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Web-Based Software Design of Tanker Ship Load Handling and Development

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Abstract*:* This study aims to design software used for planning web-based tanker cargo handling. The expected output target is the publication of accredited scientific journals and can be presented as a keynote speaker at national and international seminars. This type of research is Research and Development (R&D) with the development method using a modified Four D. The simulator design consists of 4 stages, namely Defining, Design, Development, and Deployment, so that can later use the software for planning web-based tanker cargo handling. The results of the simulator design that has been developed are as follows; Simulator can display ship data, Simulator can display displacement, Simulator can display GM (Metacentric high). In conclusion, the simulator design process broadly consists of four stages; Define, Design, Development, and Dissemination. The simulator design that have been developed are as follows; Simulator can display ship data, Simulator can display payload planning, Simulator can display ship stability calculation, Simulator can display displacement, Simulator can display GM (Metacentric high).

Keywords: *Load planning (stowage plant), Software, Tanker, Web.*

1. Introduction

Indonesia is an archipelagic country located in Southeast Asia. The territory of Indonesia is in a cross position, which has an important meaning for the economy. Indonesia's strategic geographical situation can be a strength and opportunity for developing the Indonesian economy. The spearhead of economic development is not just carrying out fuel oil distribution (BBM) throughout the country [1].

Several movements occur on the ship (ship motion) caused by external and internal forces [2]. These movements include hull motion or surging motion (movement of the ship towards the front and back of the ship), swaying motion (movement of the ship to the side), surging motion or heaving motion (movement of the ship in a vertical direction), swaying or rolling motion (the motion of the ship with a rotating axis that extends along the ship's centre of gravity), nodding motion or pitching motion (the motion of the ship with a rotating axis that crosses the ship and passes through the ship's centre of gravity), and Joli motion or yawning motion (the rotational motion of the ship on the wave with the axis of rotation of a vertical line approximately passing through the centre of gravity of the ship) [3]. In this study, software was designed to plan cargo handling on tankers so that the ship's stability is good, influenced by external and internal forces.

The movement focused on in this research is the swaying or rolling motion, often also referred to as the transverse stability of the ship. This movement is very risky to the safety of the ship. A ship needs better stability to make it capsize or sink. Research in the field of ship stability has been widely carried out, including the influence of the KG value (the distance from the centre of gravity to the bottom of the ship vertically) on the amount of cargo carried by ship, where this KG value affects the stability of the ship [4].

The change in displacement due to the modification of the fish hold on the ship will affect the ship's stability in the form of changes in the GM value [5]. The GM is the distance from the point of gravity to the metacentre point across the ship. Changes in ship geometry will affect the stability characteristics of the ship, where the greater the ratio of the width and height of the ship, the better and stability of the ship; the greater the ratio of the hull and width of the ship, the better the ship's stability [4].

Manually calculating ship stability can help predict the ship's stability in an entire state (intact stability) [6]. The manual calculation can be used as a reference and approach in determining ship stability if application software is not yet available. Rachman et al. [7] introduced manual calculation of the ship by dividing the ship into various drafts and inclination angles (0-90o). Until now, manual calculations have become a reference widely applied in various software in calculating ship stability. However, the process provided is not practical. In addition, various difficulties were found, such as requiring more time and accuracy in reading the length of each ship station. In other words, computer software is still needed to validate the analysis results. Calculate the enforcement arm and ship stability using the primary size input, shape coefficient, and other parameters [8]. This calculation method is much simpler compared to others. However, due to limited information and difficulties finding related literature, the method in Manning's book has not been widely applied in scientific research. In this study, an analysis of the static and dynamic stability of the tanker was carried out to determine the value of GZ as a reference for determining good stability and determining the *ndongak* and *nungging* period that the ship can accept. The analysis is carried out using the help of software and

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calculation formulas.

2. Literature Review

Stability is the ship's balance, which is a ship's nature or tendency to return to its original position after getting stung (tilt) caused by external forces [9]. Penambahan et al. [4] state that stability is the ability of a ship to stand back up when the ship is stung because the ship is getting external influences, such as wind, waves, and many more.

In general, the things that affect the balance of the ship can be grouped into two major groups; internal factors, namely the layout of the cargo, the shape of the size of the ship, leakage due to collision and external factors, and external factors, namely wind, waves, currents, and storms [10].

