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Article

Application of The Fuel Estimation Simulator (The Bung Tomo Training Ship)

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Abstract. Developing new routes in the shipping business, the calculation uses the formula determined by the Minister of Transportation No. KM. 58 of 2003. However, this manual calculation takes a long time, and the possibility of human error is large. So, we need a more effective and efficient way to calculate the fuel needed to cover a certain distance. In this study, a simulator was developed that uses the spherical triangle concept to determine the distance and direction of the ship and then integrates it with the formula to get the results of the fuel calculation. From the results of trials using the Bung Tomo Training Ship, the results of calculations are faster and more accurate. The simulator positively affects cadets when applied in applied mathematics classes (85% through response questionnaire results and 87% competency test).

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1. Introduction

The shipping business has great prospects in Indonesia, which is actually a maritime country [1-2]. In the shipping business, it is important to set the right rate [2-3]. One of the determinants of high and low tariffs is ship operating costs [3-4]. Engine fuel is one component of ship operating costs that must be calculated in detail and correctly. Because the correct calculation will make it easier for shipping companies to optimize the budget [5-6].

However, the problem that must be faced is that the calculation of engine fuel still uses manual calculations with formulas [7-8]. Due to the outstanding strengthe of advanced machine-leraning techniques, they have become increasingly common in predictive studies in recent years, particularly in predicting ship energy performance. In constructing predictive models, prior studies have mostly employed vessels' technical parameters to establish machine-learning algorithms [9-10]. This method takes a long time and can only be done by a few people. Researchers are interested in optimizing the calculation time so that it is faster and can be done by anyone [11-12].

The method that will be used in this research is to create an application that can quickly calculate the amount of engine fuel needed by the ship when sailing from one place to another just by clicking on the two places [11-12]. Henceforth, this application is referred to as Simulator. Simulator is a tool for the process of implementing a model into a computer program (software) or electronic circuit and executing the software in such a way that its behavior imitates or resembles a real system [10],[13]. The simulator is designed in the form of software to calculate the estimated operating costs of the ship (especially the amount of engine fuel) when the ship is about to sail [5],[8],[14].

The process of testing the simulator using engine data for the Bung Tomo Training Ship [10],[15] (1200 GT) which is a training ship belonging to the Surabaya Shipping Polytechnic in the Transportation BPSDM environment, which was built by PT. STEADFAST MARINE in Pontianak in 2016. This training ship is equipped with a MITSUBISHI 2 x 759 kW main engine and has a capacity to accommodate 20 crew members, 10 instructors, 100 cadets, and 100 passengers.

The results of the simulator development were applied to the Applied Mathematics class at the Surabaya Shipping Polytechnic and the Malahayati Shipping Polytechnic. Furthermore, it will be seen how the cadets' skills in operating the simulator are and how the cadets respond when comparing the process of calculating the amount of engine fuel using the manual method with formulas and using a simulator [16-17]

Thus, this study aims to describe the process and results of a good simulator design, as well as to analyze how it affects the learning of applied mathematics in the classroom. A good simulator is a simulator that produces the same output of calculating the amount of engine fuel manually using a formula [18-19]. However, the calculation time with the simulator is faster than the manual method using formulas and is easy to operate by anyone.

2. Research Methods

This research is an R&D (Research and Development) type which is then applied to classroom learning. There are three stages in the development of this simulator[17][20]. The first stage is the search for ship data (ship type data, ship engine, and ship engine fuel consumption data). In this study, the Bung Tomo training ship was used as a case study. The second step is to save the inputted data as a database in MySQL. The third stage is programming the simulator in PHP my Admin. At this stage the researcher entered the formula from the minister of transportation on how to calculate the engine fuel needed to reach a certain distance. The amount of fuel oil consumption can be determined using the following formula:

$$W_{FL} = \frac{(Pbme.bme + Pae.bae)\ S}{V.10^{-6}.Add}$$

$$W_{FE} = (Pae.bme).wp.10^{-6}$$

where,

W_{FL} = Fuel consumption at sea (Kw),

W_{FE} = Fuel consumption at the port (Kw),

$Pbme$ = Main Engine Power (HP),

Pae = Auxiliary Engine Power (HP),

bme = Main Engine Fuel Weight (1.2-1.6gr/Kwh),

bae = Auxiliary Engine Fuel Weight (1.2-1.6gr/Kwh),

S = Sailing Distance (Mile),
V = Speed (Knot),
Add = Reserve factor (1.3 – 1.5),
wp = Time at the port (hour).

