and

Singapore is analyzed using AIS data. The AIS system consists of an antenna, a splitter SS500, two AIS receivers SR 161 and FA30, Rectifier Unit PR-62L, converter RS-422, TP-Link (TESF1005D) and PC computer as shown in Figure.1 Primary data of ships which is obtained from an AIS receiver contains received date and time, message ID, MMSI number, IMO number, the position of the ship in term of longitude and latitude, speed of ground. The collected AIS data is simultaneously stored and updated in a hard disk on the Personal Computer. The raw data was recorded in every one minute which depends on setting up.

Figure 1: AIS System.

As an analysis collision prevention system will generate a huge number of calculations and result due to ship movement. In order to solve the problem, a program using Microsoft Visual Studio 2010 program was developed. In the program, the ship traffic patterns are evaluated using AIS data by crossing with ship database based on MMSI number to find detail of ships such as principle dimension, deadweight, gross tonnage, flag, type of ships, year built. Another data have been taken by the program from the ship database that have been created and save in the particular record. Figure.2 shows an example of ship detail recorded in a minute in the strait between Batam, Indonesia and Singapore. The ship traffic patterns are useful when evaluating ship operation modes, such as maneuvering, hotelling, and cruising.

Navigation tracking, often with a map in the background, but showing where the vessel have been and allowing to be preprogrammed, giving a line that can follow on the screen. In this programming, the marine navigation tracking shows the track of the ship using the AIS raw data that have been put in the program. The marine navigation tracking will show the position of the ship and denoted with different color based on the type of the ship. This kind of information can be detected by the program using the ships database that has been develop. That is the reason why the ship database is really important because of this matter. If the information in the database in not complete, perhaps the program cannot calculate at all the safety distance of the particular ship. The information that is very important such as the length of the ship.

Figure 2: An example of marine navigation tracking in a minute.

By using the longitude and the latitude, the position of the ships can be detected by plotting on map which is linked to Google map. Each type of ship is displayed in different colored for recognition easily. In this software, there are 31 types of ship recorded in the database. Percentage of each ship is displayed into pie chart and list view as shown in the Figure 3.

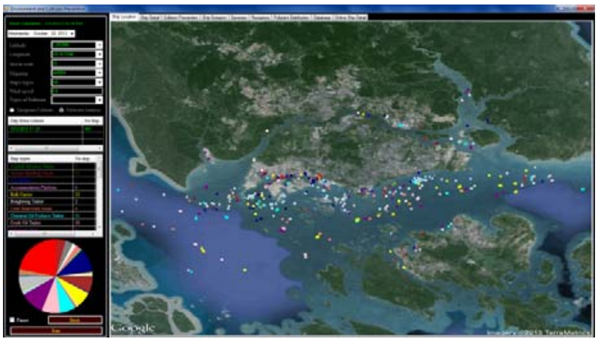

Figure 3: An example of marine navigation distribution in a minute in the strait between Batam, Indonesia and Singapore.

Figure 4 shows number of ships tracking by AIS in 2-October from 2003 to 2013 in which monthly, the average is 989 ships passed through the strait of Batam, Indonesia and Singapore. Marine traffic slowly increases to peak season at 7.00 am - 8.00 am, and then decreasing to normal condition at 10.00 am – 11.00 am until 9.00 pm before decreasing to lowest point at midnight as shown in Figure 5.

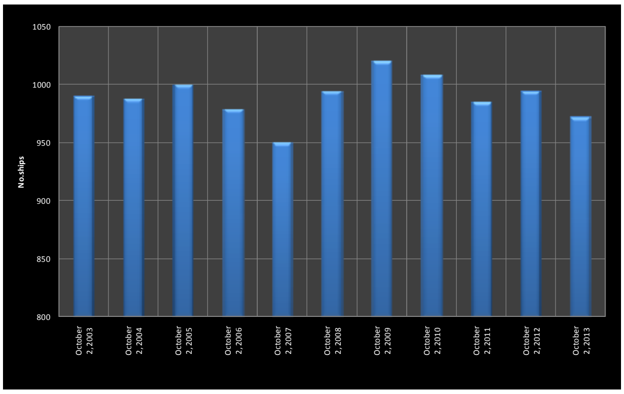

Figure 4: Number of ships passed through the strait between Batam, and Singapore in 2003 - 2013 tracking by AIS.

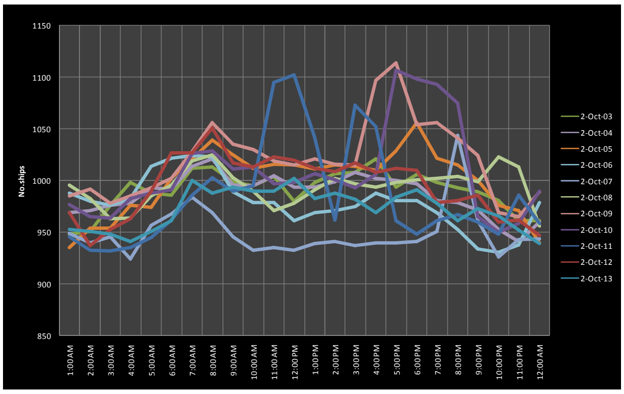

Figure 5: Number of ships hourly passed through between Batam, and Singapore on 2-October, 2003 - 2013 tracking by AIS.

3.0 COLLISION PREVENTING SYSTEM

3.1 Stopping Distance

The quantitative calculation of a ship's inertial stopping distance plays a very important role in the ship engineering field. Especially for the restricted is as such as bridge water area, the reversing stopping distance of a ship needs to be predicted accurately by quantitative calculation of the motions of a ship. The stopping and reversing stopping distance can be calculated by many different methods currently. Empirical equations are adopted by Ship's Handling. However, these theory equations do not consider the practice deeply in the calculation. Hence, the calculation result to some degree is inaccurate. More sophisticated methods is needed to handle this issue (Hirt et al., 1974; Jing, 1984; Wu, 1988; Liang et al., 2011; Barrasa et al., 2012). In order to provide precise prediction performance of ship's inertial stopping distance, this study introduces an ALE (Arbitrary Lagrangian Eulerian) algorithm to improve the prediction accuracy. The prediction result is compared with the physical model tests and related empirical equations to show high effectiveness of the proposed method.

Numerous observations (International Oil Tankers Commission, 1974) have been made concerning the stopping distance (D) of the ships in function with their speed. The principle results of maneuvering trials carried out in the fully laden condition of vessels ranging from 20,000 to 200,000 Deadweight are recorded for an initial speed of the ship 5 knots. In conclusion from observation made in Le Havre include the following:

1. The stopping distance, D will not be less than 5 times the length, L of the ship.
2. For the speeds, V exceeding 2.5m/s or 5 knots, the sopping distance is given by formula:

$$D = 4L\,[V/2.5]^{3/4} + L \quad (1)$$

3.2 Actual Distance between Ships

The actual distance between ships is determined by using the Haversine formulation. The Haversine formula expressed in terms of a two-argument inverse tangent function to calculate the actual distance between two points on the Earth as follows:

$$d = R\,c \quad (2)$$

where R is radius of the earth (6373 km) and

$$c = 2.\,atan(\sqrt{a}, \sqrt{(1-a)})$$

$$a = (sin(\frac{\Delta_{lat}}{2}))^2 + cos(lat_1).\,cos(lat_2).\,(sin(\frac{\Delta_{long}}{2}))^2$$

$$\Delta_{long} = long_2 - long_1$$

$$\Delta_{lat} = lat_2 - lat_1$$

3.3 Safety Distance Assessment

After determining the actual and stopping distance and heading angle for the particular vessel, the status of safety on navigation for that particular vessel with the other vessel will be identified. If the value of stopping distance is less than 5 times length of the ship, it can be concluded that that particular vessel is in danger condition. But before that the value of safety distance for the particular ship will be compare with the actual distance of the ship base on the longitude and latitude of that particular ship provided from the automatic identification system (AIS) data.

From the collision avoidance analysis, safety distance for the target ship and also the actual distance of the target ship with own ship is presented. As it can see in Figure.6, there are few ships probably in danger condition and the detail of danger ships will be displayed automatically.

Status of each ship whether it is in danger or not, do not depend on the distance between ships only. If the actual distance between the target ship and the own ship less that the safety distance, the ships can be consider in the dangerous condition. But it is depend on the situation also. That is why there is the reference from the website in order to consider what type of the vessel they are. For example if the target ship is tug boat, it does not matter because the tug boat maybe in process of assisting the target ship. In other words, if confirmed that the vessel is in danger condition, the information of that particular vessel can be forwarded to enforcement agency such as Marine Department of Malaysia (MARDEP) or Malaysian Maritime Enforcement Agency (MMEA). The information can be forwarded to enforcement team such as IMO number, calling-sign and other information. The additional information from website is used to determine what type of ship engaged with the target ship and it means the closest ship. Not all the value of actual distance of own ship with the own ship less that the safety distance of the own ship is in dangerous condition. With the website linked through the internet, the real identity of the ship with the picture can be identified no matter the own ship or the target ship.

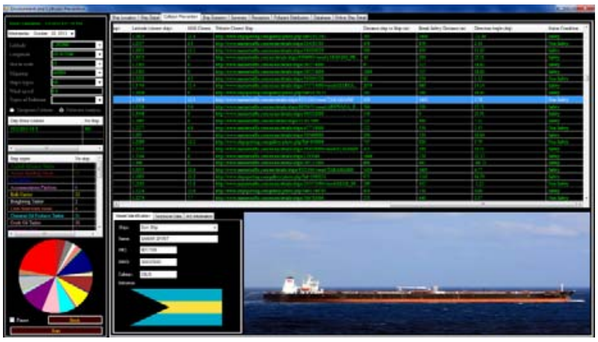

Figure 6: Results of safety assessment of marine navigation

4.0 CONCLUSION

Collision preventing system for marine navigation was developed by using data from the Automatic Identification System (AIS). The safety is assessed based on the safety distance and actual distances of the own and target ships. The safety and actual distances are calculated using International Oil Tankers Commission, 1974 and the Haversine formulation, respectively. This study showed that calculation of safety distance is able to cover all speed more than 5 knots.

