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IMPROVING ADVANCE TRANSFER TECHNIQUE: MANOEUVRING ANALYSIS USING A BULK CARRIER SHIP WHILE IN BALLAST CONDITION

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ABSTRACT

A wheel over point is specified on the charted courses in a voyage plan to indicate the point at which the ship must change direction. A late course alteration would result in an overrun of the intended course line, which can be observe by the expansion of cross-track distance. The wheel over point may be computed using the advanced transfer technique. Through a practical assessment of ATT, the research was able to identify a few gaps. The data included in the manoeuvring characteristics, particularly advance and transfer, were then utilised to develop an IATF capable of bridging the gaps. Following that, a manoeuvring study was conducted and data, including the cross-track distance, were acquired. Compliance with cross track limits and percentage change were utilised to validate the simulation analysis findings. The results demonstrated that the enhanced mathematical model was capable of providing better track keeping and was thus suited for use onboard a cargo ship.

ARTICLE INFO

Keywords:
Wheel Over Point,
Alteration Course,
Advance Transfer Technique,
Passage Planning,
Cross-Track Distance

1.0 INTRODUCTION

A ship navigates by following one course line to another course line connected by waypoints (WPT) to complete a voyage as according to the agreed passage plan prepared by the ship's wheelhouse team (ICS, 2016; Lušić et al., 2014). Failure to do so can lead to an accident (Marine Insight, 2020). Safety of ship's operations relies upon seafarers' communication, teamwork, leadership, situational awareness, result focus, decision making and desire to learn and to develop (Kamis et al., 2020). Looking at a report by Gale & Patraiko (2007), 17% of grounding incidents were caused by poor passage planning. Passage planning is a method for creating a detailed overview of the vessel's voyage from the port of departure to the port of arrival (IMO, 1999).

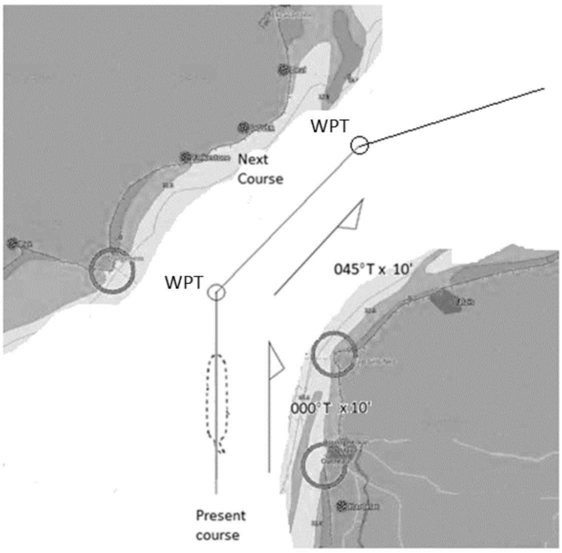


Figure 1. Various connected charted course in a voyage plan on a nautical chart

Charting courses line is one of the activities during the planning phases (IMO, 1999; Swift, 2018). As shown in Figure 1, the charted course is the course line drawn on the navigational chart connected by waypoints (ICS, 2016; IMO, 1999). Waypoint (WPT) is the point where two different course lines are connected (ICS, 2016; Swift, 2018). After completion of the planning phase, the passage plan will be executed followed by monitoring of the plan which includes ships operational status such as weather conditions, fuel consumption, collision regulations and maintaining its planned track (Swift, 2018; Zekić et al., 2015). When changing a course, the alteration needs to be carried out at an ample distance to avoid the ship from overshooting from the planned track (Vujičić et al., 2018). For this reason, a wheel over point (WOP) needs to be accurately calculated and marked on the charted course as an indication of the alteration point (Bielek, 2020; Georgiana & Stefan, 2010).

2.0 PROBLEM STATEMENT AND THE AIMS OF THE STUDY

Onboard ship, the advance transfer technique (ATT) with manual calculation on a navigational chart is the most common method of determining WOP (Anwar, 2015). Manual calculation has a few disadvantages, such as being time consuming and only being applicable to paper charts (Anwar, 2015). Apart from that, two issues with the ATT were discovered during the practical exercise using a navigation chart.

1. The formula given by the technique is ineffective for changes of course of less than 20° (see section 4.1.1).
2. The final ship's heading differs from the charted direction, resulting in second overshooting (see Figure 7).

Mathematical modelling offers better results in deciding WOP as paper charts are gradually replaced electronic charts that have been introduced in maritime navigation. The aim of this study was to create a better mathematical model that used advance transfer information from a ship's manoeuvring characteristics as variables in deciding WOP (Jeong et al., 2019; Statheros et al., 2008).