The map display used in this simulator is a google map. Users can take advantage of the map view to determine shipping routes by clicking on the map. In addition, the coordinates of the shipping lane location can be inputted. It aims to make it easy for users to operate this simulator.

After the simulator has been successfully developed, validation is carried out (simulator media experts and simulator user practitioners). The instrument used in this validation is an assessment questionnaire. Suggestions and assessments from this validator are important before conducting trials on shipping polytechnic cadets. At the simulator trial stage, cadets were asked to understand the manual book for using the simulator and then conduct several experiments in determining the route and calculating the required fuel [21-22].

During the practicum activities, the cadets' skills in operating the simulator were observed. To see the effect of the simulator media, a cadet response questionnaire and an assessment of skills were given during the practicum. The cadets in this study were 30 cadets from the Surabaya Shipping Polytechnic for the Nautical and D3 Engineering study programs and 30 cadets from the Malahayati Shipping Polytechnic for the D3 Nautical Study program and 30 cadets for Ship Engineering. The data collection process is carried out in September 2021 in the odd semester of Applied Mathematics learning. The process of this study can be seen in this figure 1 as follow.

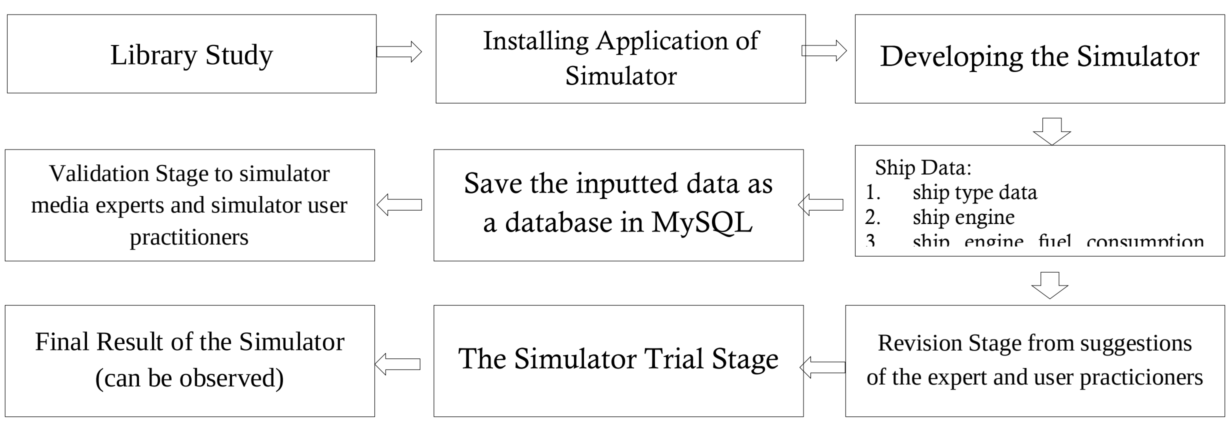


Figure 1. Flow chart of this research

3. Results and Discussion

3.1 Simulator Development

The results of the simulator development were applied to the Applied Mathematics class at the Surabaya Shipping Polytechnic and the Malahayati Shipping Polytechnic. Furthermore, it will be seen how the cadets' skills in operating the simulator are and how the cadets respond when comparing the process of calculating the amount of engine fuel using the manual method with formulas and using a simulator. Before discussing further about the fuel estimation simulator, it is better if we describe the results of the identification of the Bung Tomo trainer diesel engine below (see Table 1)

Table 1. The fuel estimation simulator

Type of engine	Status	RPM	Fuel consumption (Liter)
Main Engine I (SS)	Full Speed	1200	25/hour
	Idle Speed	700	54/ hour
	Manoeuvre	900	25/ hour
Main Engine II (PS)	Full Speed	1200	25/ hour
	Idle Speed	700	54/ hour
	Manoeuvre	900	25/ hour
Generator SS (STBD)	Idle Speed	720	30/ hour
Generator MS (Middle)	Idle Speed	720	30/ hour
Generator PS (port)	Idle Speed	720	30/ hour
Generator Harbour	Idle Speed	600	25/ hour
Main Engine AX	Full Speed	50	15/ hour
Main Engine AX	Full Speed	100	15/ hour

The development of this simulator uses PHP My Admin as a prototype/display, MySQL as a database, and Google map as a digital map. The design of the simulator is made/designed to make it easier for users to operate it. This simulator is software for calculating ship engine fuel that can be used easily by users. Figure 2 below is the main display design of the simulator.