Therefore, stability is closely related to the shape of the ship, cargo, draft, and size of the GM value. The position of M is almost fixed according to the style of the ship, the centre of buoyancy B is driven by the draft, while the centre of gravity varies in position depending on the load. While point M depends on the shape of the ship, and its relationship with the shape of the ship, namely the width and height of the ship, if the width of the ship widens, then the position of M increases and will increase the influence on stability. Concerning the shape and size, calculating the ship's stability is very dependent on several basic sizes related to the ship's main dimensions.

The basic measurements that are the basis for measuring ships are length, breadth, depth, and draft [11]. As for the length in the measurement of the ship, several terms are known, such as LOA (Length Over All), LBP (Length Between Perpendicular), and LWL (Length of Water Line).

Some things that need to be known before calculating ship stability are: (a) The submerged weight (gross content) or displacement is the number of tons of water displaced by the submerged portion of the ship in the water. (b) Empty ship weight (Light Displacement) is the weight of an empty ship, including machinery and equipment attached to the ship. (c) Operating load (OL) is the weight of the facilities and equipment to operate the ship, where the ship cannot sail without this tool.

$$\mathbf{Displ = LD + OL + Capacity}$$
$$\mathbf{DWT = OL + Capacity}$$

Based on its nature, ship stability or balance can be divided into two types: static stability and dynamic stability.

Static stability is intended for ships at rest and consists of transverse and longitudinal stability [10]. Transverse stability is the ship's ability to stand upright when subjected to shocks in the transverse direction due to external influences acting on it. In contrast, longitudinal stability is the ship's ability to return to its original position after being shaken in the longitudinal direction by external influences acting on it. The transverse stability of the ship can be divided into small stroke angles (00-150) and large stroke angles (>150). However, for initial stability, it is generally taken into account only up to 150 and in the discussion of transverse stability only.

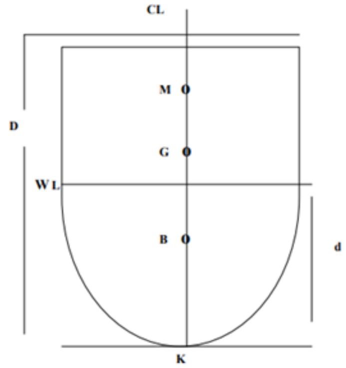
Meanwhile, dynamic stability is intended for ships shaking or nodding or when they have a significant stroke. In general, the ship only has a minor stroke. Then, a big shock, for example, exceeding 200, is not a common thing to experience. These big shocks are caused by several conditions, such as a storm, giant swing, or an internal force, including an opposing GM.

Instability theory, the term initial stability is also known, namely the ship's stability at a slight sting (between 00-150). Three points determine initial stability, namely the centre of gravity or commonly referred to as point G, the point of buoyancy (Centre of buoyancy) or point B, and the point of meta-centric (Meta centric) or point M.

There are three kinds of stability, namely Positive Stability (stable equilibrium), a condition where point G is above point M so that a ship with steady stability, when stinging, must have the ability to straighten again. Neutral stability is a state of stability where point G coincides with point M, so the moment of the ship's erection with neutral stability is equal to zero or cannot re-erect while swaying. Negative stability (Unstable equilibrium) is A state of stability where the point G is above the point M so that a ship that has negative stability when slinging cannot stand back up, even the angle of the stroke will increase, which causes the ship to tilt again and even become capsized.

Essential points in stability include the centre of gravity (G) (centre of gravity), known as the point G of a ship, which is the point of capture of all the downward forces on the ship. The location of this point G on the ship can be known by reviewing all the weight distributions. The more weight placed on the top, the higher the location of the G point. The floating point (B) (centre of buoyancy), point B of a ship, is the point of capture of the resultant forces pushing vertically upwards of the submerged portion of the ship. Catch point B is not a fixed point, but will move around by changes in the draft of the ship and point M The metacentric point of a ship, is a pseudo point of the boundary where point G should not pass above it so that the ship still has positive stability (stable). Meta means changing, so the metacentric point can change its location depending on the magnitude of the strike angle.

Fig. 1. Key points in stability.



Information: K = Keel
B = Buoyancy
G = Gravity
M = Metacentric
d = Ship draft
D = Depth
CL = Centre Line
WL = Water Line

The main dimension of ship stability includes:

2.1. KM (Height of the metacentric point above the keel)

KM is the vertical distance from the keel of the ship to the point M, or the sum of the distance from the keel to the floating point (KB) and the distance from the floating point to the metacentric (BM) so that the formula can find KM:

$$\mathbf{KM = KB + BM}$$

It is obtained from the metacentric diagram or hydrostatical curve for each current draft.