3.0 METHODOLOGY

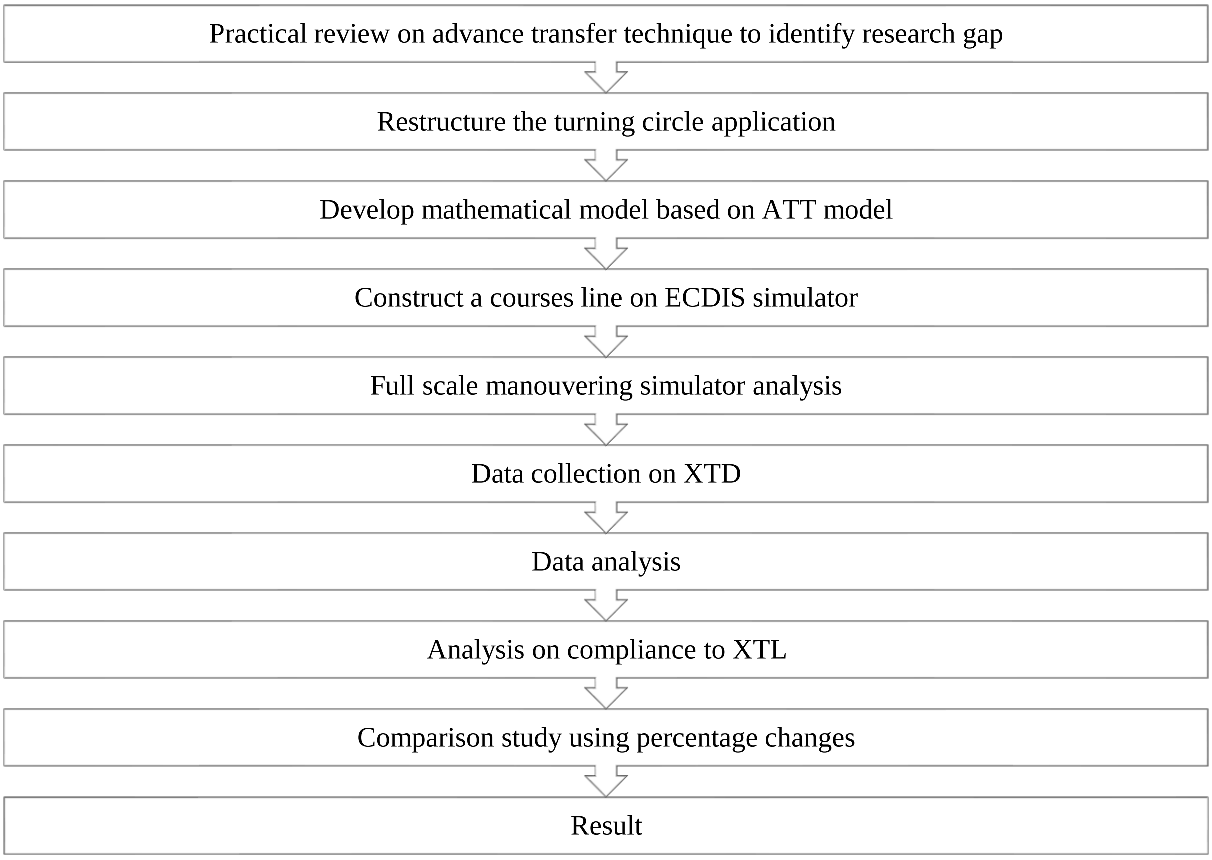


Figure 2. Research flow

For this purpose, the study began with a simulation exercise to determine WOP using the ATT for the purpose of understanding its shortcomings. As a result, an improved model namely Improved Advance Transfer Formula (IATF) was developed. A new introduced system should be compared with the existing system to ensure the effectiveness and improvements (Voit, 2020). For this reason, a ship simulator was used to test both ATT and IATF.

The Wartsila ship simulator was used to collect data during the full-scale simulation. A series of courses for each 10° alteration were first developed using an ECDIS simulator. ATT and IATF were evaluated through the manoeuvre analysis, and the XTD for each course alteration was gathered before comparing them to analyse the improvement.

The manoeuvre simulation XTD data will be evaluated in two phases. In the first phase, the XTD for each alteration was compared to the XTL, using formula given by Kristić et al. (2020). The purpose of this phase was to see which approach produced better compliance with XTL. XTL is defined as the maximum perpendicular distance by which a ship can safely diverge from the planned track. However, although a ship needs to comply to the XTL as expressed in general by IMO (IMO MSC, 1998, 2006, 2007), IMO did not provide the exact value of XTL. Thus, this research used the recommendation in a study conducted by Kristić et al. (2020) to decide XTL for the respective ship.

Then, the validation by percentage change was carried out in the second phase to show the improvement trend over existing method. The expression "percentage change" refers to the amount of a variation over a specified period (Bansilal, 2017). It is commonly utilised for a variety of commercial purposes, most notably to denote price changes (Bansilal, 2017; Beck, 2020). Similarly, the percentage change in this analysis was able to illustrate the propensity of IATF to minimise XTD as compared to ATT.

3.1 THE ADVANCE TRANSFER TECHNIQUE AND THE APPLICATION

ATT is a course alteration technique that used maximum rudder angle while turning. It is frequently utilised in inland water and is preferred for pilotage since the turning circle's characteristics are not affected by the vessel's speed (Kim et al., 2005). The rudder angle specified for a particular movement has an effect on the vessel's manoeuvring characteristics (Drachev, 2012; Kim et al., 2005). Upon ship delivery, a sea trial manoeuvre will be conducted, resulting in a ship-specific manoeuvring characteristic. The turning circle for each rudder angle, as well as the diameter of the turning circle based on the loaded/ballast condition and the shallow/deep water region covered will be recorded throughout the process (IMO, 2002; ITTC, 2002; Kim et al., 2005). A shallow water region is defined as one that has a water depth less than 1.5 times the ship's draft, a medium deepwater area as one that has a water depth between 1.5 and 3.0 times the ship's draft, and a deepwater area as one that has a water depth larger than 3.0 times the ship's draft (Duarte et al., 2016; Sian et al., 2014).