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Improving Hull Design for Better Efficiency and Environmental Protection

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ABSTRACT

The efficiency of ships has become a hot topic in the maritime industry in recent years. Increasing fuel prices and also depletion of resources has raised concern to improve the quality of fuel and also improve the ship efficiency. Currently, more focus is given to environmental friendly ships so as to minimize the emissions and reduce the impact of global warming. Sustainability is also very important to protect our planet so that future generations also utilize the resources. There are various methods which can be used to improve ship efficiency one method can be following Shipboard Energy Efficient Management plan and also modifying the Engine by using Renewable Energy or Dual fuel to cut out the harmful Emissions. The shape of hull will determine the overall efficiency of the ship and will play a key role in minimizing the resistance offered by the waves. In this paper a study will be done to analyze which type of hull form is suitable for future ships and how we can make environmental friendly ships so as to improve transport efficiency and control carbon footprint so as to provide safer ships and cleaner oceans.

KEY WORDS: *Ship Efficiency, Environmental Affect, Hull Optimization, Energy Savings.*

NOMENCLATURE

EEDI	Energy Efficiency Design Index
IMO	International Maritime Organization
Cb	Block coefficient
LCB	Longitudinal Centre of Buoyancy

1.0 INTRODUCTION

With the increase in population the demand for natural resources has raised drastically and at the same time is causing shortage of these sources. The fossil fuel is expected to last for 30-40 years and if we do not take any action to control it our future generations will suffer a lot. One of the other main concerns these days is the emissions from industries and transport systems. The temperature of the earth is rising at a rapid pace causing global warming. We should thus introduce a concept of sustainable development in our future ship designs so that we reduce the consumption of fuel and also emissions. Almost all emissions from ships are reduced when less energy is consumed [2].According to IMO's study on greenhouse gases it was found that there is a potential for improvement in the existing technologies such as more efficient engines and propulsion systems, improved hull designs and larger ships it simply means improvement through technical and design based measures that can achieve reduction in fuel consumption and emissions from ships. It was also found that reductions could be obtained through operational measures such as lower speed, voyage optimization, etc. [12].

Although shipping is well known as the most fuel-efficient mode of transport, it has been tasked with reducing its greenhouse gas emissions and one of the technical measures that have resulted from this is the Energy Efficiency Design Index (EEDI), which will be mandatory for new build vessels from January 1st, 2013 as per IMO. The intent of the EEDI is to provide a new building standard, assuring that ship designs achieve a certain level of efficiency and decreased carbon emissions. It represents the energy efficiency of a ship's design, indicates the ratio between environmental impact (CO_2 emission per transportation work) and economic benefit and provides a benchmark against which ship efficiency may be evaluated [12].

We are designing eco-friendly ships only for the reason that our future generations can also utilize the natural resources to its fullest. Environment is a gift of nature to the mankind and we are responsible to protect it. Sustainable development is hence necessary to safeguard our planet. Sustainability includes three elements; people, planet and profit and has three pillars; economic, social and environmental. Shipping industry should be safe and secure, environmentally responsible, reliable and efficient in operation.

Figure 1: Sustainability of shipping.

The figure above shows life cycle of shipping from design to construction and operation to disposal. It is important to note that efficient shipping is only possible if we balance the three aspects of sustainability i.e. economic responsibility, society and concern for environment. The design of the ship is the first step and optimization of hull design will play a major role in reducing resistance and emit less greenhouse gases. In this paper focus will be given to modifications in hull design in order to improve overall efficiency with environment benefits.

A Ship design is a complex process. It involves a lot of study as well as requires many calculations to produce a design. There are various enablers which are to be considered before designing a ship it includes economy, technology, accidents, environment, security people and cultures. A design spiral is widely used which forms a structured format for designing efficient and innovative ship designs as shown in figure below.

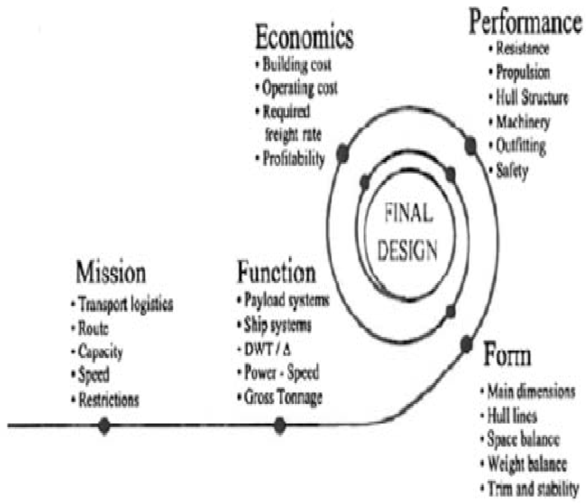

Figure 2: System based ship design

The hull of a ship is divided into three main parts- Fore part, Parallel middle body, Aft part. There are modifications done in the fore and aft part of the ship to improve the ship design. The lines plan drawing of a ship is thus important in knowing the shape of the hull and also gives information on hydrostatic data. In modern ships some new technologies have been used to better the efficiency of the ship which is further discussed in the paper.

2.0 Developments in ship hull

Presently, there are modifications done in dimensions of ship and hull forms to reduce the total weight so as to move faster and consume less fuel. Increasing the length while reducing the beam and maintaining the draft, displacement and block coefficient (Cb) constant typically yields improvements in hull efficiency, provided additional ballast is not needed to maintain adequate stability. A higher length/beam ratio tends to reduce wave making resistance, while the reduced beam/draft ratio tends to reduce wetted surface and therefore the frictional resistance [7]. Hull form optimization is mostly done in fore and aft of ship. The modifications in hull design will greatly improve design efficiency. The improvement areas include

•Fore body optimization
•Aft body optimization
•Propeller wake optimization

The figure below describes the three main parts of a hull- fore part, middle part and aft part. It also determines the basic outline of measurements for optimizing the hull.

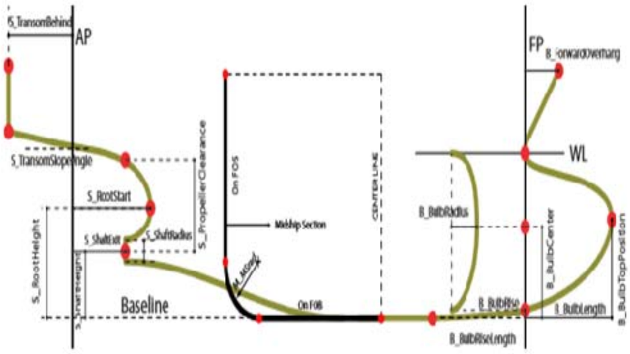

Figure 3: Exposed parameters for aft and bow parts of the ship and midship section.

2.1 Fore Body Optimization

The properly designed bulbous bow reduces wave making resistance by producing its own wave system that is out of phase with the bow wave from the hull, creating a canceling effect and overall reduction in wave making resistance. The flow is more horizontal, reducing eddy effects at the forward bilge. Physical factors considered in bulb optimization include volume, vertical extension of the center of volume, longitudinal extension and shape [6].

Improving bulb characteristics is a complex process. We should know what kind of bow matches with the design. There are different types of bulbous bow design like the pear shaped bow, Goose neck type bow, V shaped hull etc. These modifications can be done using advanced computer software's by fairing the B-spline and also checking the pressure variations towards the hull.

A bulb with a reverse pear- shaped section is primarily effective at the design condition; pear-shaped bulbs work best for drafts below the design draft. A V-shape may be introduced at the base of the bulb to mitigate slamming impact loads. Faster, more slender vessels favor larger volume and forward extension of the bulb. 'Goose-neck' type and stretched bulbs are particularly effective when draft and speed vary over a small range [13]. The characteristics of the bulbous bow must be carefully balanced with the shape of the entrance and the transition towards the forward shoulder and bilge. Bulbs are most effective at certain Froude number (speed-length ratio) and draft. Changes in speed and draft significantly change the wave created, such that reductions in draft or speed can actually lead to increases in wave making resistance. Maersk Lines reports fuel savings of over 5 percent by modifying the bulbous bow of a shipyard design which was optimized to the design draft, Hence it provided more favorable performance over the anticipated operating profile of drafts and ship speeds.

Bow flare also influences motions and added resistance in waves. V-shaped rather than U-shaped flare is generally preferred, as it tends to reduce motions without adding resistance. The increased resistance in heavy seas due to pronounced flare is currently not fully understood, and consequently rarely considered during the design process; however efforts are ongoing to develop an understanding [13].

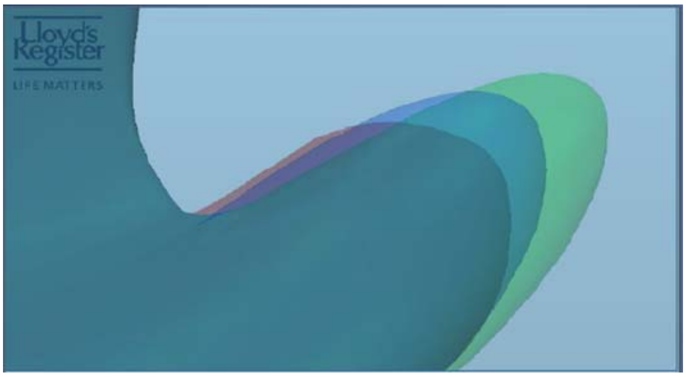

Figure 4: Bulbous bow variations.

