Procedure of Safety Assessment on High-Speed Navigation in Congested Sea Area with the SEATRAS

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EXTENDED ABSTRACT

Aiming at realization of safer and more effective marine transportation, a national project of a highway network on sea surface has been progressed in Japan. A high-speed transportation in congested sea area is one of the key items to be realized in the project. As each high-speed craft (HSC) has its peculiar configuration and mission, safety assessment of its navigation should be evaluated taking traffic condition, craft performance, navigation aids and human operators corresponding to each craft into account.

A procedure of the safety assessment based on ship handling simulator experiments is proposed as follows:

About a high-speed craft to be assessed, a traffic environment in service sea area, maneuvering performance of HSC, maneuvering interface, sight from the navigation bridge are appropriately modeled and installed in a simulator. According to appropriate scenarios, simulator experiments are executed with expert mariners as examinees. The results should be analyzed as follows.

(1) To confirm adequacy of the experiments by examinees' subjective evaluation, to show the resulting maneuver to be safe and to confirm HSC to be clearly identified.
(2) To show less duration and less counts of obstructed condition in HSC experiments than ordinary-speed ship by objective evaluation based on OZT.

Objective evaluation based on OZT
<Evaluation conditions>
1) To keep constant HSC speed.
2) Course change within ±30degrees allowed.
3) Evaluate from 0.5 NM to 2.0 NM around HSC.
4) Radius of virtual circle of target ship is set as 0.07 NM(130m)
Ambiguity in speeds of HSC and target ships is ±1 Knot
(Note) These conditions should be modified according to each assessment.
<Procedure of Evaluation>
1) To divide courses within ±30degrees into 12 zones 5 degrees width each and to count number of zones with more than 2 degrees gap of OZT.
2) OZT gap should be checked from 0.5 NM to 2.0 NM around HSC and to get the Free Zone Number by counting zones with gap(s).
3) When the Free Zone Number=0, re-evaluation should be done at the point 0.5 NM behind the most distant point without obstruction by OZT.
4) To get durations and count of the Free Zone Number=0 (obstructed condition) and to evaluate safety margin in decision making to maneuver in comparison to those of ordinary speed ships.

The procedure comprises suitable modeling and installation to the simulator, adoption of the typical and most difficult scenarios and combination of expert mariners' subjective evaluation and objective evaluation with appropriate indices. A safety margin based on OZT (Obstacle Zone by Targets) is also proposed as an appropriate index for objective evaluation of high-speed navigation in congested sea area (Figure 1.).

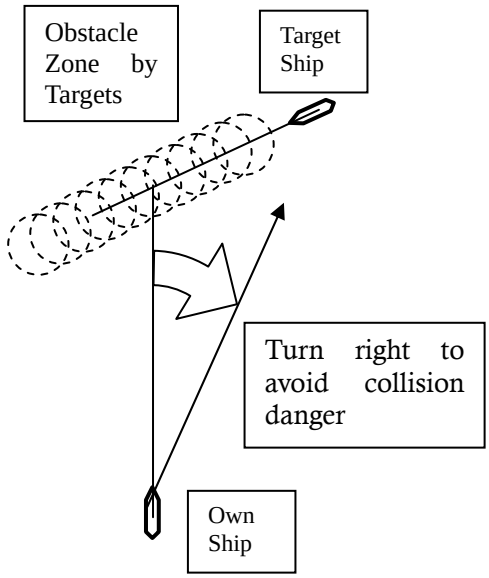

Figure 1. Concept of OZT.

1. INTRODUCTION

A safer and more effective marine transportation is one of the solutions for improvement on economy and ecology. A national project of highway network on sea surface has been progressed in Japan (Ministry of Land, Infrastructure and Transport(2003)). Fast transportation on sea surface is the key item in the project. Navigational safety can be established as an integrated behavior comprised with human operation and ship maneuver. Also high-speed crafts have a lot of variations according to their objectives, i.e., variations in size, speed, type, navigation environment, etc.. A safety assessment procedure using a ship-handling simulator is proposed to evaluate such comprehensive high-speed navigation.

We propose a procedure of the safety assessment using a ship-handling simulator. In the procedure, we introduced an index for safety margin in decision-making to maneuver as a quantitative index. According to the procedure, installing an existing ship performance to the simulator, experiments have been executed as an example.

2. SAFETY ASSESSMENT ON HIGH SPEED NAVIGATION

The basic concepts of the navigation safety are: (1) to keep right and (2) to keep rules and regulations. In case of a high-speed navigation encountering to an ordinary speed ship, a collision avoidance maneuver of the ordinary speed ship is often difficult because of the big speed difference. An early avoidance maneuver of the high-speed ship is recommended in such cases. Also it is required not to disturb a smooth traffic on the sea surface.