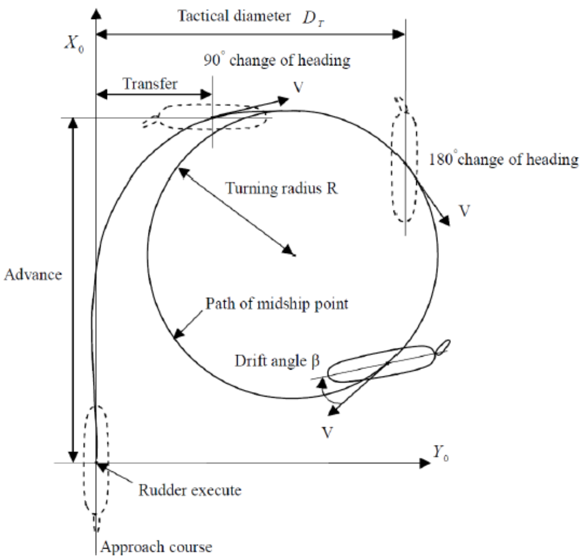


Figure 3. Ship’s manouvering characteristic (ITTC, 2002)

The advance transfer technique by Anwar requires two variables namely advance and transfer from the maneuvring characteristics as seen in Figure 3. Advance and transfer distances are measured from the ship's centre of gravity (CG) (ITTC, 2002) from the instant the vessel commences the turn by turning the rudder to maximum angle until the ship's heading changes by 90 degrees, where advance is measured along the X0 axis and transfer along the Y0 axis, as seen in Figure 4 (ITTC, 2002). Anwar (2015) proposed a way to use the given information to determine the WOP as explained below;

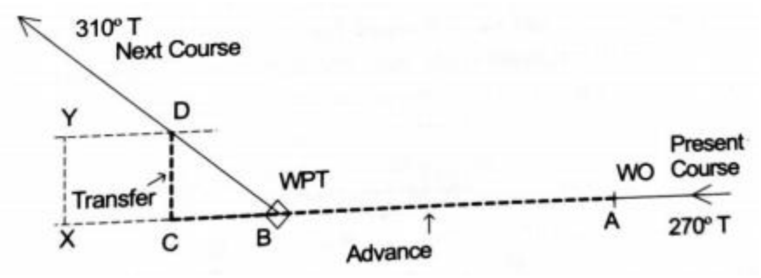


Figure 4. WOP identification using the advance transfer technique (Anwar, 2015)

With references to Figure 5, the steps of determining WOP are as follows:

i. At point B, extend the present course line 270°T
ii. At any point, 'X' is on this line, draw a perpendicular line 'XY' towards the alteration so that 'XY' = Transfer
iii. At 'Y', draw a line parallel to 'BX' so that it cuts the course line 310°T. The point at which the parallel line cuts the next course line is 'D'. Now, if the line is drawn at 'D', which is parallel to 'XY', point 'C' would be obtained on the extension of the present course line.
iv. From 'C', measure the advance backwards i.e. in the direction 090°T (reciprocal of 270°T) to obtain point 'A'. 'A' is the WOP, where 'CA' equals advance distance.

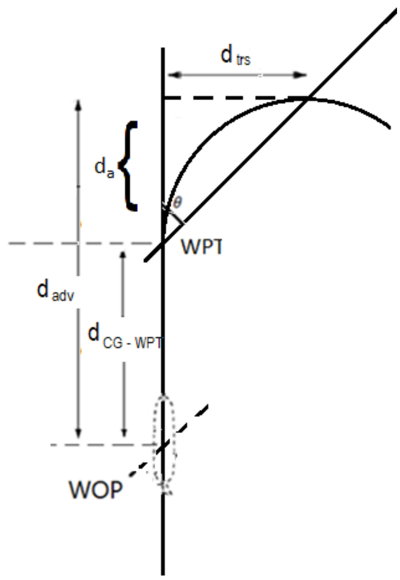


Figure 5. Marking WOP (Anwar, 2015)

Abbreviation;
d_{adv} = Advance value
d_{trs} = Transfer value
$d_{CG\text{-}WPT}$ = Distance from ship CG to WPT
d_{WOP} = Distance of WOP' from WPT
θ = Change of course angle

According to Figure 5;

$$d_{CG-WPT} = d_{adv} - d_a \tag{1}$$

To obtain d_a the following tangent rules can be used:

$$\tan\theta = \frac{d_{trs}}{d_a}$$

$$d_a = \frac{d_{trs}}{\tan\theta}$$

Therefore, the equation by Anwar (2015) can be re-written as below,

$$d_{CG-WPT} = d_{adv} - \frac{d_{trs}}{\tan\theta} \tag{2}$$

The principle of the technique worked as shown in Figure 6, however, the final ship's heading was 090°T and did not correspond to the 045°T in which the desired course should be achieved.

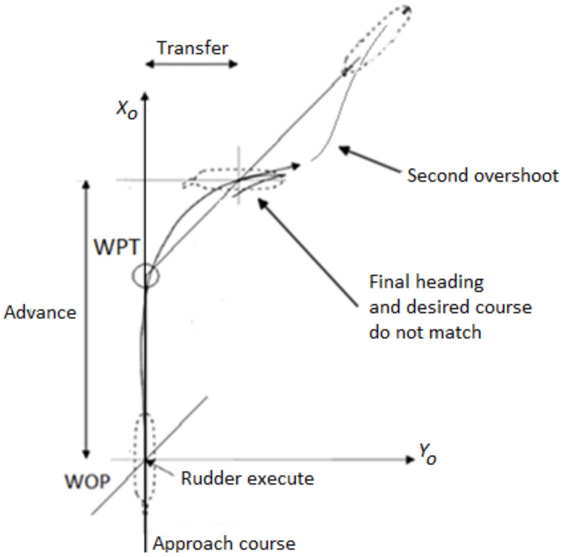


Figure 6. Existing advance transfer technique (ATT) principle, ship ended up on the next course at 90° from the original course (Anwar, 2015)

3.2 OPTIMISING ADVANCE AND TRANSFER USAGE

The purpose of this study was to improve the advance and transfer techniques for estimating WOP. The ATT will be improved accordingly to make sure the final ship's heading matched the planned course.