According to Lloyd's register it says that variation in bulbous bow can give fuel saving of 3 tons per day for a feeder container ship. In the figure above blue color is the original shape, Red color gives the worst results and Green color is considered to give best results [11].

2.2 Modern Bow Designs

With the advancement in technology many well-known companies put a lot of emphasis on developing efficient hulls. One of the advances in forward hull design is done by 'Ulstein design companies'. They came up with a concept of X-bow hull design which introduces a larger and smoother volume distribution in the fore ship, which allows for submersion, combined with a sharper bow shape, the typical challenges of conventional bow shapes were solved. The shape of the hull has been optimized with a view to high top speeds, low resistance and reduced fuel consumption. Great emphasis has been placed on the crew's safety and comfort [15].

The key benefits of using this type of hull design are

- Elimination of slamming and bow impact.
- Soft entry in waves.
- Less spray.
- Low acceleration levels .
- Reduced vibration levels.
- Increased comfort and available crew rest time.
- Safer workplace due to smoother motions and protection provided by hull.

Figure 5- X bow type Hull

Another type of advancement in the forward part of hull design is done by Roll's Royce which got patented this year. The design features a bow with a vertical stem for a smooth entry into the water. When a wave is encountered, the hull shape pierces through the water rather than rides over the top, while the bulb contours the shape of waves along the ship's side to reduce wave resistance. The straight flare in the bow design also minimizes speed loss and slamming during operation.

2.3 Aft Body Optimization

Aft body optimization includes efforts to mitigate stern waves, improve flow into the propeller and avoid eddy effects. A properly designed stern can reduce the aft shoulder crest wave as well as the deep wave trough and stern waves. Improving the nature of the stern flow can lead to improved propulsive efficiency. The aft body optimization is a bit tricky when compared to forward part because of the appendages present like rudder, propeller etc.

Single screw sterns forward of the propeller may be V-shaped, U-shaped or bulb types. The tendency today is towards the bulb shape, as the improved wake reduces cavitation and vibration. This is one of environment friendly designs as these days, Pram type stern hulls are used to shift the longitudinal Centre of buoyancy(LCB) aft wards enabling smoother forward shoulders and lower waterline entrance angles which thus reduces resistance [1].

Three types of aft ship hull shapes could be distinguished:

a. Extreme pram type aft ships

b. Variations of a moderate pram type with a moderate stern bulb

c. Aft ship shapes featuring a moderate tunnel (originated from inland waterway vessels with draught limitations) [9].

Among the three types of aft ship hull shapes the third one is most efficient and latest in operation because it can allow a propeller with larger diameter with high efficiency and the tunnel shape ensures a steady flow into the propeller even in heavy seas, reduces propeller racing, providing sustained good thrust as shown in figure 5.

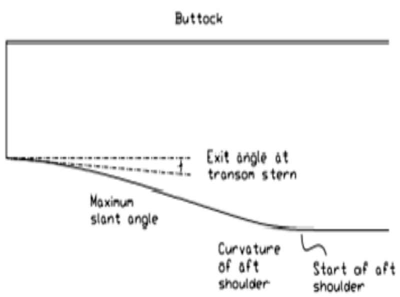

Figure 6: Aft hull seen from starboard side includes slant angle, exit angle and start of aft shoulder.

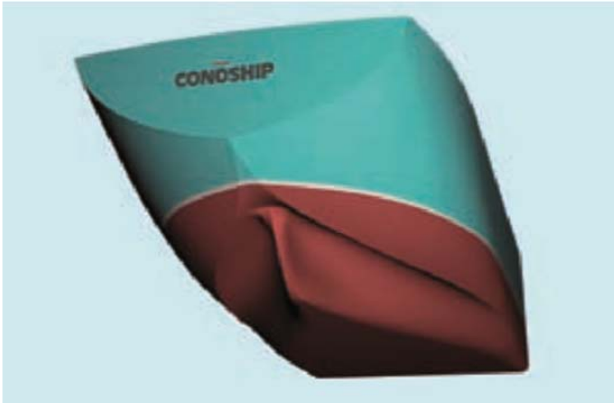

Figure 6: Moderate tunnel shaped aft ship.

When a ship hull is properly improved it can reduce resistance which means less power will be required to propel the ship. This will also help in reducing overall emissions from the engine, hence increasing the overall efficiency of ship.

2.4 Propeller Rudder Interaction

The efficiency of a ship also depends greatly on propulsive efficiency. There has been a regular study on propeller and rudder for a long time. With the developing technology engineers and designers of Rolls Royce have come up with a unique and interesting technology of Propeller and Rudder integration to satisfy the demands of energy efficient design. It is named as 'Promas Lite'.

Behind a normal propeller hub there is a strong low pressure vortex (hub vortex) that acts on the propeller hub, increasing drag and reducing propeller thrust. In the Promas lite a special hubcap is fitted to the propeller which stream- lines the flow onto a bulb that is added to the rudder, effectively reducing flow separation immediately after the propeller. The result is an increase in propeller thrust, as previously wasted energy is recovered from the flow. In addition, the bulb on the rudder also streamlines the flow aft of the rudder, further reducing drag. The hubcap is mounted outside of the propeller hub and acts purely as a hydrodynamic fairing. No special hub design is needed, thus cost and technical complexity is kept to a minimum [8,10].

Benefits of this design include:

•Reduced fuel consumption – improvements of between 5-15% is possible, depending on the vessel's operating profile.

•Reduced environmental impact – corresponding reduction in emissions with lower emission taxes, wake wash and noise.

•Short payback period – depends on vessel operating hours, but the return on invest- ment is often less than two years.

•Increased propulsive efficiency – integrated rudder and propeller design, reduced pressure pulses for improved comfort.

•Simple and quick installation – can be normally fitted within a week

•Lower maintenance costs – reduced engine loads means less oil consumption and potentially reduced engine wear.

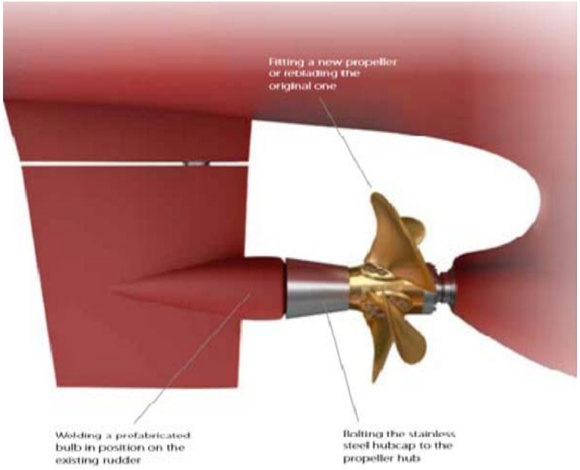

Figure 7: Propeller rudder interaction by Rolls Royce.

3.0 Analysis of Hull optimization and Fuel savings

The table shown is taken from a report of Lloyds's register. It describes that when a hull of a ship is optimized it affects the trim of ship ahead and aft. If we carefully distribute the weight along the length of ship and produce a stable trim a reduced resistance and savings on fuel oil consumption is found. This optimization was done on various ships types and it was found that there is a confirmed savings on fuel greater than 1-2% and improvement in ship speed. The resistance is minimized and also fuel oil consumption is reduced as less power is used to propel the ship at the same time increasing overall efficiency.

TRIM Optimisation	Design Year	FOC improvement expected / confirmed in Operation
VLCC	2006	>1% confirmed Saving abt. $250k/year
ULCS 13k teu	2007	>1% - 2% confirmed Saving abt. $700k/year
PCTC	2005	1 - 2% confirmed
87k dwt Bulk Carrier	2004	Speed-up experienced
Feeder Container		Speed-up experienced
MR Tanker		Speed-up experienced
32k dwt Bulk Carrier		0.2 knots increase on average speed for same FOC
General Cargo	2013	0.4 knots increase speed at 14 knots

Table 1- Trim Optimization

3.1 Examples of Hull optimized ships

If we analyze the table 2 and table 3 as shown below we can see that optimization of hull not only helps in fuel savings, but also helps in environment protection. The results are shown based on Lloyd's register survey which is one of the best classification societies and is involved in ship design for years. Table 2 shows the bulk carrier which was delivered in 2013 in this integrated hull form optimization has been done and its performance shows that it has high cargo volume and a great reduction of Co2 content i.e. EEDI 21% below required limit. It is highly environment friendly and if this technology is applied to most of the future ships then we can produce eco-friendly ships with high efficiency. Table 3 also describes a bulk carrier and optimization in its super structure and propeller also amounts to savings of at least 3% in fuel oil consumption and EEDI of 12% below required limit. These two ships have been proven to be efficient and environment friendly.

DeltaMarin B DELTA 39k dwt Bulk Carrier for CNCO Delivered in 2013	
INNOVATIVE SOLUTION	Integrated Hull Form Optimization
PERFORMANCE	• FOC of 18.5 t/day @ 4554 kW • EEDI 21% below required limit • High Cargo Volume • Shallow Draft • High Deadweight Design

Table 2- Integrated hull form optimization

VICTORIA STEAMSHIPS 95k dwt BC Flettner Rotors & Aerodynamic Accommodation	
INNOVATIVE SOLUTION	Optimization of Hull (Superstructure) and Propulsion) by Lloyd's Register , Nakashima and Flettner Rotors
PERFORMANCE	• Up to 3% FOC savings against 22 knots headwind • "Saving 700 kW" • EEDI about 12% below required limit • 15 t/day @ 10.5 knots!

Table 3- Optimization of hull and propeller

Developments of hull form is important to minimize the weight of the structure as this is related to resistance and to consume less fuel so that even our future generations use the natural resources and we provide them a cleaner blue planet.