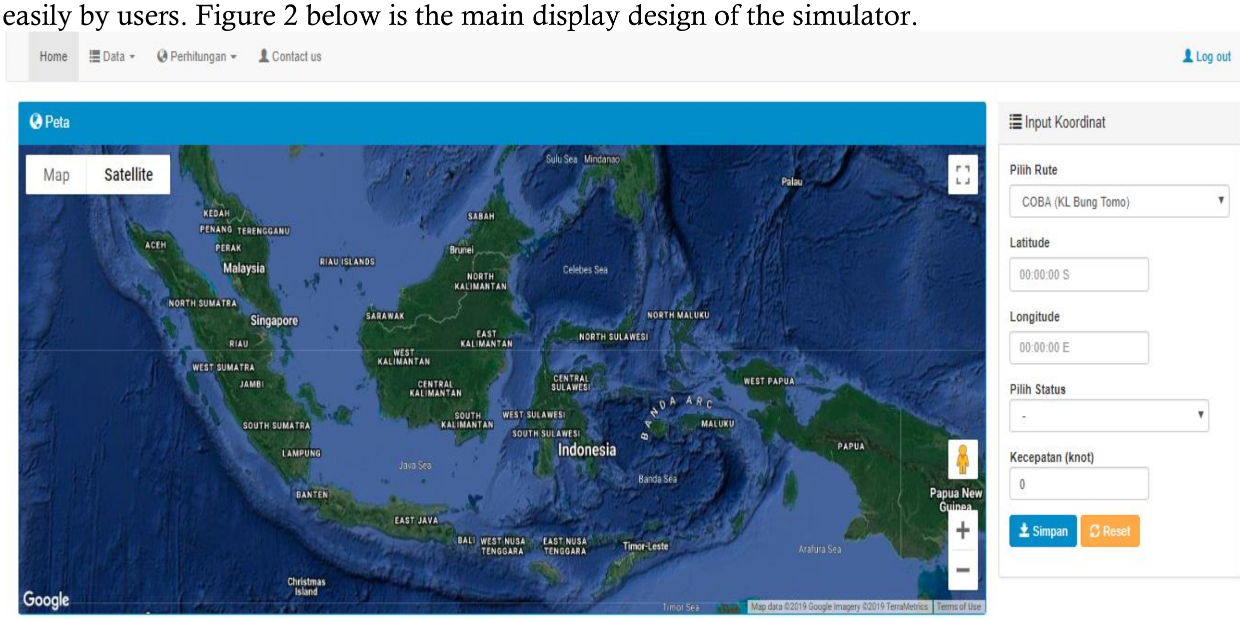
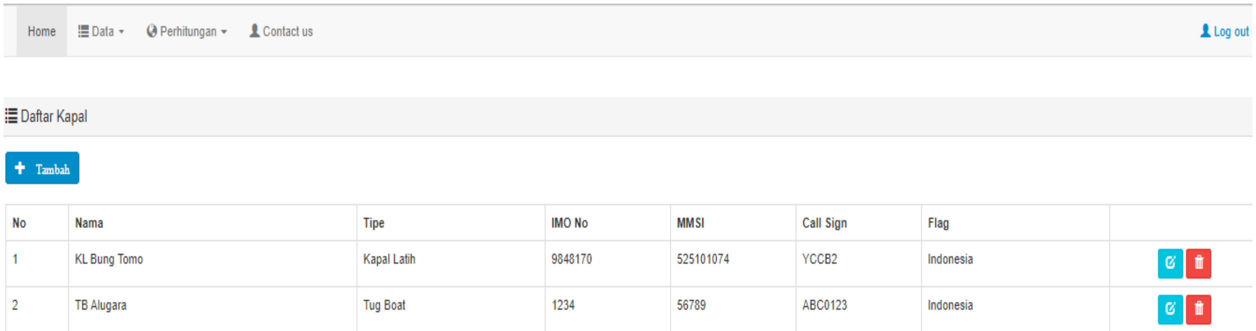


Figure 2. Main page map

To be able to find out the fuel consumption of the Bung Tomo Training Ship's engine, we first input the ship's data as follows (see Figure 3 and Figure 4)