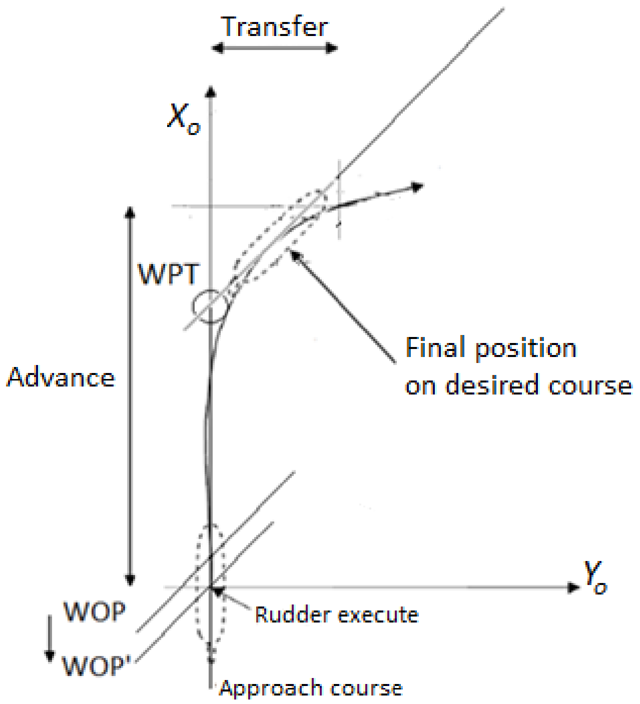


Figure 7. Concept of the study, final heading match charted course

For this reason, this research sought to adapt the approach as illustrated in Figure 7 in order to verify that the ship's final heading matched the planned next path.

3.3 CONSTRUCTING NEW MATHEMATICAL MODEL

The ATT equation (2) was utilised as the core model for constructing the IATF. Adapting the similar concept, the following figure 8 were constructed to aid the explanation on the development of IATF.

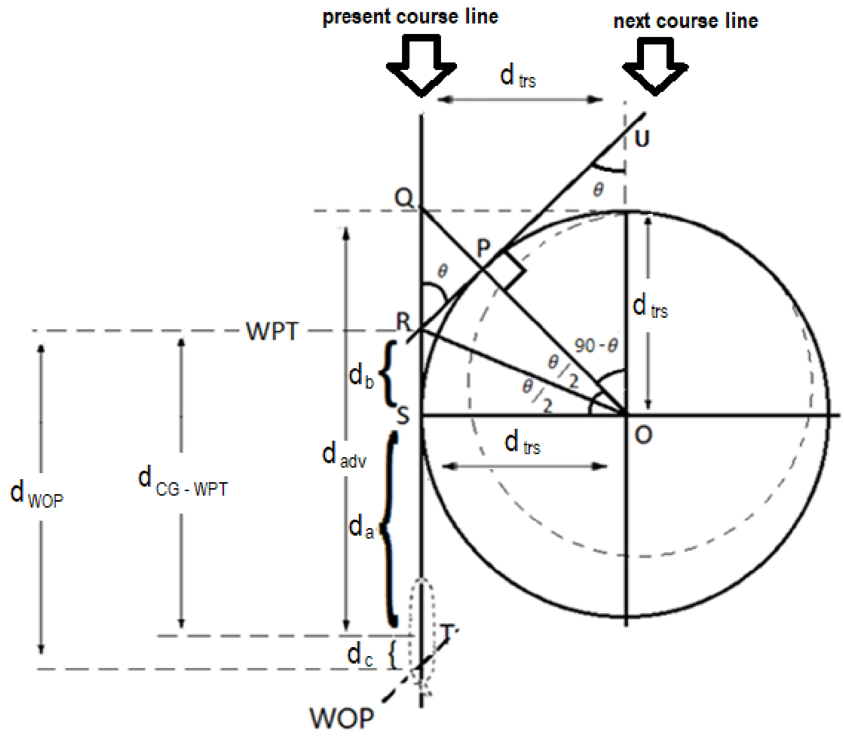


Figure 8. Distribution details

As shown in figure 8, the d_{WOP} which is the position of WOP measured from WPT will be divided as follow.

$$d_{WOP} = d_{CG\text{-}WPT} + d_c$$

$$d_{CG\text{-}WPT} = d_a + d_b$$

$$d_{WOP} = d_a + d_b + d_c \qquad (3)$$

da is the distance from CG to the line perpendicular to the centre of tactical diameter, and the radius of tactical diameter is equal to transfer, hence,

$$d_a = d_{adv} - d_{trs} \qquad (4)$$

d_b is the distance between R and S, WPT or R is the intersection of present course line and next course line, and both course lines are tangent to an imaginary circle. Since both of courses line are tangent to the circle, and the QS is parallel to OU, by the rule of tangent (Mathews, 1915; Srinivasan, 2002), the angle of PRQ and PUO has the same value, ∠PRQ = ∠PUO, hence the change of course, ∠PRQ, represent by θ is equal to angle PUO, θ = ∠PUO