3.2 Methods of Energy Improvement

To improve on fuel efficiency and ship efficiency we can use some methods that will improve the existing systems efficiency,

Optimization of Ballast and Trim-The Ballast, cargo and bunker distribution and the relationship between these are fundamental in giving the modern ship its optimal position in the water – a crucial consideration in optimizing fuel efficiency. If these operations are carefully carried on board it can save upto 4% of fuel [4].

Optimization of Propeller/Hull interface can also save upto 4% fuel saving.

Light weight construction that is reduction in the ship's weight can lead to reduction in the propulsive energy required and hence can lead to fuel savings.
Alternate Fuel engines can also help in saving fuel and environment protection.
Air Lubrication System-The frictional resistance of the hull can be quite significantly reduced by the introduction of thin layer of air pumped between hull and water. It can save upto 15% of fuel and increase ship efficiency [3].

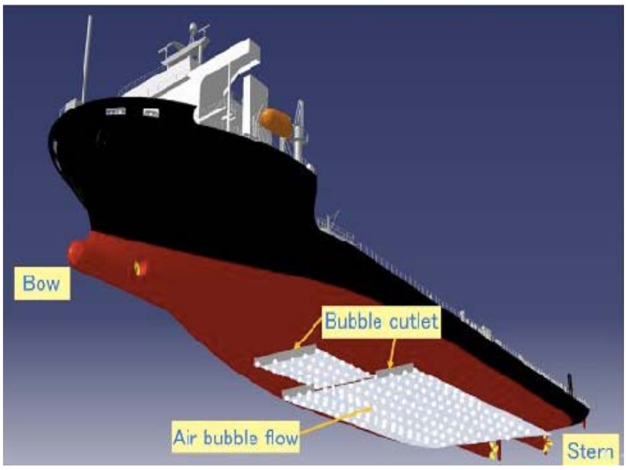

Figure 8: Ship Air Lubrication System.

Waste heat recovery system-The heat of the engine exhaust can be captured and converted into electrical power for on-board applications, mechanical power (e.g. shaft of a steam turbine, or used directly for heating, reducing the demand on auxiliary power generators can save upto 10% of fuel.

3.3 Expected Future Ship

In future some environmental friendly ships are expected one of them being 'The NYK Super Eco Ship 2030',It is so named because, with its energy efficiency, it is expected to produce far fewer CO2 emissions than current vessels. It is considered energy efficient design because the water resistance of its hull has been reduced by cutting down on its dead weight – a simple but effective solution to increase energy efficiency and also propulsion power is increased through the use of energy sources such as LNG-based fuel cells, solar power and wind power, which emit little or no CO2.It also refined the cost-saving model by creating an in-built loading system in the hull. The independent in-built cranes not only reinforce the ship's strength, but could reduce loading and unloading time, without relying on third-party onshore operators [14].


Figure 9: NYK ECO SHIP 2030.

4.0 CONCLUSION

In this paper, a brief analysis based on hull form is done to predict what kind of ships will be made in future and how efficient they will be. An optimized hull design is both cost effective and environment friendly. A well designed hull can reduce resistance and also reduce the emissions as there is a great saving in fuel oil consumption. The reduced emissions also help in reducing global warming. In terms of hull design we need to improve the fore and aft part of ship to get better efficiency. X bow type designs have been found efficient as they reduce slamming effect and are smooth in operation, they have been found to reduce the wave making resistance because of its sharper bow. In terms of aft body pram type hulls extended with a tunnel are found to be efficient because they allow a steady flow to the propeller and produces good thrust. For good propulsion and sea keeping it is important to have propeller rudder interaction which reduces fuel consumption and emissions. A integrated hull form optimization also helps in reducing noise and wake wash. Some other methods to reduce fuel consumption have been discussed which helps to improve overall ship efficiency. The ships in future will be efficient in terms of hull profile as well as reduce emissions so as to cater the needs for environment protection. A concept design of future ship named NYK eco ship has also been shown. This is just a beginning of a sustainable planet.

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Application of Dependency Structure Matrix Model in FPSO Electrical House Module Fabrication Scheduling

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ABSTRACT

The electrical House is a complete power plant system that supplies the electrical distribution network to site. Installation this power plant system have used in the world wide especially in industrial, utilities, renewable energy, outdoor switchgear and moveable substation. In offshore industries, application of Electrical House (E-House) can be installed in Floating Production and Storage Offloading (FPSO). As the engineering work is procedural and repeatable and complexity process, thus, problem happens stemming which involves interdependent such as feedback and iteration in designing and fabricating process that affect the schedule of the project. Project management tools such as CPM, PERT and Gantt widely used to scheduling application do not address complexity of the interdependency and feedback iteration. In this research discusses scheduling of FPSO E-House module Fabrication Model using Dependency Structure Matrix (DSM) method in order to address the complexity. Partitioning DSM process is to minimize the amount of iteration (iteration) within the process. As a result, reducing probability of iteration will affect to the time reduction to complete the project.

KEY WORDS: *Floating Production and Storage Offloading; Electric House; Dependency Structure Matrix.*

NOMENCLATURE

DSM	: Dependency Structure Matrix
FPSO	: Floating Production, Storage and Offloading
CPM	: Critical Path Method

1.0 INTRODUCTION

The increasing demand world-wide on oil and gas have given big impact in massive growth of offshore industry .Various companies oil and gas compete in step to design Floating Production, Storage and Offloading (FPSO) with complete Electric House (E-House). FPSO is a floating vessel used for the processing and storage of oil and gas. A FPSO is designed to receive oil or gas produced from nearby platforms or subsea template, process it, and store it until oil or gas can be offloaded onto a tanker or transported through a pipeline.

Electric house (E-House) is industrial electric plant which represents an innovative approach especially in oil and gas sector. The E-House with complete electrical and control equipment are located inside a single fabricated steel building. E- House also contain all necessary electrical equipment for the operation of the plant like medium and low voltage switchgear, the electrical control system, the motor control center, and transformers.

Installation E-House also gives various benefits such as reduce risk, reduce cost, reduce delivery time and ensure long- term support causes interest to clients, but more challenging in order to design and fabricate E-House due to the complexity of the processes and systems. Therefore, applying Dependency Structure Matrix (DSM) is the solution to address complexity and interdependency of fabrication and scheduling process. Floating Production Storage Offloading (FPSO) is standalone structure that do not need external infrastructure such as pipelines. The gas and oil are offloaded to a shuttle tanker at regular intervals which is depending on production and storage capacity. The FPSO currently is with a high storage capacity and deck load. The wellheads or subsea risers from the sea bottom are located on a central turret so that the ship can rotate freely to point into wind, waves or current. A variation of FPSO uses a circular hull, which shows the same profile to wind, waves and current regardless of direction. It does not rotate and therefore does not need a rotating turret.

1.1 Problem Statement

Since traditional management tools including PERT, CPM and Gantt chart cannot address feedback and iteration of the complex project. They only allow modeling of sequential and parallel process only. Dependencies structure matrix (DSM) present the new approach to improve the traditional management tools because of difficulties to reschedule of certain project due to repetition procedure and iteration of the complex project. As Adler et al (1996) have discussed about the problem of traditional tools where these tools fail in aiding firms to speed new products to market.

Therefore, this research is carried out to develop Design Structure matrix (DSM) scheduling for fabrication Electric House of FPSO and their application. The critical problem in this research is to identify the sequence that minimizes expected project completion time the sum of the expected stage times of all the activities for a set of activities with given activity completion times and iteration probabilities.

1.2 Research Objective

Main aim of this research is to develop Dependency Structure matrix (DSM) model scheduling for fabrication Electric House of FPSO Fabrication process is complex processes where need a managing tools to rescheduling the process properly. Suitable approach will reduce the cost and time risk in project. Analyze the comparison of the traditional management tools with the new approach basic theory of the DSM.

1.3 Scope of Study

This research will focus on the develop DSM model on the Electric House fabrication scheduling of FPSO. Fabrication scheduling of E-House is specially designed and manufactured according to individual set of requirements defined by the customer and will be installed on FPSO. Understanding FPSO E-House model and Dependency Structure Matrix (DSM) method is important in order to develop DSM model

2.0 LITERATURE REVIEW

Due to demanding the safety requirement in the oil and gas industries, E-houses represent an innovative approach to the electric power plants where it is completely designed and installed on FPSO. As Eppinger said “Engineering work is procedural and repeatable”. Complexity process will repeat again and again. Thus, problem happens stemming when complex processes which involves interdependent (feedback and iteration) in designing and fabricating of E-House. Various method use in project management such as PERT, CPM even GANTT also could not allow feedback and iteration of engineering work. They only allow for simple sequential and parallel process.

Originally, DSM proposed by Professor Don Steward of California State University, Sacramento (1970’s). He explained benefit of DSM method “to develop an effective engineering plan, showing where estimates to be used, how design iterations and reviews are handled and how information flows during the design work”. ”. Researcher has determined DSM is powerful management tool to plan sequence activity by feedback present and can manage the exchange. A model based method for organizing tasks in product development.

According to reference book introduction to design structure method, DSM is one of the new technique to help people especially project engineer to have better design, develop and manage complex system. This book defines DSM as a network modeling tool represent the element comprising and interactions in designed structure. DSM commonly use in engineering management area. However widely used in health care management, public policy, financial system and etc. This book focuses on DSM research and applications to date for complex system. Next, DSM reviewed their application by Browning (2001) and continued development other researcher Vieira and Richardson (2002) take a more practical approach by defining a method for analyzing software component dependencies.