2.2. KB (Floating point height of keel)

The location of point B above the keel is not a fixed point but moves around by changes in the draft or sting of the ship [8]. KB value can be searched:

Table 1. KB value.

For bottom plate type ships, KB	0,56d
For ship type V bottom, KB	0,67d
For U bottom type ships, KB	0,53d

Whereas d = ship draft

From the metacentric diagram or hydrostatic curve, where the value of KB can be found at each current draft of the ship.

2.3. KB (Floating Point Height of Keel).

According to Alfiyan and Winarno [12] BM is called the metacentric radius. After all, if the ship churns with small angles, then the movement trajectory of point B is part of a circular arc where M can still be considered fixed because the swing angle is slight (100-150).

BM = b2/10d, whereas:
b = ship width (m)
d = shift draft (m)

2.4. KG (Height of Centre of Keel)

The KG value for the empty ship is obtained from the inclining experiment. Then the KG can be calculated using the moment theorem:

KG total = ∑ M / ∑ W

Whereas, ∑ M = Number of moments (ton) (1)
∑ W = the number of times the center of gravity multiplied by the object's weight (m ton) (2)

2.5. GM (Metacentric Height)

Metacentric height (GM) is the vertical distance between points G and M. From the formula it is stated:

GM = KM -KG

GM = (KB + BM) - KG

This GM value indicates the initial stability of the ship or the stability of the ship during the later voyage.

2.6. Righting Moment and Righting Arms

The enforcement moment is the moment that will return the ship to its upright position after the ship tilts because of external forces, and these forces are no longer working [13].

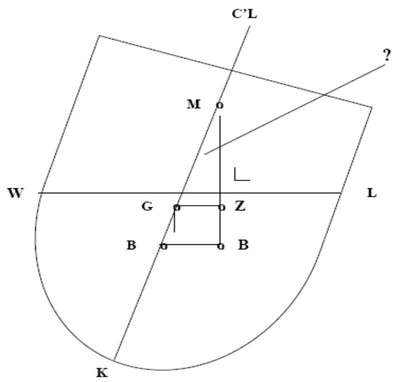


Fig. 2. Elevating moment or enforcing arm.

To calculate the GZ value as follows:
Sin α = GZ / GM
GZ = GM x Sinus α
Enforcer moment = W x GZ

2.7. Free Surface Effect

Free surface occurs in the ship when there is a liquid surface that moves freely when the ship is rocking at sea and the liquid in the tank is moving. As a result, the centre of gravity of the liquid is no longer in its original place [14]. The point G of the liquid is now above the liquid, and this phenomenon is called the apparent increase in the centre of gravity. Thus, it is necessary to correct the GM value, which we calculate from the apparent increase in the centre of gravity of the liquid when the ship is cranking so that a practical GM value is obtained.
Calculations for free surface correction can use the formula:

$$gg_1 = r.x\frac{1\ x\ b^3}{12\ x\ 35\ x\ W} \qquad (1)$$

Whereas;
gg1 = vertical shift of point G to G1
r = the specific gravity in the tank divided by the density of the liquid outside the vessel
l = tank length
b = tank width
W = ship displacement

There are two types of tankers: product tankers and crude carriers. Apart from that, there are more specialized tankers, such as chemical tankers, gas carriers, and asphalt/bitumen carriers. FSO/FPSO vessels also work as shelters in crude oil exploration areas. Until 2016, there were 7,065 Oil Tankers in the world. Oils with a gravity of more than 40 degrees are considered light oils, while oils with a gravity of less than 20 degrees are considered heavy oils.
Crude oil with gravity between 20 to 40 degrees is called medium oil (moderate). In addition to density, the sulphur content (sulphur) will determine the purity of crude oil; this factor also determines the classification of crude oil as sweet (sweet) or sour (sour). Sulphur is acidic, so the higher sulphur content means it is considered acidic, while less sulphur is classified as sweet.
Product loads are divided into two, which include clean product oil and dirty product oil. Light oil products, such as gasoline, kerosene, and gasoil, are called clean product oil, while heavier ones, such as fuel oil and residue, are called dirty product oil. The purpose of this research is to design software to describe the results

and process of designing web-based tanker cargo handling planning software.