To get d_b the following tangent rules can be applied,

$$\tan \angle ROS = d_b / d_{trs}$$

$$d_b = d_{trs} \times \tan \angle ROS \qquad (5)$$

Since RP and RS is tangent to the circle, by the rule of tangent to the circle, both distances will be the same, | RP | = | RS | so, the angle of ROS and POR is same, ∠ROS = ∠POR. Hence, ∠ROS has half of value of ∠POS, so,

$$\angle ROS = \angle \frac{POS}{2}$$

$$\angle ROS = \frac{\theta}{2} \quad (6)$$

With references to equation at (3), and input from (4),

$$d_b = d_{trs}\ x\ tan\ \angle ROS$$

$$d_b = d_{trs}\ x\ tan\frac{\theta}{2} \quad (7)$$

Considering WOP position will be monitored using GPS, which is located at the ship's wheelhouse, the real WOP indicated on the chart should incorporate the distance between the CG and the wheelhouse, specifically the position of GPS antenna, thus $d_{CG} = d_c$, applied as follow:

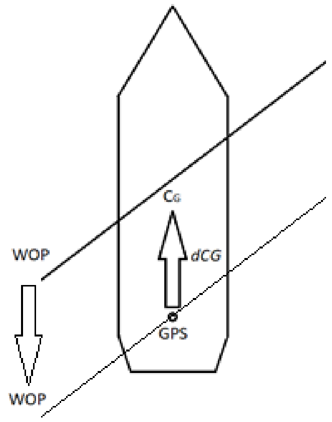


Figure 9. d_{CG} is the distance between the GPS antenna and the CG

therefore,

$$d_c = d_{CG} \quad (8)$$

in summary, with references to equation (3), and input from equation (4), (7) and (8),

$$d_{WOP} = d_a + d_b + d_c$$

$$d_{WOP} = d_{adv} - d_{trs} + (d_{trs}\ x\ Tan\ (\frac{\theta}{2})) + d_{CG}$$

$$d_{WOP} = d_{adv} - d_{trs}\ (1 - Tan\ (\frac{\theta}{2})) + d_{CG} \quad (9)$$

4.0 FINDINGS AND DISCUSSION

The Wartsila Ship Simulator was used to carry out manouvering analysis to see the impact on the ship's XTD when course alteration was carried out referring to the WOP calculated by ATT and IATF. A bulk carrier with a displacement of 23565 tonnes while in ballast condition was selected for the analysis. The tests were carried out in shallow and deep water for port and starboard alternation.

Figure 10. Selected ship for this study

The data regarding the chosen ship were obtained from the simulator. Nine charted courses was prepared on the ECDIS simulator and WOP for each courses were identified using ATT and IATF. A helmsman was instructed to follow the course and execute the turn at marked WOP by the application of hard rudder angle. Then, the XTD of the vessel was monitored and recorded.

4.1 DATA COLLECTION

XTD for each simulation were recorded in table 2 and 3. Two phases of analysis were conducted on the data obtained from the manoeuvring simulation. The data was first analysed by comparing the XTD to XTL. The XTL for the selected ship in this study was determined as follows:

Table 1: XTL value (Kristić et al., 2020)

Area A1	d_{zoc}	$d_{breadth}$	d_{pos}	d_{na}	d_{so}	XTL (m)
Restricted Water	6.5	11.3	15	50	37	119.8

4.2 XTD RESULT

Table 2: Manoeuvring analysis result for deep water (Source: Authors)