No	Nama	Tipe	IMO No	MMSI	Call Sign	Flag
1	KL Bung Tomo	Kapal Latih	9848170	525101074	YCCB2	Indonesia
2	TB Alugara	Tug Boat	1234	56789	ABC0123	Indonesia

Figure 3. Ship data input process

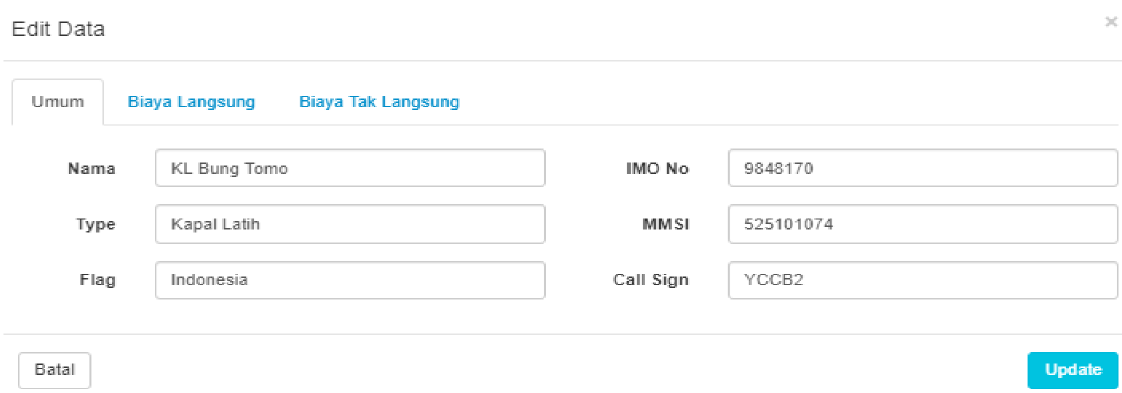
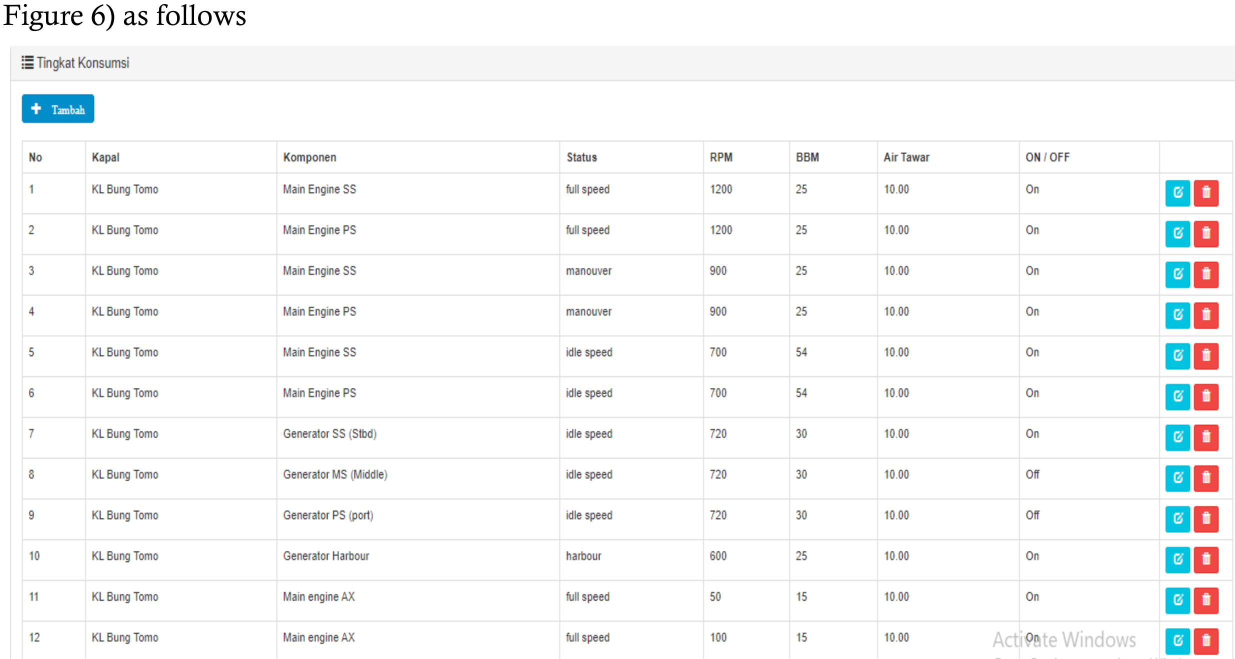