Further development research on where DSM was began at NASA, Intel and General Motors until DSM research community exists late 1990s. DSM community massive growth involve worldwide researcher from various universities such as Australia, South America, Europe and Asia. DSM community also acts as software developers and consultants to DSM users. Various documents and different application had developed by researcher and can be found on DSM community website which is (www.dsmweb.org). This website proves the new development of DSM theory.

Research done by scientist before about DSM was proven more advantages of DSM method. According J.U. Maheswari, K. Varghese (2005) because of DSM in matrix form, they easy to read, able to translate to systematic mapping and easy to identify the sequences. They also said that even DSM powerful tool to plan sequence activity, however its application in scheduling is very limited. So far, DSM used enable to calculate the critical path by assigning the amount of effort or work done as duration each activity. Besides, advantages of DSM include also compact format, visual nature, intuitive representation, powerful analytical capacity, and flexibility.

DSMs have been developed for planning and managing projects in the building construction, photographic, semiconductor, automotive, aerospace, telecom, and electronics industries written by R. Browning (1998). This research shows important to improve project management tool of complex project by using Dependency Structure Matrix (DSM) method in offshore industries and develop DSM software for scheduling E-House fabrication of FPSO.

Indra Gunawan and Kamarul Ahsan (2010) said since traditional tool such as CPM and PERT do not work to address interdependency activities in terms of feedback and iteration, DSM approach to solve the problem since DSM used to represent the dependencies and show the sequence of activity that would be performed. In additional they use DSM to account for feedback and iteration.

Dr.Sc.Amra Talic-Cikmis (2013) used DSM method for solving problem in wind tunnel “Armfield C15-10” where is present the experiment of fluid flow over the air profiles. Because of DSM power, new computational DSM aid known as PSM 32 software is introduced. He agreed that DSM can minimize feedback within the design process

3.0 DEPENDENCY STRUCTURE MATRIX

What is Dependency Structure Matrix (DSM) all about? DSM is known as design structure matrix, dependency source matrix, and dependency structure method which is a basic matrix tool approach as management tools. A DSM also can be define as square matrix that have equal number of rows and columns (m x n). DSM also is general method representing the relationship between the activities of the project and provides concise way to present complex project.

3.1 DSM Data Types

Browing, (2001) have introduced where DSM can be represent in four different types data with different type analysis method with different application.

- **Task-Based** where data represent in task and activity relationship. This DSM type execute in project scheduling, sequence activities and minimize time cycle. Analysis method for this kind of data implement Partitioning, Tearing, Banding, Simulation and Eigenvalue Analysis.
- **Parameter-Based** is type of data which represent parameter decision points and necessary precedents. This type usually used for low level activity sequencing and process construction. Analysis method for parameter-based use Partitioning, Tearing, Banding, Simulation and Eigenvalue Analysis.
- **Team-Based** represent multi-team interface characteristics which use for organizational design, interface management, and team integration. Clustering as analysis method.
- **Component-based** is multi component relationship use in system architecture, engineering and design. Method use for analyze is clustering.

3.2 Type of Task Dependencies of DSM

According to (Yassine, 2005) dependencies can be divided into 3 types which are dependent, independent and interdependent as shown in the Figure.1 Sequential is dependent information where activity-2 related to activity-1. After activity-1 is completed, activity-2 is continued. This means one activity influences the decision and behavior of another activity. Besides, Parallel is known as independent information where relationship have not influence between two activities. For example, activity-2 does not interact with activity-3. Both activities can be performed simultaneously. Contrast for coupled relation where activity-2 influence flow activity-3 and activity-3 influence flow activity 2 (intertwined).

Figure.2 shows basic matrix activities schedule in matrix form and their relationship. Mark "x" in upper side is the continuity of the activities and lower side is the repetition activity. Refer to row activity-1, Activity-1 provides information to activity-2 and 4 which mean after finish activity-1 at certain time, flow proceed to activity-2 and activity-4 which is independently and not related to each other therefore the process can flow as parallel.

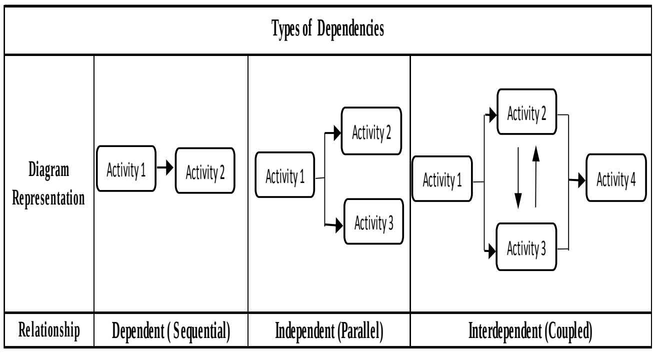


Figure 1: Types of dependency structure matrix

	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6
Activity 1		×		×		
Activity 2			×			
Activity 3		×			×	
Activity 4					×	×
Activity 5						×
Activity 6						

Figure 2: Shows the DSM in matrix layout

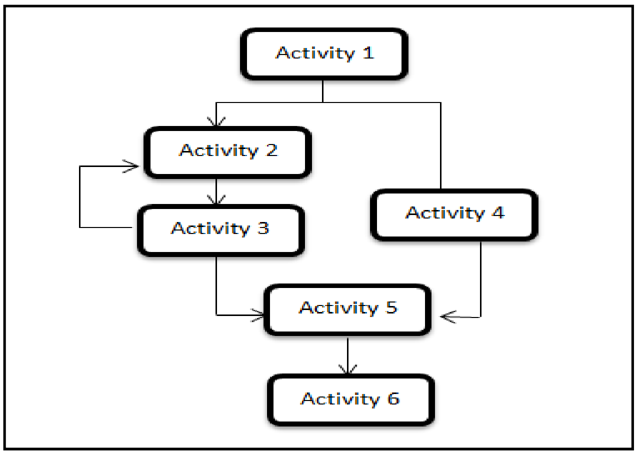


Figure 3: Shows the sequence of the DSM matrix

Of particular interest are cases where marks appear in the lower- triangular region of DSM. Activity-2 will have to make assumption about the information it needs from activity-3. Iteration may occur before activity-3 is begun and activity-2 is rework. Dependent relationship can be seen in activity-5 to 6 where after complete activity-5, activity 6 is continued till finish.

Mark at the lower- triangular reveal the chance of having iteration, which could have given impact on cost and schedule. In order to reducing the impact, bring the marks to the above or close to the diagonal which call partitioning analysis.

3.3 Type of Dependencies in Matrix Form

	A	B
A		X
B		

Dependent (Sequential)

	A	B
A		
B		

Independent (Parallel)

	A	B
A		X
B	X	

Interdependent (Coupled)

Figure 4: Type of dependencies in matrix form.

3.4 DSM Partitioning Analysis

Partitioning is the sequencing or reordering of the rows and columns of DSM with new arrangement which does not have feedback and looping mark at the below diagonal. The mark below diagonal is transformed into the above diagonal. Main goal of partitioning analysis is to eliminate the feedback and looping marks to move as close as the diagonal.

3.4.1 Path Searching

In path searching, information flow is traced either backwards or forwards until a task is encountered twice. All tasks between the first and second occurrence of the task constitute a loop of information flow. When all loops have been identified, and all tasks have been scheduled, the sequencing is complete and the matrix is in block triangular form.

An example of the path searching partition proceeds are started from original DSM as shown in Figure.5. Task F does not depend on information from any other tasks as indicated by an empty column. Schedule task F first in the matrix and remove it from further consideration as shown in the Figure.5.b. Task E does not provide information to any tasks in the matrix as indicated by an empty row. Schedule task E last in the matrix and remove it from further consideration as shown in the Figure.5.c. Now, no tasks have empty rows or columns. A loop exists and can be traced starting with any of the remaining tasks. In this case, we select task A and trace its dependence on task C. Task C is simultaneously dependent upon information from task A. Since task A and task C are in a loop, collapse one into the other and represent them in a single, composite task (i.e. task CA) as shown in the Figure.5.d. Task CA has an empty column indicating that it is not part of any other loop. Schedule it last and remove it from further consideration as shown in the Figure.5.e. Trace dependency starting with any unscheduled task: task B depends on task G which depends on task D which depends on task B. This final loop includes all the remaining unscheduled tasks as shown in the Figure.5.f. The final partitioned matrix is shown in the Figure.5.g.

	A	B	C	D	E	F	G
A			X				
B			X	X			
C	X						
D	X						X
E							
F			X		X		X
G		X	X				

Figure 5.a

	A	B	C	D	E	F	G
A			X				
B			X	X			
C	X						
D	X						X
E							
F			X		X		X
G		X	X				

Figure.5.b

	F	A	B	C	D	E	G
F				X		X	X
A				X			
B				X	X		
C		X				X	
D		X					X
E							
G			X	X			

Figure.5.c

	F	A	B	C	D	G	E
F				X		X	X
A				X			
B				X	X		
C		X					X
D		X					
G			X	X			
E							

Figure 5.d

	F	B	D	G	C	A	E
F				X	X		X
B			X		X		
D				X			
G		X				X	
C						X	X
A					X		
E							

Figure.5.e

	F	CA	B	D	G	E
F		X			X	X
CA	X					X
B		X		X		
D		X			X	
G		X	X			
E						

Figure.5.f

	F	B	D	G	CA	E
F				X	X	X
B			X		X	
D					X	
G		X			X	
CA						X
E						

Figure.5.g

Figure 5: An example of the path searching partition.