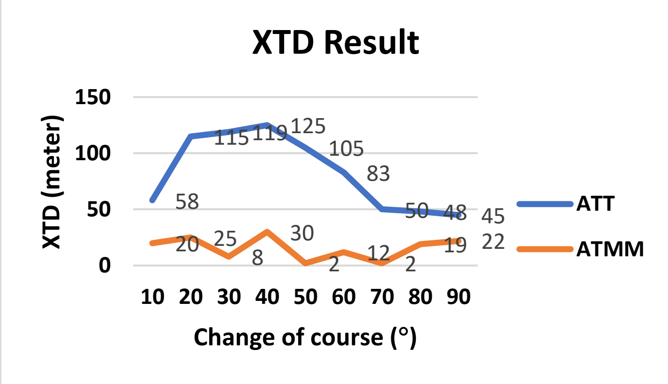
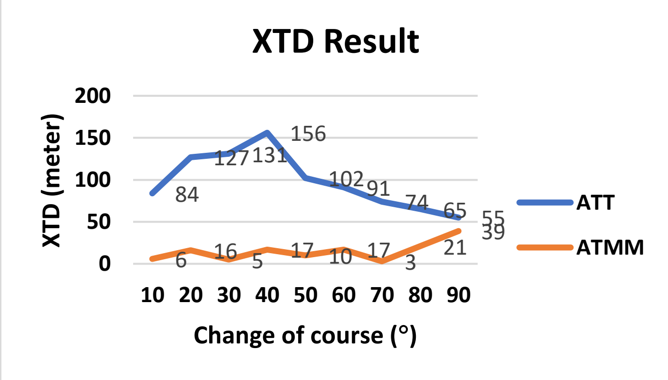
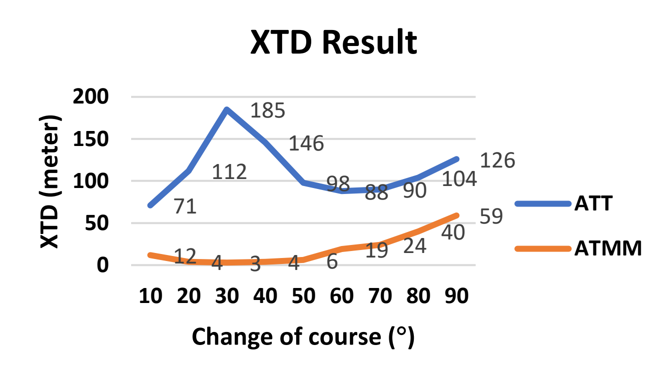
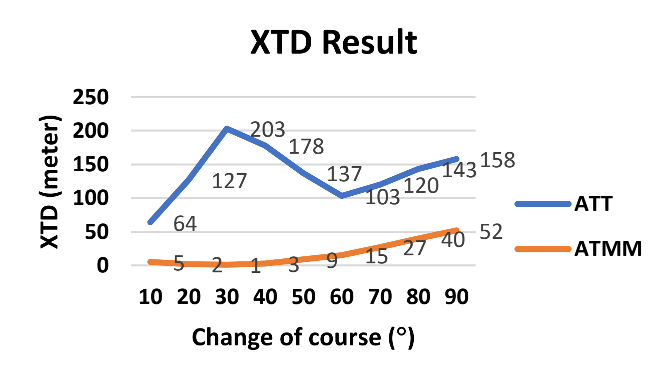
Location and ENC number	Side	θ	d_{adv} (nm)	d_{trs} (nm)	d_{CG} (nm)	d_{WOP} ATT	d_{WOP} IATF	XTD < XTL(119.8m) ? ATT (m)		XTD < XTL(119.8m) ? IATF (m)		Comparison Graph
Kemaman, Malaysia ENC number: 3JS P9200 04°10.78' N 103°35.4'E 23.8-29.3m (deep water)	Starboard	10°	0.24	0.108	0.0329	-0.372	0.174	58	YES	20	YES	
		20°	0.24	0.108	0.0329	-0.057	0.184	115	YES	25	YES	
		30°	0.24	0.108	0.0329	0.053	0.194	119	YES	8	YES	
		40°	0.24	0.108	0.0329	0.111	0.204	125	NO	30	YES	
		50°	0.24	0.108	0.0329	0.149	0.215	105	YES	2	YES	
		60°	0.24	0.108	0.0329	0.178	0.227	83	YES	12	YES	
		70°	0.24	0.108	0.0329	0.201	0.241	50	YES	2	YES	
		80°	0.24	0.108	0.0329	0.221	0.256	48	YES	19	YES	
		90°	0.24	0.108	0.0329	0.240	0.273	45	YES	22	YES	
	Port	10°	0.23	0.102	0.0329	-0.348	0.17	84	YES	6	YES	
		20°	0.23	0.102	0.0329	-0.050	0.179	127	NO	16	YES	
		30°	0.23	0.102	0.0329	0.053	0.188	131	NO	5	YES	
		40°	0.23	0.102	0.0329	0.108	0.198	156	NO	17	YES	
		50°	0.23	0.102	0.0329	0.144	0.208	102	YES	10	YES	
		60°	0.23	0.102	0.0329	0.171	0.22	91	YES	17	YES	
		70°	0.23	0.102	0.0329	0.193	0.232	74	YES	3	YES	
		80°	0.23	0.102	0.0329	0.212	0.246	65	YES	21	YES	
		90°	0.23	0.102	0.0329	0.230	0.263	55	YES	39	YES	

Table 3: Manoeuvring analysis result for shallow water (Source: Authors)

Location and ENC number	Side	θ	d_{adv} (nm)	d_{trs} (nm)	d_{CG} (nm)	d_{WOP} ATT	d_{WOP} IATF	XTD < XTL(119.8m) ? ATT (m)		IATF (m)		Comparison Graph
Baltimore, USA ENC number: 4414n120 38°55.21' N 076°24.78'W 10.7-14m (shallow water)	Starboard	10°	0.29	0.139	0.0329	-0.498	0.196	71	YES	12	YES	
		20°	0.29	0.139	0.0329	-0.092	0.208	112	YES	4	YES	
		30°	0.29	0.139	0.0329	0.049	0.221	185	NO	3	YES	
		40°	0.29	0.139	0.0329	0.124	0.234	146	NO	4	YES	
		50°	0.29	0.139	0.0329	0.173	0.249	98	YES	6	YES	
		60°	0.29	0.139	0.0329	0.210	0.264	88	YES	19	YES	
		70°	0.29	0.139	0.0329	0.239	0.281	90	YES	24	YES	
		80°	0.29	0.139	0.0329	0.265	0.301	104	YES	40	YES	
		90°	0.29	0.139	0.0329	0.290	0.323	126	NO	59	YES	
	Port	10°	0.28	0.132	0.0329	-0.472	0.189	64	YES	5	YES	
		20°	0.28	0.132	0.0329	-0.092	0.201	127	NO	2	YES	
		30°	0.28	0.132	0.0329	0.048	0.213	203	NO	1	YES	
		40°	0.28	0.132	0.0329	0.120	0.226	178	NO	3	YES	
		50°	0.28	0.132	0.0329	0.166	0.239	137	NO	9	YES	
		60°	0.28	0.132	0.0329	0.201	0.254	103	YES	15	YES	
		70°	0.28	0.132	0.0329	0.229	0.27	120	NO	27	YES	
		80°	0.28	0.132	0.0329	0.254	0.289	143	NO	40	YES	
		90°	0.28	0.132	0.0329	0.277	0.31	158	NO	52	YES	

4.3 FIRST PHASE ANALYSIS – XTL COMPLIANCE

4.3.1 10° and 20° change of course negative value

The estimated dWOP value for all conditions analyses using the ATT method was negative at 10° and 20° turns, meaning the turn had to be performed beyond the WPT, which was contradictory as the ship is already overshoot. As a result, negative value dWOP was executed exactly at WPT.

4.3.2 Compliances with XTL

In the deep water region, a bulk carrier in ballast condition was used for the first simulation analysis. Just half of the turns were compatible with XTL when using ATT. When the ship used the IATF, however, its XTL adherence improved to 100%.