Figure 4. Bung Tomo's KL data input process

Then we input the Engine Tariff Consumption Data (see Figure 5) and Ship Route Plan Data (see Figure 6) as follows



No	Kapal	Komponen	Status	RPM	BBM	Air Tawar	ON / OFF
1	KL Bung Tomo	Main Engine SS	full speed	1200	25	10.00	On
2	KL Bung Tomo	Main Engine PS	full speed	1200	25	10.00	On
3	KL Bung Tomo	Main Engine SS	manouver	900	25	10.00	On
4	KL Bung Tomo	Main Engine PS	manouver	900	25	10.00	On
5	KL Bung Tomo	Main Engine SS	idle speed	700	54	10.00	On
6	KL Bung Tomo	Main Engine PS	idle speed	700	54	10.00	On
7	KL Bung Tomo	Generator SS (Stbd)	idle speed	720	30	10.00	On
8	KL Bung Tomo	Generator MS (Middle)	idle speed	720	30	10.00	Off
9	KL Bung Tomo	Generator PS (port)	idle speed	720	30	10.00	Off
10	KL Bung Tomo	Generator Harbour	harbour	600	25	10.00	On
11	KL Bung Tomo	Main engine AX	full speed	50	15	10.00	On
12	KL Bung Tomo	Main engine AX	full speed	100	15	10.00	On

Figure 5. Machine consumption level input process

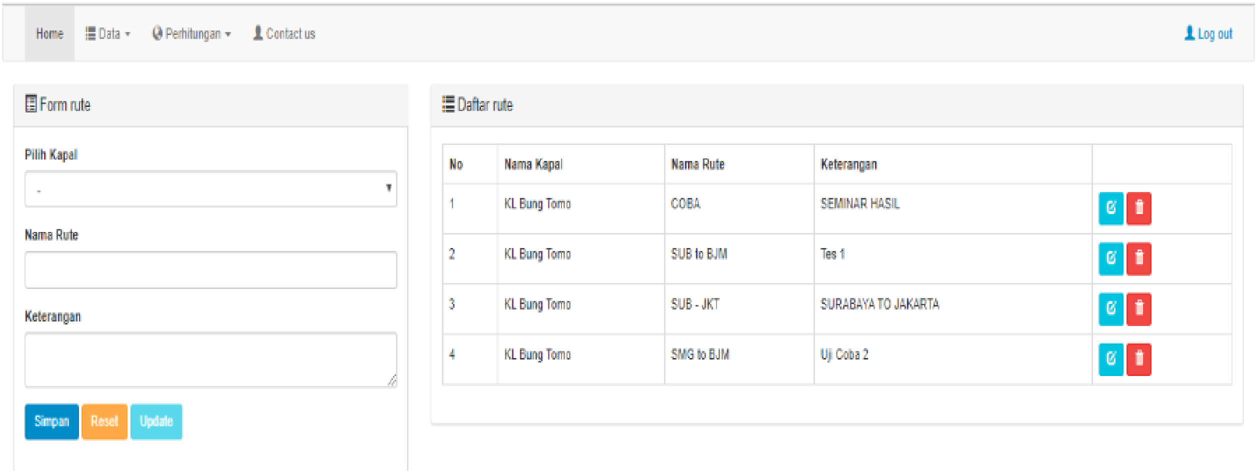


Figure 6. Sailing flow plan input process

The first trial was carried out with a shipping route from the port of Surabaya to the port of Makassar. We can see in Figure 7 below