3. Research Method

This research is development research. In this development research, the researcher develops a product based on a pre-existing product with a different concept. Then it is developed by reviewing the literature and studies from experts. Researchers involve experts, lecturers, and cadets in developing these products so that they can produce products in the form of web-based container shipload planning software with good quality.
This research focuses on product development in the form of web-based container ship cargo handling planning software at the Surabaya Shipping Polytechnic. This research by Kurniawan and Dewi [15] uses the Thiagarajan development process known as the Four-D model or a modified 4D model.
According to Kurniawan and Dewi [15] there are four steps to developing a product. In carrying out the four steps of the product development process, it can be seen in the flow chart as shown in the following figure:

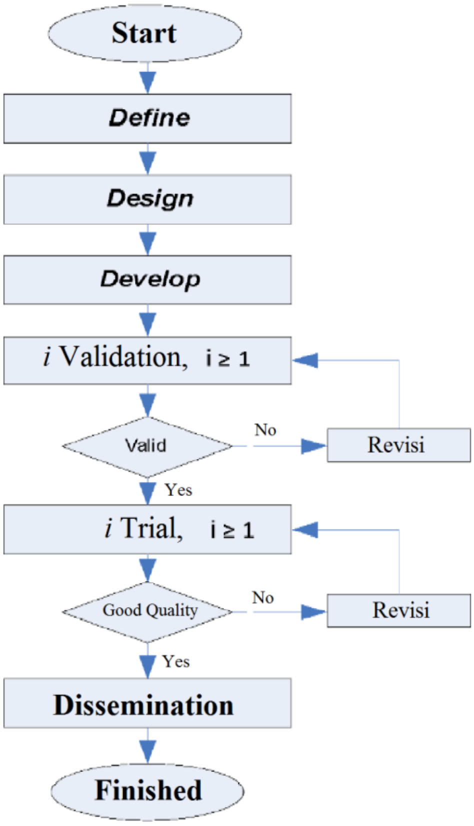


Fig. 3. 4D development model flowchart.

While the procedure for planning cargo on tankers is shown in the following flowchart:

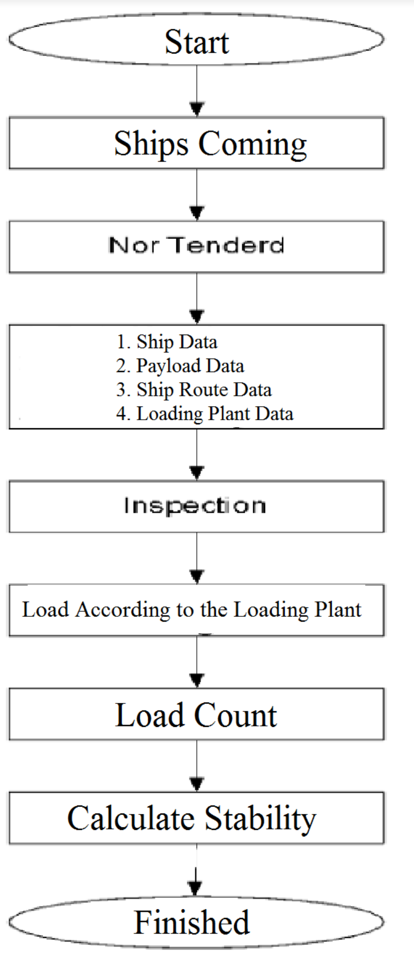


Fig. 4. Tanker cargo handling design flowchart.

4. Result And Discussion

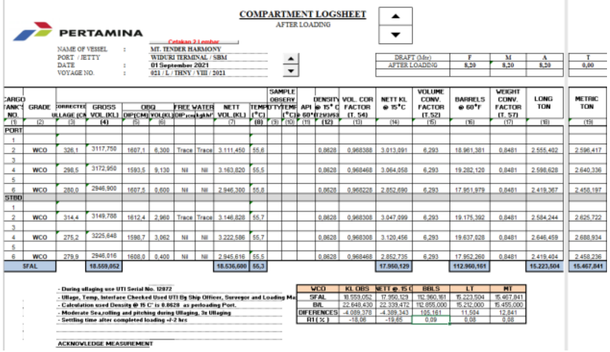
The development carried out in this study follows the stages of the modified Four-D Model 4D development model, namely Define, Design, Develop, and Dissemination. The simulator developed in this study is a simulator for cargo planning and ship stability on tankers. The results of the research at each stage can be described in more detail as follows:

4.1. Description of Define

In this step, what has to be done are:

4.1.1. Ship type identification

The type of ship used is a tanker. A ship used to transport liquid cargo between islands in Indonesia. The following is the ship data used in this study:



PERTAMINA

COMPARTMENT LOGSHEET
AFTER LOADING

NAME OF VESSEL : MT. TENDER HARMONY
PORT / JETTY : WIDURI TERMINAL / SBM
DATE : 01 September 2021
VOYAGE NO. : 021 / L / THNY / VIII / 2021

DRAFT (Mtr)	F	M	A	T
AFTER LOADING	8,20	8,20	8,20	0,00

CARGO TANK'S NO. (1)	GRADE (2)	CORRECTED ULLAGE (CM) (3)	GROSS VOL (KL) (4)	OBQ DIP (CM) (5)	OBQ VOL (KL) (6)	FREE WATER DIP	FREE WATER kg/kl	NETT VOL (KL) (7)	TEMP (°C) (8)	SAMPLE OBSERV TEMP (9)	(°C) (10)	API @ 60°F (11)	DENSITY @ 15°C (12)	VOL. COR FACTOR (T. 54) (13)	NETT KL @ 15°C (14)	VOLUME CONV. FACTOR (T. 52) (15)	BARRELS @ 60°F (16)	WEIGHT CONV. FACTOR (T. 57) (17)	LONG TON (18)	METRIC TON (19)
PORT																				
1																				
2	WCO	326,1	3117,750	1607,1	6,300	Trace	Trace	3.111,450	55,6				0,8628	0,968388	3.013,091	6,293	18.961,381	0,8481	2.555,402	2.596,417
3																				
4	WCO	298,5	3172,950	1593,5	9,130	Nil	Nil	3.163,820	55,5				0,8628	0,968468	3.064,058	6,293	19.282,120	0,8481	2.598,628	2.640,336
5																				
6	WCO	280,0	2946,900	1607,5	0,600	Nil	Nil	2.946,300	55,8				0,8628	0,968228	2.852,690	6,293	17.951,979	0,8481	2.419,367	2.458,197
STBD																				
1																				
2	WCO	314,4	3149,788	1612,4	2,960	Trace	Trace	3.146,828	55,7				0,8628	0,968308	3.047,099	6,293	19.175,392	0,8481	2.584,244	2.625,722
3																				
4	WCO	275,2	3225,648	1598,7	3,062	Nil	Nil	3.222,586	55,7				0,8628	0,968308	3.120,456	6,293	19.637,028	0,8481	2.646,459	2.688,934
5																				
6	WCO	279,9	2946,016	1608,0	0,400	Nil	Nil	2.945,616	55,5				0,8628	0,968468	2.852,735	6,293	17.952,260	0,8481	2.419,404	2.458,236
SFAL			18.559,052					18.536,600	55,3						17.950,129		112.960,161		15.223,504	15.467,841

- During ullaging use UTI Serial No. 12072
- Ullage, Temp, Interface Checked Used UTI By Ship Officer, Surveyor and Loading Ma
- Calculation used Density @ 15 C° is 0.8628 as perloading Port.
- Moderate Sea,rolling and pitching during Ullaging, 3x Ullaging
- Settling time after completed loading +/-2 hrs

WCO	KL OBS	NETT @ 15 C	BBLS	LT	MT
SFAL	18.559,052	17.950,129	112.960,161	15.223,504	15.467,841
B/L	22.648,430	22.339,472	112.855,000	15.212,000	15.455,000
DIFERENCES	-4.089,378	-4.389,343	105,161	11,504	12,841
R1 (%)	-18,06	-19,65	0,09	0,08	0,08

ACKNOWLEDGE MEASUREMENT

Fig. 5. Ship data and type.

In the picture above is the MT Tanker Ship data. Tender Harmony is Owned by PT. PERTAMINA.

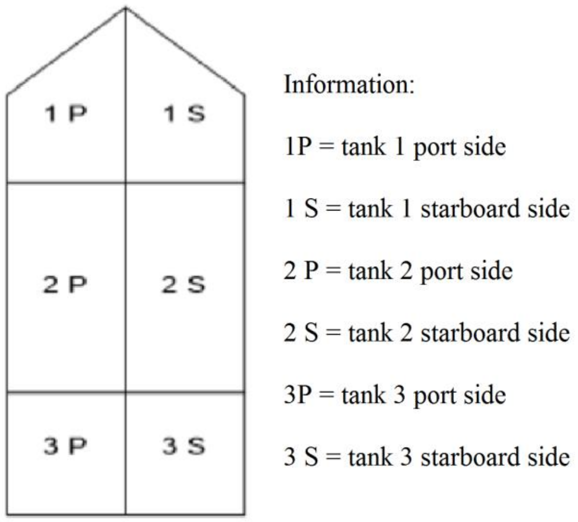


Fig. 6. Ship tank data.