3.5 Type of Overlapping

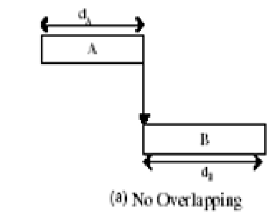
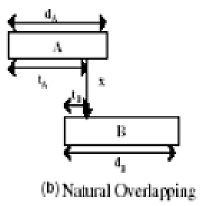
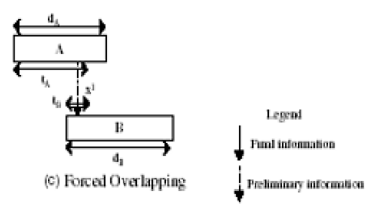
	Activity A give information to B. The duration of A is assumed to be d_A while B is d_B
	A release certain piece of information 'x' after t_A which is less than d_A and B require information after t_B which is less than d_b
	A is forced to release 'x' (in form 'x[1]') even or before t_A and/or B requires information before t_B

Figure 6: Type of overlapping of activities.

3.6 DSM Estimation Project Duration

According J.Uma Maheswari and Korshy Varghese (2005) proposed estimate the project Duration using DSM as formula below:

$$(ES)_i = (ES)_i + A_{ii}, \qquad 0 < i \le n \qquad (1)$$

$$(ES)_j = MAX[(EF)_i + A_{ji}], \qquad 0 < i \le n,\ 0 < j \le n \qquad (2)$$

Normal project Duration= $MAX[(EF)_j]$, $0 < j \leq n$ (3)

4.0 E-HOUSE CONSTRUCTION

Electric House is a complete power plant system that supplies the electrical distribution network to site. Installation this power plant system have used in the world wide especially in industrial, utilities, renewable energy, outdoor switchgear and moveable substation. As we can see, in offshore industries application, Electrical House can be installed in Floating Production and Storage Offloading (FPSO).

Despite Electric House contains medium and low switchgear voltage, but in sea application, Electric House practically functioning as power plant to control medium voltage power supply. Electric House is specially designed which consist of several main components which are switchgear room, emergency room, battery room, and transformer room. Before complete Electric House system is introduced, FPSO vessel received their medium voltage switchgear, auxiliaries' equipment and air conditioning systems from multiple electrical equipment suppliers and fabricator. As a result, increases in risk of integration error and costs probability system breakdown. Therefore, complete Electric House system act as solution.

There are many steps in fabrication sequence of E-House of FPSO as follows:

a) Temporary Stool Arrangement
b) Transportation Beam Arrangement
c) Column installation on Base Framing
d) 1st Floor Main Framing installation on Column
e) 1st Floor Secondary Framing to be installed on Main Framing.
f) Diagonal racing to be installed on 1st Floor Framing to Column
g) Column to be installed on 1st Floor Framing
h) Main Frame and Secondary member for Roof Framing to be installed onto Column
i) Floor plating 1st floor framing
j) Roof plating Installation
k) Crimped wall installed on module framing
l) Raised Floor Framing & Walkway Installation

Figure.7.a

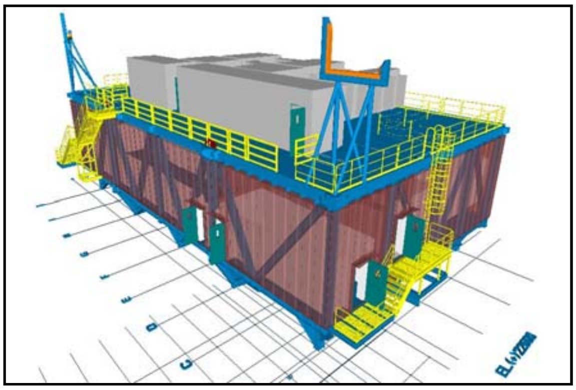


Figure.7.b

Figure 7: (a) Fabrication of the E-house and (b) Fabrication of a 3D model E-house.

E-house Fabrication Scheduling if Microsoft project manager is shown in the Figure.8 and development of DSM in visual basic program is shown in Figures 9 - 11.

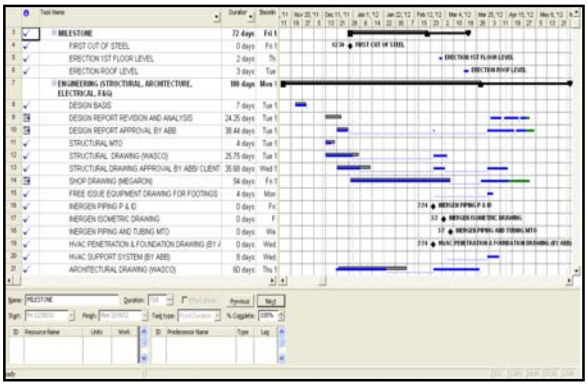


Figure 8: Schedule of FPSO E-house.

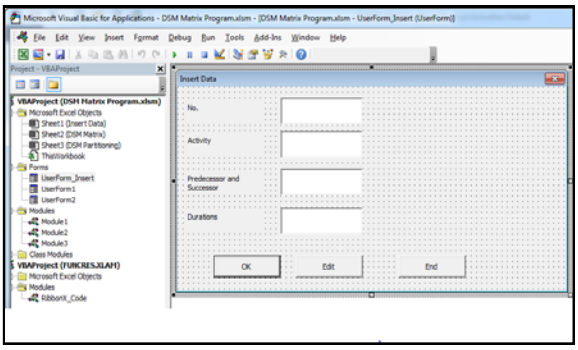


Figure 9: Microsoft Office Excel Visual Basic Programming for DSM.

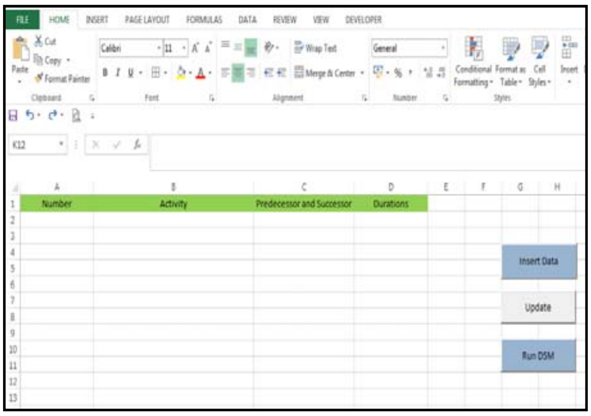


Figure 10: User Interface of DSM software

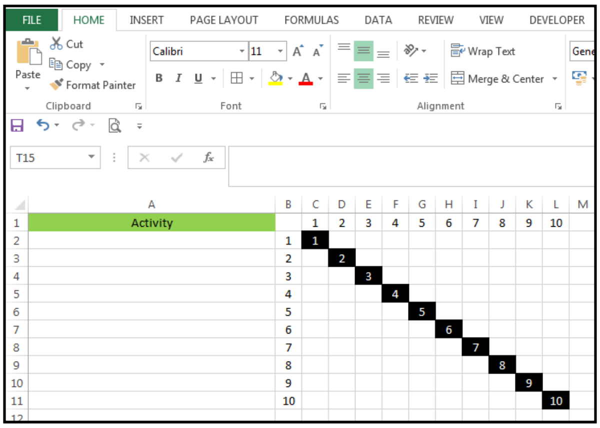


Figure 11: Sample User Insert number of element for DSM

5.0 RESULTS AND DISCUSSION

The scheduling of Electrical house of FPSO has been evaluated using the Dependency Structure Matrix model. The 1st stage of the Dependency Structure Matrix Model is shown in Figures.12 and 13. The overall result show a matrix form 134 by 134 completed with mark that show the dependencies of each activity. The dependencies include dependent, independent and interdependent. In this DSM form, below the diagonal show probability of interdependent activities which means activities that require rework and iteration. While, upper the diagonal show the sequences of the information flow.

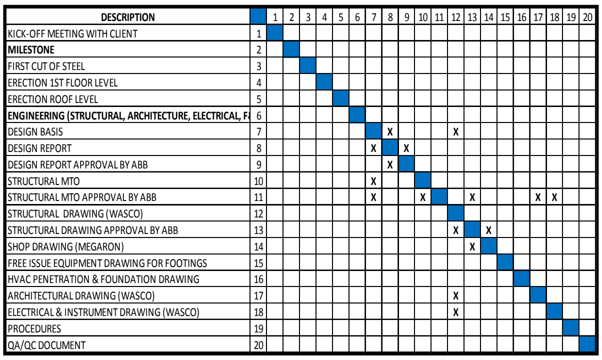


Figure 12: 1st Stage Dependency Structure Matrix Model

Since the DSM model in 134x134 matrix, it difficult to apply partitioning DSM analysis, the DSM model have be divided into 8 stages that transformed DSM model into smaller DSM matrix model as shown in Figure.14. Once the DSM is partitioned, activity in series are identified and executed sequentially. Independent activity can be executed concurrently**.** For interdependent activity ones, upfront planning is necessary.

A long the column, the first column show activates information. Second column and first row show the number of activities which important to identify the relationship of the activities. Major activities show in the DSM which include milestone, engineering (structural, architecture, electrical, etc), procurement, structural fabrication / installation, fabrication of the vertical columns/ wall, erection, blasting and painting, architectural fabrication/ installation, mechanical, electrical, testing and commissioning, preparation for load out.