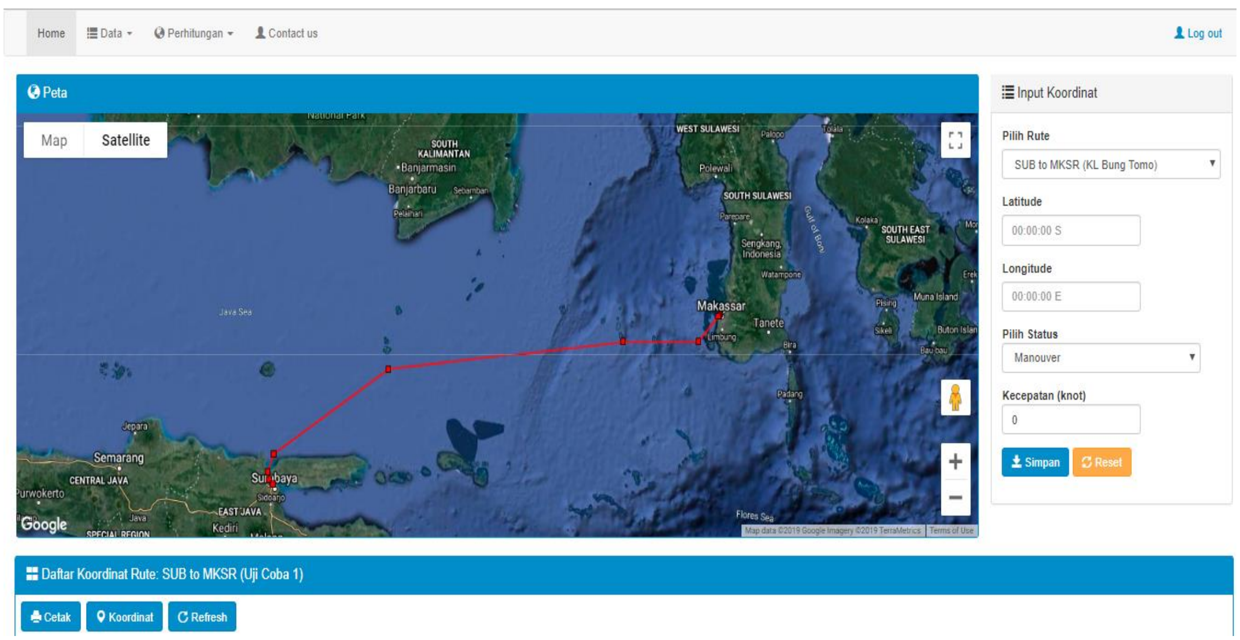


Figure 7. Route in the first trial (Surabaya-Makassar)

Daftar Koordinat Rute: SUB to MKSR (Uji Coba 1)

Cetak | Koordinat | Refresh

WP	Latitude	Longitude	Status	Jarak	Haluan	Waktu	BBM	Air Mesin
0	7:11:52.74 S	112:43:59.83 E	harbour	0	310.4	0	0	0
1	7:8:57.38 S	112:40:32.19 E	manouver	4.51	350.57	01:30:11	75	0.045
2	7:3:2.93 S	112:39:32.86 E	manouver	5.99	19.81	01:59:46	100	0.06
3	6:49:33.3 S	112:44:26.56 E	idle speed	14.34	58.98	02:52:06	396.06	0.1292
4	5:47:38.91 S	114:27:37.49 E	full speed	119.79	84.57	13:18:37	1064.8	0.7986
5	5:27:8.43 S	117:57:33.18 E	full speed	209.92	89.98	20:59:32	1679.2	1.2594
6	5:27:2.97 S	119:4:37.61 E	full speed	66.77	45.05	06:40:37	534.4	0.4008
7	5:8:55.02 S	119:22:51.75 E	idle speed	25.66	58.07	05:07:56	707.94	0.2309
8	5:8:23.03 S	119:23:43.3 E	manouver	1.01	28.61	00:12:06	10	0.006
9	5:6:51.62 S	119:24:33.35 E	manouver	1.74	0	00:34:42	29	0.0174
		Total :		449.73 millaut		53.2592	4596.4 liter	2.9472 liter

Figure 8. List of first trial fuel consumption

Based on the first trial data (see Figure 8) for the Surabaya-Makassar trip, the distance is 449.73 km with a travel time of 53 hours 25 minutes, so it requires 4596.4 liters of fuel in the engine. The second trial was carried out with a shipping route from the port of Semarang to the port of Banjarmasin. We can see in Figure 9 below