4.1.2. Identification of tank table

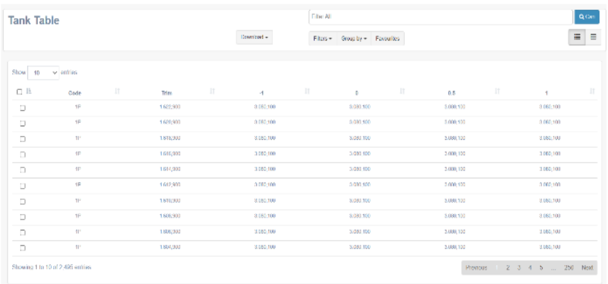


Figure 7. Data tank table

The picture above is a Tank table that compares the volume of liquid contained in the tank and the depth of the liquid.

4.1.3. Identify initial conditions

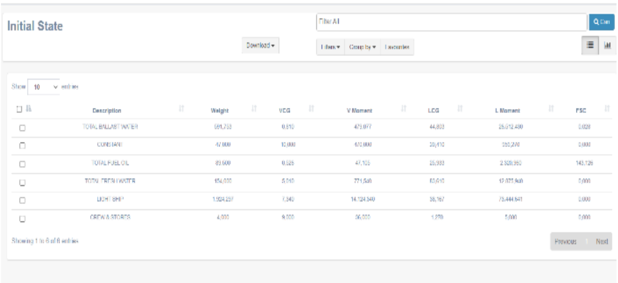


Fig 8. Initial condition

The table above contains initial conditions before loading and a summary of total ballast water, content, fuel oil/BBM, freshwater, lightship, and crew & stores.

4.1.4. Identification of compartment table

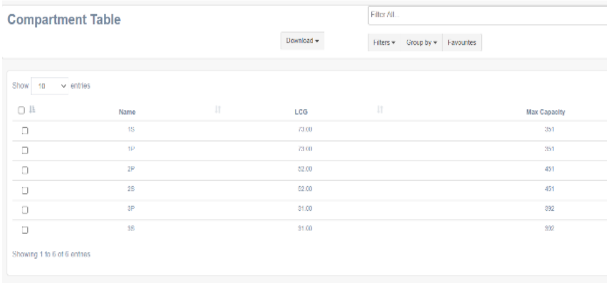


Fig 9. Compartment table

Loading data compartment includes Longitudinal Center of Gravity (CG) and Maximum Capacity.

4.1.5. Identification of Hydrostatic Table

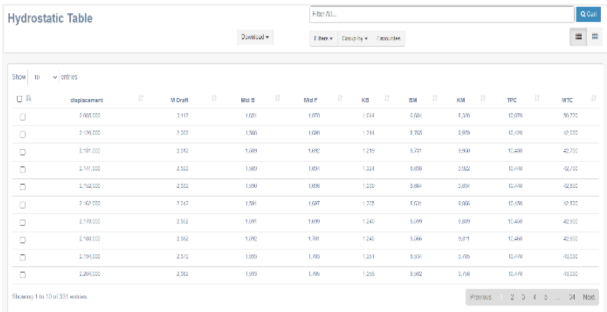


Fig 10. Hydrostatic table

4.2. Description of Design

In this step, what has to be done are:

4.2.1. Simulator aim

The goal at the design stage is to make a simulator in the form of software that can display cargo planning and determine the stability of the tanker.

4.2.2. Scope

The simulator developed is focused on cargo planning and knowing the stability of the tanker in one trip. The charge used is liquid.

4.2.3. Trial schedule

At this stage, the trial planning schedule is carried out. The planning schedule is presented in the following table:

Table 2. Trial planning schedule

NO	NAME	TIME
1	1st Trial	September 2, 2021
2	2nd Trial	September 8, 2021
3	3rd Trial	September 13, 2021

4.3. Description of Develop

In this stage, the simulator is made based on the simulator prototype that has been designed previously. The following are the stages of developing the initial simulator product.

a. Web as a means of making simulators is because the web is very flexible and user-friendly and can be used in various browsers.
b. Create a menu display for ship data input, tank table, initial condition, compartment table, and hydrostatic table.

c. Make input data load to be loaded.
d. Create a stability calculation view.
e. Create a main view.
f. The design includes color, typeface, and font size.