The same bulk carrier at ballast was used in the second simulation analysis in a shallow water. When the simulation carried out by referring to the WOP calculated using ATT, results show only 50% of the XTD complied to XTL. However, when the simulations changed to WOP calculated using IATF, 100% compliance was recorded.

4.4 SECOND PHASE ANALYSIS – PERCENTAGE CHANGE

Table 4: Percentage change of XTD by change of course (Source: Authors)

Change of course	Condition	Water depth	Direction	XTD (m)		% Change of XTD	
				ATT	IATF	Individual turn	Average
10°	Ballast	Deep	Starboard	58	20	-65.5%	-83.4%
			Port	84	6	-92.9%	
		Shallow	Starboard	71	12	-83.1%	
			Port	64	5	-92.2%	
20°	Ballast	Deep	Starboard	115	25	-78.3%	-90.1%
			Port	127	16	-87.4%	
		Shallow	Starboard	112	4	-96.4%	
			Port	127	2	-98.4%	
30°	Ballast	Deep	Starboard	119	8	-93.3%	-96.9%
			Port	131	5	-96.2%	
		Shallow	Starboard	185	3	-98.4%	
			Port	203	1	-99.5%	
40°	Ballast	Deep	Starboard	125	30	-76.0%	-90.2%
			Port	156	17	-89.1%	
		Shallow	Starboard	146	4	-97.3%	
			Port	178	3	-98.3%	
50°	Ballast	Deep	Starboard	105	2	-98.1%	-93.9%
			Port	102	10	-90.2%	
		Shallow	Starboard	98	6	-93.9%	
			Port	137	9	-93.4%	
60°	Ballast	Deep	Starboard	83	12	-85.5%	-82.7%
			Port	91	17	-81.3%	
		Shallow	Starboard	88	19	-78.4%	
			Port	103	15	-85.4%	
	Ballast	Deep	Starboard	50	2	-96.0%	-85.7%

70°			Port	74	3	-95.9%	
		Shallow	Starboard	90	24	-73.3%	
			Port	120	27	-77.5%	
80°	Ballast	Deep	Starboard	48	19	-60.4%	-65.4%
			Port	65	21	-67.7%	
		Shallow	Starboard	104	40	-61.5%	
			Port	143	40	-72.0%	
90°	Ballast	Deep	Starboard	45	22	-51.1%	-50.1%
			Port	55	39	-29.1%	
		Shallow	Starboard	126	59	-53.2%	
			Port	158	52	-67.1%	

The negative percentage change specified the reduction of XTD by per cent. As a result, during the manoeuvring analysis, a considerable reduction in XTD was observed. It can be seen from table 4, that during manoeuvring analysis in deep water, the XTD was reduced by 51.1% – 98.1% for starboard alteration, while for manoeuvring analysis with port alteration, the XTD was successfully reduced by 29.1% – 95.9%. Meanwhile, in shallow water, XTD for starboard manoeuvring analysis was reduced by 53.2% – 98.4%, and reduction by 67.1% – 99.5% for port manoeuvring analysis. Average XTD reduction for all analysis ranged from 50.1% to 96.9%.

When this study changed from ATT to IATF during the manoeuvring analysis, the results showed the XTD was reduced significantly. The series of reduction for every 10° course alterations indicated the ship was manoeuvring closer to the course line.

5.0 CONCLUSION

Ships navigate from one destination to the next by following the course line plotted out by the navigation officer. Staying on the intended course line is critical for the ship's safety and will help reduce fuel consumption. However, most importantly, it will keep the vessel safe, as many incidents have occurred due to not staying on the charted course. Therefore, this study aims to examine the ATT and determine how it could be improved so that an accurate WOP can be calculated to reduce XTD while turning.

This study discovered that the ATT, one of the methods of assessing WOP, can be improved after an initial practical exercise using a ship simulator. By understanding the research gap IATF was successfully developed. To verify the effectiveness of IATF compared to ATT, the study calculated WOP for a set of charted courses and executed the manoeuvring analysis using the Wartsila ship simulator. It can be concluded that this study has achieved its objective by improving the method of calculating WOP. WOP can also be utilised as an abort point where it indicates the final point to alter course, or else the ship will overshoot.

5.1 RESEARCH CONTRIBUTION

The IATF may be utilized as an algorithm in the ECDIS to improve a ship's safety since it was created to considerably lower the XTD and is ideal for usage onboard merchant ships as one of the ways for estimating WOP, particularly while turning in a restricted water or during pilotage. During route planning, an ECDIS equipped with pre-installed vessel manoeuvring data may automatically calculate the WOP for each course change based on the vessel's state, such as ballast and loaded condition. As a consequence of this research, IATF integrated with the ECDIS may identify when the navigator performs an inaccurate WOP calculation, and the

ECDIS may provide a warning showing the wrong input. As a result, this issue may be resolved utilising the integrated IATF.

REFERENCES

Anwar, N. (2015). *Navigation Advanced Mates/Masters* (2nd ed.). Weatherby Seamanship International, a Division of Witherbys Publishing Group Limited. https://www.witherbyseamanship.com/navigation-advanced-for-matesmasters-2nd-edition.html

Bansilal, S. (2017). The application of the percentage change calculation in the context of inflation in Mathematical Literacy. *Pythagoras*, *38*(1), 1–11. https://doi.org/10.4102/pythagoras.v38i1.314

Beck, K. (2020). *How to Calculate Percent Difference*. https://sciencing.com/calculate-percent-difference-6331196.html

Bielek, M. (2020). *ECDIS in Passage Planning: As wide as possible, as narrow as necessary*. https://www.safelearn.com/ecdis/ecdis-in-passage-planning/

Drachev, V. N. (2012). Calculating Wheel-Over Point. *Asia-Pacific Journal of Marine Science&Education*, *2*(1), 27–46.