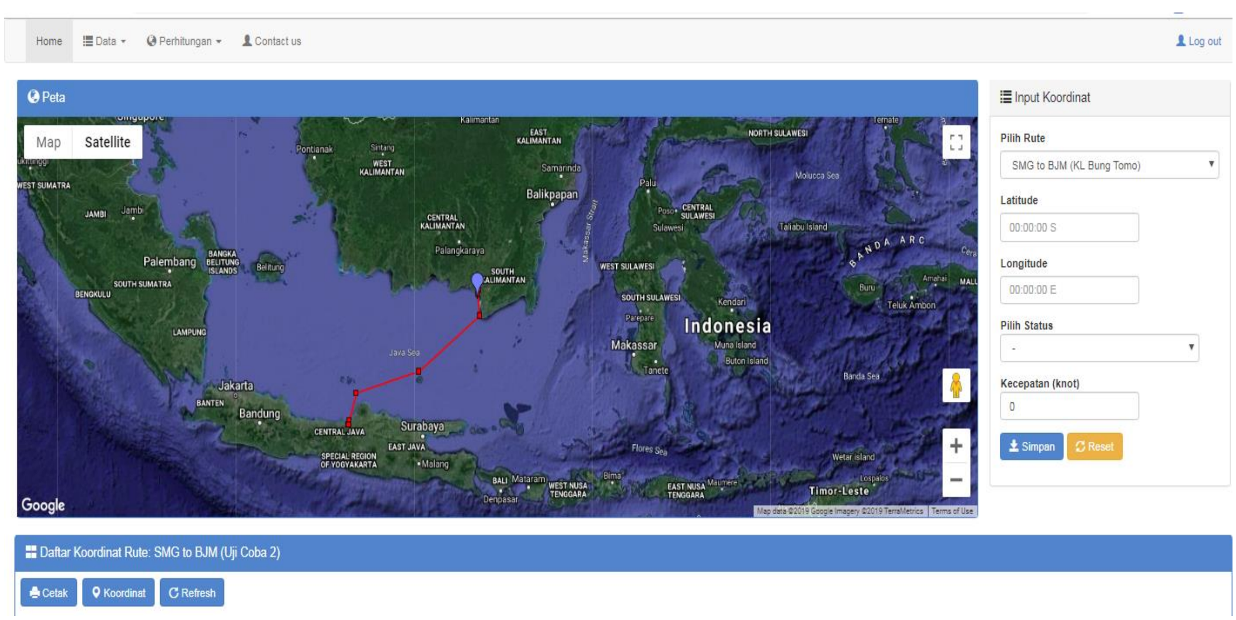
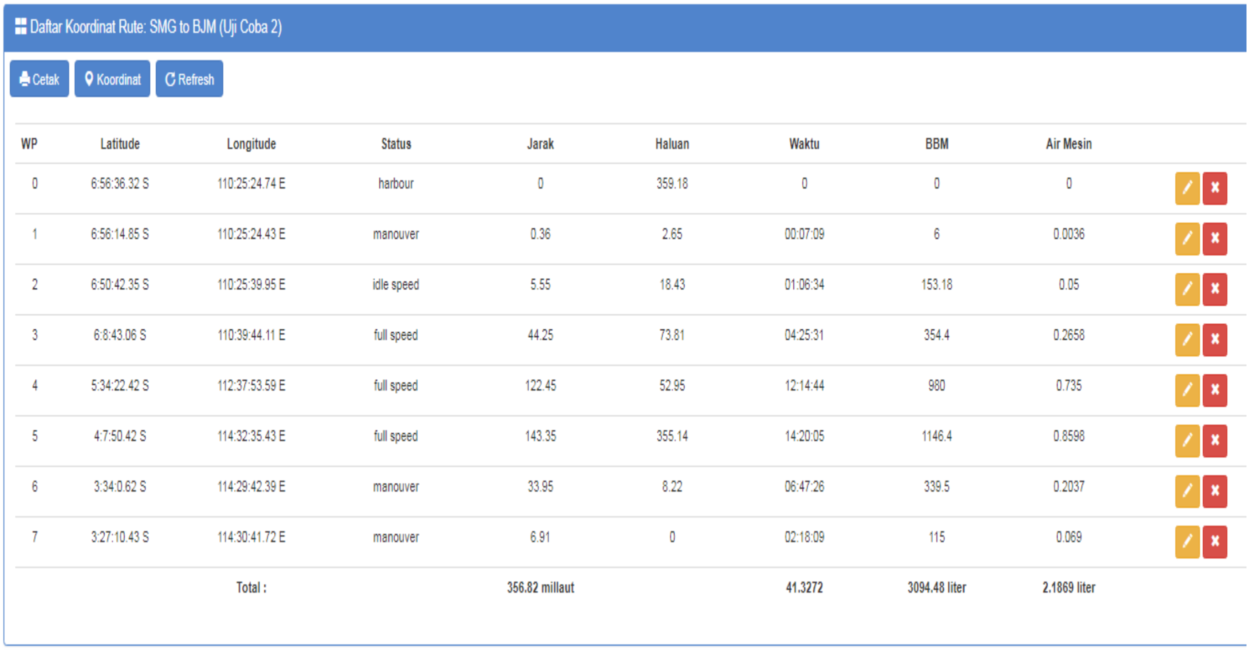