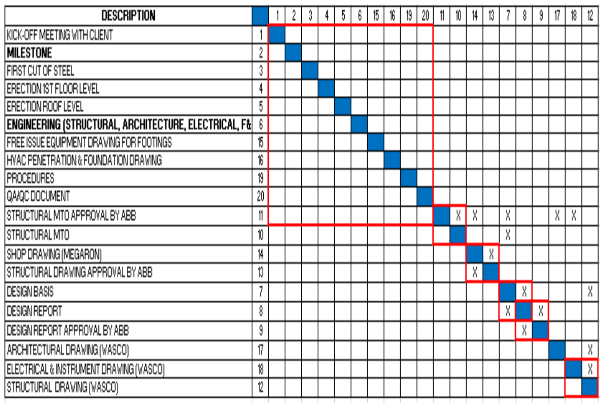


Figure 13: 1st Stage Partitioning Dependency Structure Matrix Model

STAGES	ACTIVITIES	NO. OF ITERATION BEFORE PARTITIONING	NO. OF ITERATION AFTER PARTITIONING
1	MILESTONE & ENGINEERING (STRUCTURAL, ARCHITECTURE, ELECTRICAL, F&G)	9	3
2	PROCUREMENT	1	1
3	STRUCTURAL FABRICATION / INSTALLATION	13	12
4	FABRICATION OF THE ROOF DECK	8	5
5	FABRICATION & INSTALLATION SUPPORT AND FOUNDATION	1	1
6	FABRICATION OF THE VERTICAL COLUMNS/ WALL, ERECTION, BLASTING AND PAINTING	16	15
7	MECHANICAL, ELECTRICAL	7	7
8	FREE ISSUED EQUIPMENT, TESTING AND COMMISSIONING,PREPARATION FOR LOAD OUT	7	7
	TOTAL	62	51

Figure 14: Number of iteration.

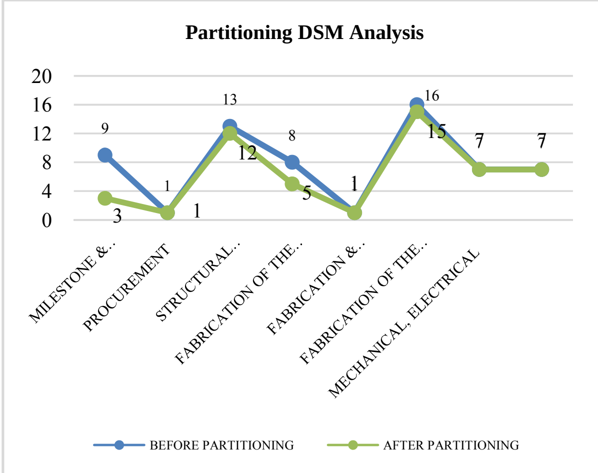


Figure 15: Partitioning DSM analysis.

In major activities also have sub activities such structural material, architecture material, electrical and instrument material, free issue, preparation, fabrication of the 1st floor deck, fabrication of the roof deck, fabrication & installation support and foundation, small power & lighting, instrument & equipment supply by client and free issued equipment.

In the partitioning of the DSM analysis, the differences of the DSM analysis before and after show reduction of iteration, even stage 5, 7, and 8 show same which do not show the reduction of the iteration as shown in Figure.15. This is because, some activities are not effect when applying the partitioning DSM, due to sequence constrained and in this research partitioning focusing on addressed to activities with no overlapping time and DSM basically rearranged the activities into parallel sequences.

Partitioning DSM model analysis, require procedure as step path searching. This method is processed reorder the sequence and minimizes the number of iteration and feedback. According the partitioning analysis DSM model result, reordering the activities by path searching enable the activities execute either dependent or independent only relationship into small block. In addition, in this research, only consider activities which no overlapping and ignoring the others. This is due to difficulties to address the overlapping activities. The DSM model also indicates the number of iteration where probability to rework again which is important to identify the interdependent activities of the whole activities.

In this research, application of DSM to the Electrical-House fabrication scheduling of FPSO shows reduction time in order to complete the project. Figure 6.6, shows reduction time of DSM Analysis which means by applying the DSM method time to complete the project reduced from actual time 130 days to 123 days as shown in Figures.16 and 17. Even only 5.4 percent improvement of DSM scheduling, but it will affect the overall schedule. Reduction of time will give benefit due to reduce risk and cost of the overall project.

STAGES	ACTIVITIES	Microsoft Project (Days)	DSM (Days)
1	MILESTONE & ENGINEERING (STRUCTURAL, ARCHITECTURE, ELECTRICAL, F&G)	125	124
2	PROCUREMENT	91	90
3	STRUCTURAL FABRICATION / INSTALLATION	62	61
4	FABRICATION OF THE ROOF DECK	27	26
5	FABRICATION & INSTALLATION SUPPORT AND FOUNDATION	16	16
6	FABRICATION OF THE VERTICAL COLUMNS/ WALL, ERECTION, BLASTING AND PAINTING	68	67
7	MECHANICAL, ELECTRICAL	40	40
8	FREE ISSUED EQUIPMENT, TESTING AND COMMISSIONING,PREPARATION FOR LOAD OUT	5	5
	TIME TO COMPLETE	130	123

Figure 16: Time reduction according stages.

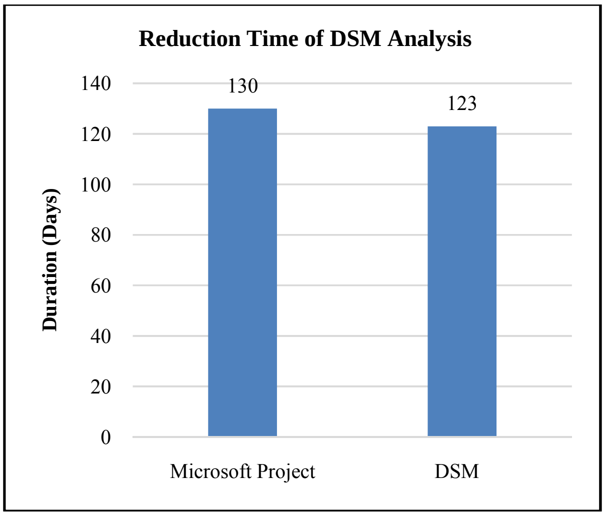


Figure 17: Time reduction using DSM compared to Microsoft project.

6.0 CONCLUSION

As conclusion of the study, Dependency Structure Matrix model has been applied for scheduling for fabrication of electric house of FPSO. The simulation results show construction time reduced 7 days due easy in managing of information exchange and plan the sequence.

ACKNOWLEDGEMENTS

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Feasibility of Using Surface Piercing Propellers and Diesel Engine for Small Scale Fishing Boats

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ABSTRACT

The rising of fuel price globally has adverse effects on the small-scale fishing industry. Presently, Malaysian small fishing boats use petrol (gasoline) outboard motor. However, petrol outboard engines have higher fuel consumption compared to diesel engines. The higher relative cost of petrol adds to the problem. Efforts to introduce diesel engines to the small boats are hampered by the size of the engines and the suitability of propellers. This paper describes a study to determine the potential using combination of surface piercing propellers and diesel engine in small fishing boats. An analysis of fuel consumption reduction will be presented, together with an economic feasibility study. This economic review will identify the fuel savings gained as to determine the simple payback period on the initial cost and conclude the viability of using the system in terms of fuel and overall monetary savings.

KEY WORDS: *Inshore fishing, Fuel saving, Surface piercing propeller.*

NOMENCLATURE

NPV	Net Present Value
HP	Horsepower
SPP	Surface Piercing Propeller
RM	Ringgit Malaysia
EAC	Equivalent Annual Cost
FC	Fuel Consumption

1.0 INTRODUCTION

The national fishery sector production value is worth 10.26 billion ringgit and inshore fishing constitutes about 53.71 % from total value and nearly half of the vessel is powered by petrol outboard motor [1].According to Pauzi et al.[2] fuel cost normally accounts for more than 50% of the annual operating expenses. The high fuel cost has exposed fishermen to uncertain future where fuel price in long term would keep increasing. Furthermore, the fisheries revenue is decreasing. Figure 1 shows a data of landing fish from 2006 to 2011. It can be seen from the graph that the fish landings value for inshore fishing shows a decreasing trend where offshore otherwise. This due to a small scale fishermen operation zone is limited to the coast or inshore because of the operations cost and safety factors as well as conditions of the boat that do not allow them to go further. Furthermore, alternative fuel saving technology such as solar and electric still far to be applied on traditional fishing boats due to lack of technology and financial constraints.

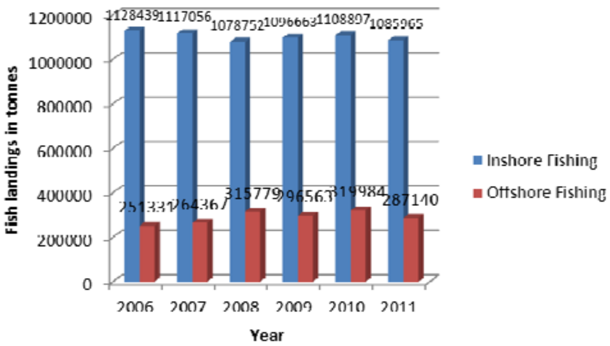

Figure 1: Landing of capture fisheries, 2006-2011[1].

It is believe that alternative methods such as promoting diesel engine can be potential solution to the growing prices crisis. According to Wilson [3], a diesel engine is about 2.4 times more fuel-efficient than a petrol engine. This is similar to findings in [4] which describes fuel consumption trials of petrol driven outboard engine and inboard diesel engine at speed of 5.5 knots. The fuel consumption data exhibits inboard diesel consumes 1 litre per hour while petrol consumes 2.5 litres per hour at 4HP and 7HP respectively. It is about 60% saving.The data highlights that diesel engine promised a fuel saving over petrol outboard motor. Beside the great advantage, diesel engine can run on fuels from renewable sources. One of example is biodiesel. Biodiesel is has properties which is similar to conventional diesel. This strengthens the reason why diesel engine can be as future more stable than fossil resources. In our previous paper [5], we proposed an alternative propulsion system using diesel and surface piercing propeller for inshore fishing boats. It has been shown that a fuel saving gain than outboards with acceptable speed performance. The fuel consumption analysis reveals about 40 % fuel saving can be gained as shown in Figure 2.