The results are in software that can be used for cargo planning and knowing the ship's stability in one trip called a simulator. The following view of the simulator can be presented in the following figure:

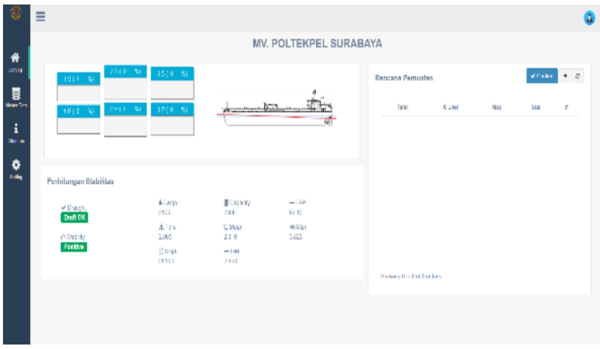


Fig 11. Main view

In general, three conditions can be experienced by ships, namely:

- Evenkeel, i.e., the forward draft of the ship, is the same as the rear draft of the ship.
- Trim bow (trimby bow), i.e., the rear draft is smaller than the front draft.
- Trim stern (trimbystern) is the rear draft greater than the front draft.

Can be described as the image below:

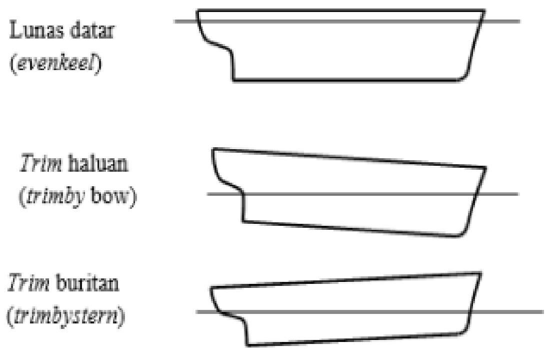


Fig 12. Condition of the ship lengthwise

4.3.1. First trial

The first trial was carried out on September 2, 2021, to find out the calculation of the ship's stability if all tanks were full.

Fig 13. First trial

In the figure above, the first test of the calculation of the stability of the ship displacement value is 4852.6, the fore value is 4.887, and the mean value is 4.769. Because the after value and the fore value are close to the same and are still within the mean, the ship is in an *evenkeel*/balanced state.

4.3.2. Second trial

The second trial was carried out on September 8, 2021, to calculate the ship's stability if the one starboard side tank and one port side tank were filled while the other tanks were empty.

Fig 14. Second trial

In the figure above, the second trial of calculating the ship's stability has a displacement value of 3810.6, a GM value of 2.929, an after the value of 2.338, a fore value of 5.531, and a mean value is 3.935. Because the after the value is greater than the fore value, the ship is in a trim by bow/*nungging* position.

4.3.3. Third trial

The second trial was carried out on September 13, 2021, to calculate the ship's stability if the three starboard side and three port side tanks were filled while the others were empty.

Fig 15. Third trial

In the picture above, in the third trial of calculating ship stability, the displacement value is 3810.6, the GM value is 2.169, the after the value is 5.515, the fore value is 2.051, and the mean value is 3.783. Because the value of force is greater than the value of after, the ship is in the trim by stern/*ndongak* position.

4.4. Description of Dissemination

The deployment stage was not carried out due to limited time.

5. Conclusion

Based on the description and analysis of the simulator Design using the modified Four-D development model can be concluded several things as follows:

1. The simulator design process broadly consists of four

stages; Define, Design, Development, and Dissemination.

2. The results of the simulator design that have been developed are as follows:
    a. Simulator can display ship data;
    b. Simulator can display payload planning;
    c. Simulator can display ship stability calculation;
    d. Simulator can display displacement;
    e. Simulator can display GM (Metacentric high).

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Author contributions

Tri Mulyatno Budhi H1: Conceptualization, Methodology, Software, Field study **Manungku Trinata Pramudhita2:** Data curation, Writing-Original draft preparation, Software, Validation., Field study **Agus Dina Mirianto3:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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