Figure 9. Route in the second trial (Semarang-Banjarmasin)



Daftar Koordinat Rute: SMG to BJM (Uji Coba 2)

Cetak Koordinat Refresh

WP	Latitude	Longitude	Status	Jarak	Haluan	Waktu	BBM	Air Mesin
0	6:56:36.32 S	110:25:24.74 E	harbour	0	359.18	0	0	0
1	6:56:14.85 S	110:25:24.43 E	manouver	0.36	2.65	00:07:09	6	0.0036
2	6:50:42.35 S	110:25:39.95 E	idle speed	5.55	18.43	01:06:34	153.18	0.05
3	6:8:43.06 S	110:39:44.11 E	full speed	44.25	73.81	04:25:31	354.4	0.2658
4	5:34:22.42 S	112:37:53.59 E	full speed	122.45	52.95	12:14:44	980	0.735
5	4:7:50.42 S	114:32:35.43 E	full speed	143.35	355.14	14:20:05	1146.4	0.8598
6	3:34:0.62 S	114:29:42.39 E	manouver	33.95	8.22	06:47:26	339.5	0.2037
7	3:27:10.43 S	114:30:41.72 E	manouver	6.91	0	02:18:09	115	0.069
		Total :		356.82 millaut		41.3272	3094.48 liter	2.1869 liter

Figure 10. List of second trial fuel consumption

Based on the data of the second trial above for the Semarang-Banjarmasin trip, the distance is 356.82 km with a travel time of 41 hours 32 minutes, so it requires 3094.48 liters of fuel in the engine.

3.2 Application of the Simulator

Before the simulator is implemented, validation is carried out by simulator media experts and simulator user practitioners. The following aspects need to be assessed regarding simulator development: Content, Writing, Color, Accessibility (compatibility), Media Integration, Ease of Navigation, User Friendly Rules, Techniques of Use, Usability, and Overall Functions [22-23]. From the validation results, it can be concluded that the simulator is suitable for use with several suggestions for improvement.

In this case, the previous research by Altosole, that a turbocharged diesel engine numerical model, suitable for real-time ship maneuver simulation. While some engine components (mainly the turbocharger, intercooler, and manifolds) are modeled by a filling and emptying approach, the cylinder simulation is based on a set of five-dimensional numerical matrices (each matrix is generated using a more traditional thermodynamic model based on in-cylinder actual cycle) [23-24], it can be said that there was another simulation that difference with this study but it can be our reference to literate this study. Thus, this application can be used to calculate the amount of fuel needed according to the distance traveled and the speed of the ship based on the selected trajectory, in this statement in line with the result of the research by Gunarti, et.al [14], [23].

The implementation of the simulator will be carried out in September 2021 at the Surabaya Shipping Polytechnic (30 cadets) and Malahayati Shipping Polytechnic (30 cadets). The achievement of the learning objectives of applied mathematics practicum this time are; (1) Operate ON/OFF the simulator system properly, (2) Understand the simulator system and the function of each navigation button, (3) Make a route planning on the simulator, (4) Calculate the required amount of fuel according to the specified route.

After completing the practicum module, the cadets make a report which is then followed by an assistance session to the lecturer/instructor/lecturer assistant (for evaluation and assessment). From the evaluation results, 85% of cadets gave a positive response to this simulator. While the results of the assessment showed that 87% of cadets passed the competency test in calculating ship fuel according to the specified route. This is a positive influence for learning applied mathematics in the classroom. This fact is in line with research conducted by Rahman, Santoso, Cahyadi dan Asnawi [18], [19],[22],[25].

4. Conclusion

Based on the description and analysis of the results of the discussion, it appears that the Simulator can display the distance of the ship and the direction of the ship so that it can display the estimated fuel consumption correctly. The time needed for calculations is not as long as manual calculations using formulas from the ministry of transportation, because the results can be obtained immediately after the data input process is carried out. This simulator can be used by anyone with a guarantee that the calculation of the amount of fuel used will be the same as manual calculations using formulas. In its application, this simulator has a positive influence on applied mathematics learning because it is proven by 85% positive responses of cadets and 87% of competency test completeness.

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