Duarte, H. O., Droguett, E. L., Martins, M. R., Lutzhoft, M., Pereira, P. S., & Lloyd, J. (2016). Review of practical aspects of shallow water and bank effects. *Transactions of the Royal Institution of Naval Architects Part A: International Journal of Maritime Engineering*, *158*(December), 177–186. https://doi.org/10.3940/rina.ijme.2016.a3.362

Gale, H., & Patraiko, D. (2007, July). *Improving navigational safety*. Seaways. https://www.nautinst.org/uploads/assets/uploaded/b311f375-f2da-4c3c-aacfa6df9f604b50.pdf

Georgiana, S., & Stefan, G. (2010). Planning And Execution Of Blind Pilotage And Anchorage. *Constanta Maritime University Annals*, *14(2)*, 35–40. http://www2.cmu-edu.eu/annals/on-line-journal/

ICS. (2016). *Bridge Procedure Guide* (Fifth ed). Marisec Publications. https://www.academia.edu/29814888

IMO. (1999). *Guidelines for voyage planning - Resolution A.893(21)* (Vol. 893, Issue November).

IMO. (2002). Standards For Ship Manoeuvrability. In *MSC Resolution: Vol. 137(76)* (Issue December).

IMO MSC. (1998). *Resolution MSC.74(69) - Adoption of New and Amended Performance Standards*.

IMO MSC. (2006). Adoption of the Revised Performance Standards for Electronic Chart Display and Information Systems (ECDIS) MSC 82/24/Add.2. In *MSC Resolution* (Vol. 82, Issue 24).

IMO MSC. (2007). *Adoption of the Revised Performance Standards for Integrated Navigation Systems (INS) Resolution MSC.252(83)*.

ITTC. (2002). *Full Scale Measurements Manoeuvrability Full Scale Manoeuvring Trials Procedure*. ITTC - Recommended Procedure. https://www.ittc.info/media/8179/75-04-02-01.pdf

Jeong, M. G., Lee, E. B., Lee, M., & Jung, J. Y. (2019). Multi-criteria route planning with risk contour map for smart navigation. *Ocean Engineering*, *172*(August 2018), 72–85. https://doi.org/10.1016/j.oceaneng.2018.11.050

Kamis, A. S., Ahmad Fuad, A. F., Mohd Fadzil, M. N., & Saadon, S. I. (2020). The Impact of Basic Training on Seafarers' Safety Knowledge , Attitude and Behaviour. *Journal of Sustainability Science and Management*, *15*(6), 137–158. https://doi.org/10.46754/jbsd.2020.08.012

Kim, M.-S., Shin, H.-O., Kang, K.-M., & Kim, M.-S. (2005). Variation of the Turning Circle by the Rudder Angle and the Ship's Speed-Mainly on the Training Ship KAYA-. *Bulletin of the Korean Society of Fisheries Technology*, *41*(2), 156–164. https://doi.org/10.3796/KSFT.2005.41.2.156

Kristić, M., Žuškin, S., Brčić, D., & Valčić, S. (2020). Zone of confidence impact on cross track limit determination in ECDIS passage planning. *Journal of Marine Science and Engineering*, *8*(8). https://doi.org/10.3390/JMSE8080566

Lušić, Z., Kos, S., & Galić, S. (2014). Standardisation of Plotting Courses and Selecting Turn Points in Maritime Navigation. *PROMET - Traffic&Transportation*, *26*(4), 313–322. https://doi.org/10.7307/ptt.v26i4.1437

Marine Insight. (2020). *Real Life Accident: Voyage Plan Ignored – Vessel Scrapes Bottom*. MARS Report. https://www.marineinsight.com/case-studies/real-life-accident-voyage-plan-ignored-vessel-scrapes-bottom/

Mathews, R. M. (1915). THE PROOFS OF THE LAW OF TANGENTS. *School Science and Mathematics*, *15*(9), 798–801. https://doi.org/10.1111/j.1949-8594.1915.tb16374.x

Sian, A. Y., Maimun, A., Priyanto, A., & Ahmed, Y. M. (2014). Assessment of ship-bank interactions on LNG tanker in shallow water. *Jurnal Teknologi (Sciences and Engineering)*, *66*(2), 141–144. https://doi.org/10.11113/jt.v66.2500

Srinivasan, V. K. (2002). Two circles and their common tangents. *International Journal of Mathematical Education in Science and Technology*, *33*(4), 627–636. https://doi.org/10.1080/002073902320300919

Statheros, T., Howells, G., & McDonald-Maier, K. (2008). Autonomous ship collision avoidance navigation concepts, technologies and techniques. *Journal of Navigation*, *61*(1), 129–142. https://doi.org/10.1017/S037346330700447X

Swift, A. J. (2018). *Bridge team management: A practical guide* (Second Edi). Nautical Institute.

Voit, E. O. (2020). Introduction to Mathematical Modeling. *A First Course in Systems Biology*, 19–50. https://doi.org/10.4324/9780203702260-2

Vujičić, S., Mohović, R., & Tomaš, I. Đ. (2018). Methodology for controlling the ship's path during the turn in confined waterways. *Pomorstvo*, *32*(1), 28–35. https://doi.org/10.31217/p.32.1.2

Zekić, A., Mohović, Đ., & Mohović, R. (2015). Analysis of the level of knowledge and understanding of regulations for preventing collisions at sea. *Pomorstvo*, *29*(2), 143–149.