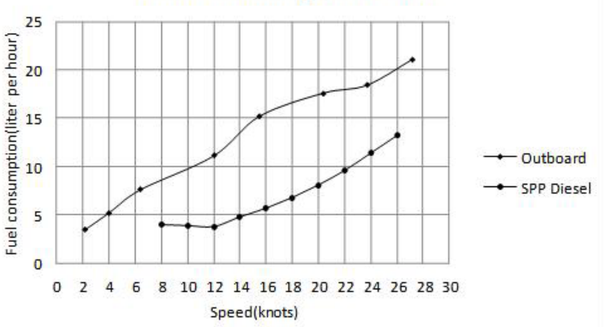

Figure 2: Fuel consumption curve comparison [5].

From the results, it can be a turning point for inshore fishing to adapt a diesel engine instead remains with outboard. However, the operation cost not only associated with fuel cost.it involves another such as initial cost and maintenance cost in order to meet the reality condition.Thus,the economic analysis should be carried out to validate the overall saving.

2.0 METHODOLOGY

In this paper, the fishermen community area at Manjung,Perak are selected as a location of case study and a 23 ft fiberglass fishing boat powered by 60 horsepower engine has been chosen. The methodology starts with identification of overall cost such initial cost, operation cost, maintenance cost, and salvage value. Other data required for this economic analysis such fuel consumption data, fishing route and fish catch, was based on estimation from findings and surveys. These data will be used to determine Net Present Value for both systems. During the research period, there is inconsistency in the data due to unstable economy market. As example, price of fuel changes several times while the research is conducted. Thus, some assumption has been made to simplify the economy analysis as follow:

a) The duration for every trip is constant.
b) Fuel consumption of both systems is constant for every trip.
c) The price of petrol and diesel is constant along the year.
d) The operational life is estimated for 10 years.
e) The maintenance costs are equal for both systems.

Analysis will also take into account fuel price with subsidy and without subsidy to further investigate the benefits of proposed system.

3.0 RESULTS AND DISCUSSION

3.1 Fuel consumption analysis

Fuel consumption analysis is the key factor in this study. The fuel consumption of any is proportionally to power used. The more power used to achieve desired speed, the more fuel consumed. The calculation of power used will indicate accurate fuel consume for every trip. The best approach to determine the accurate total fuel consumed is by calculate the actual speed at particular fishing trip route. The trip route are divided into three phase which are from the port, open sea and fishing ground as shown in Figure 3.

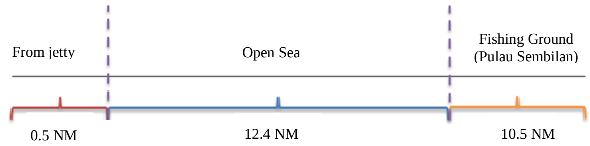

Figure 3: Fishing route.

The distance from jetty to river mouth is about 0.5 nautical miles. The common fishing ground for selected boat is Pulau Sembilan located 12.4 nautical miles from shore. From observation, the fishing route in fishing ground area is varying. It depends on the availability of fish stock and sea condition. Some of fishermen with higher engine capacity may go up to Pulau Jarak which is around 30 nautical miles off to west. From the figure, it can be seen that for every phase, the boat are propel at different speed level. From that, the average speed for each phase is calculated.The fuel consumption curve in Figure 2 is used to calculate fuel consumption per trip for each phase using interpolation method and results are presented in Table 1.

Table 1: Total fuel saving

	From Port	Open Sea	Fishing Ground	Total
Average speed(knot)	15.56	25.40	20.50	
FC outboard petrol (l/h)	15.22	19.71	17.62	17.52
FC SPP diesel (l/h)	5.50	12.66	8.51	8.89
Travelling time per trip (h)	0.01	2.00	1.00	3.01
Total fuel outboard (l)	0.15	39.42	17.62	57.19
Total fuel SPP diesel (l)	0.06	25.32	8.51	33.89
Fuel savings (liters)	0.10	14.10	9.11	23.31
Fuel savings (%)	63.86	35.77	51.70	40.75

The fuel consumption for each phase is calculated and summed.The fishing boat that uses outboard petrol consumes 57.19 liters of fuel per trip. If the boat uses SPP diesel it will consumes approximately 33.89 liters of fuel per trip. For overall fuel consumption, the percentage of fuel reduction is determined by obtaining the difference between amount of fuel used by outboard petrol and SPP diesel. The difference then divided with fuel amount of outboard petrol and multiplied with 100 to get the percentage. By using SPP diesel, it would give 23.31 liters of fuel saving or 40.75 % in percentage. The fuel saving gained in other hand give an extra mileage to fishermen. The government is giving a subsidy to fishermen as incentive to reduce fuel burden among Malaysian fishermen.

At the moment the industries enjoys government subsidies for fuel prices for both petrol and diesel at RM 1.25.The market fuel price for petrol and diesel without subsidy is RM 2.10 and RM 2.00 respectively .However, there is the challenge is where government now is starting to reduce fuel subsidy. As example, in 2011, government has cut of subsidy for offshore fishing boats. Therefore, to access a monetary saving, the calculation will consider both subsidize price and unsubsidized price of fuel costs. Table 2 shows a total fuel costs per trip for both systems. The total subsidized fuel cost of outboard petrol is RM 82.93 and RM 49.13 for SPP diesel. Meanwhile total unsubsidized fuel cost of both systems is RM 120.10 and RM 67.77 respectively. If the government cutting out subsidies on fuel, the fuel cost for SPP diesel is RM 67.77 which is still lower than fuel cost of outboard petrol with subsidy.

Table 2: Monetary saving

	Total fuel (liters)	Total fuel cost with subsidy(RM)	Total fuel cost without subsidy (RM)
Outboard Petrol	57.19	82.93	120.10
SPP Diesel	33.89	49.13	67.77
Cost Savings		33.80	52.33
Cost Savings (%)		40.75	43.57

3.2 Economic analysis

The economic analysis is carried out to determine the profitability of the SPP diesel compared to outboard petrol. This will includes calculation of Net Present Value (NPV) and Equivalent Annual Cost (EAC). NPV is difference between the present value of cash inflows and the present value of cash outflows. Cash flows diagram are used to presents the summarized cost and benefits of projects over a time. Table 3 shows Net Present Value of both cases for comparison. For 10 years operational life, SPP diesel gives a savings of RM 3962 per year. This result has proved that using SPP diesel is more economical and monetary savings. From Figure 4 and Figure 5, it can be said that large portion of saving are gained from reduction in operation cost where majorly contributed by less fuel consumption of SPP diesel.

The aim of economic analysis is to determine whether a proposed system is feasible to be applied. In this study, two methods had been used, which were NPV and EAC. The use of NPV showed higher positive value at RM64636 for 10-year lifespan. It must be noted that the interest rate of 0.1 and salvage depreciation rate of 10% were used for this study, but those values may not totally reflect the reality if inflation is extremely fickle.

Table 3: Net present value

	Outboard Petrol Engine	SPP Diesel Engine
Initial cost, P_O	RM 21000	RM 23200
Annual operation cost,A_1	RM 22971	RM 16213
Salvage value, F_O	RM 7322	RM 8099
Annual income, A_2	RM 30000	RM 30000
Interest rate, *i*	0.1	0.1
Lifespan, *n*	10	10
(P/A/i/n) at 10%	6.1446	6.1446
(P/F/i/n) at 10%	0.3855	0.3855
Net Present Value	RM25010	RM64636

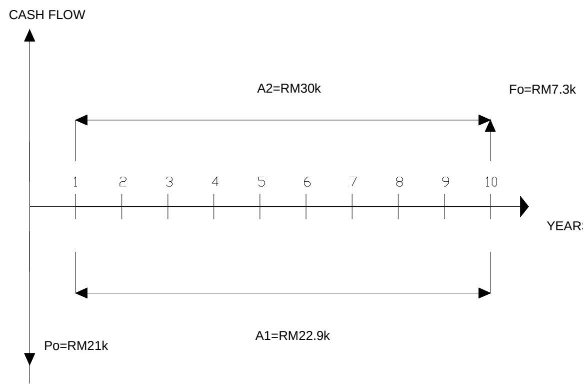

Figure 4: Cash flow diagram for fishing boat using outboard.

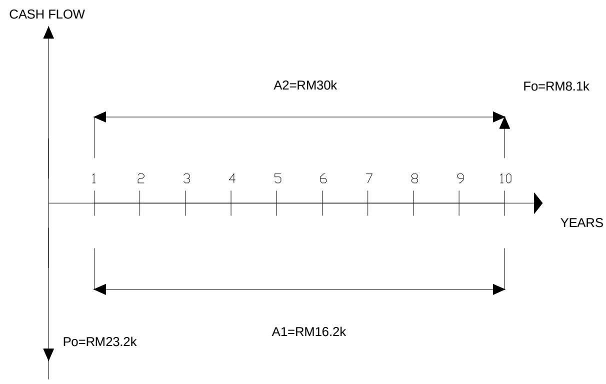

Figure 5: Cash flow diagram for fishing boat using SPP diesel.

The use of EAC can reduce the annual cost as much as 24%. The estimation of costs for proposed system, maintenance/repair and engine lifespan, however, might not be absolutely correct. However, as economic simulation, the most important is to achieve reduction in fuel consumption and fuel cost.

Even though the initial cost of SPP diesel engine is much higher than that of outboard engine, the expenditure can be reduced from operation cost. The operation cost per year for SPP diesel engine can be significantly reduced as much as RM6758, which is majorly contributed from reduction of fuel cost. The use of diesel driven propulsion system instead of petrol outboard motor can result in considerable cost savings, and thereby improved economic performance.

4.0 CONCLUDING REMARKS

The outcome of this paper has proved the combination of diesel with SPP offer less fuel consumption compare to outboard. Techno economic analysis reveals that it financially viable to be adapt and increase the turnover fish landing and give a significance contribution to sustain fisherman livelihoods.

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