Navigation safety can be established by appropriate decision-making to maneuver and a sufficient performance to realize the decision. A safety assessment should be, therefore, made from those viewpoints.

2.1 Safety Margin For Decision-Making To Maneuver

An extent of obstruction is often used for the evaluation of navigation difficulties. It is an index of difficulty in going straight around a ship's planned course, e.g., within 30 degrees course changes.

Expert mariners often pointed out that a lower-speed ship seemed to stop from an operator of a higher-speed ship in case of encounters of large speed difference and an operator of the higher-speed ship can, therefore, take a collision avoidance maneuver easily. Taking encountered target ships' speeds and their ambiguity into account, the "OZT (Obstacle Zone by Targets)" is proposed as showing obstruction by other ships' collision danger.(Imazu, et. al., 2002) A new evaluation index of an extent of obstruction is proposed applying OZT as the obstruction zone. Figure 2. shows a schematic diagram of OZT.

Combining analyses of safety margin in decision-making to maneuver and a sufficient performance to realize the decision, a safety assessment procedure is proposed as shown in Table 1 and 2. This procedure comprises an appropriate modeling, expert mariners' subjective evaluation and quantitative evaluation in comparison to those of ordinary-speed ships.

About a high-speed craft to be assessed (HSC), a traffic environment in service sea area, maneuvering performance of HSC, maneuvering interface, sight from the navigation bridge are appropriately modeled and installed in a simulator. According to appropriate scenarios, simulator experiments are executed with expert mariners as examinees. The results should be analyzed as shown in Table 1..

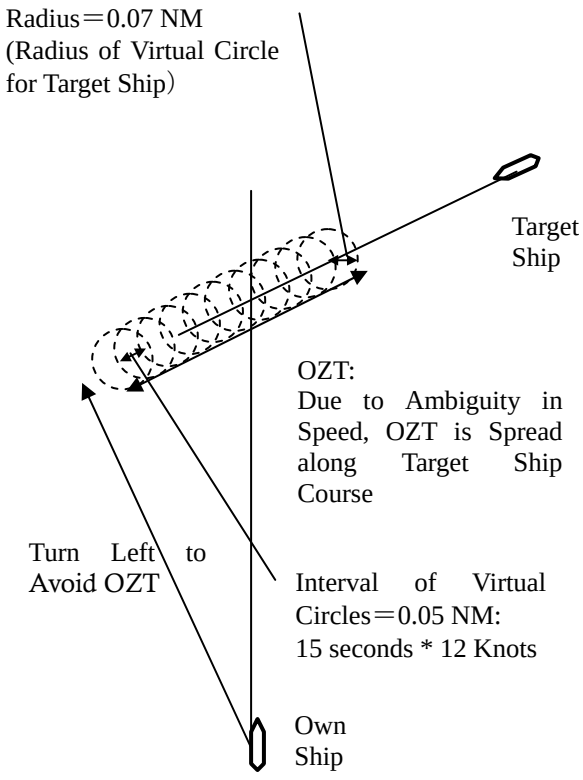

Figure 2. A schematic diagram of OZT.

Table 1. Procedure of safety assessment on high-speed navigation in congested sea area using ship-handling simulator.

Assessment process			Contents
(1)			To confirm adequacy of the experiments by examinees' subjective evaluation, to show the resulting maneuver to be safe and to confirm HSC to be clearly identified.*
(2)			To show less duration and less counts of obstructed condition in HSC experiments than ordinary-speed ship by objective evaluation based on OZT.
Objective evaluation based on OZT	Evaluation conditions	(1)	To keep constant HSC speed.
		(2)	Course change within ± 30 degrees allowed.
		(3)	Evaluate from 0.5 NM to 2.0 NM around HSC.
		(4)	Radius of virtual circle of target ship is set as 0.07 NM (130 m)
		(5)	Ambiguity in speeds of HSC and target ships is ±1 Knot
		(Note)	These conditions should be modified according to each assessment.
	Procedure of evaluation	(1)	To divide courses within ± 30degrees into 12 zones 5 degrees width each and to count number of zones with more than 2 degrees gap of OZT.
		(2)	OZT gap should be checked from 0.5 NM to 2.0 NM around HSC and to get the Free Zone Number by counting zones with gap(s).
		(3)	When the Free Zone Number=0, re-evaluation should be done at the point 0.5 NM behind the most distant point without obstruction by OZT.
		(4)	To get durations and count of the Free Zone Number=0 (obstructed condition) and to evaluate safety margin in decision making to maneuver in comparison to those of ordinary speed ships.

* The examinees' subjective evaluation should be got taking items listed in **Table 2.**

Table 2. Examinees' subjective evaluation in simulator experiments.

Evaluation items	Contents
(1) Traffic environment	To realize ships' traffic in the simulator based on the field observation.
(2) Maneuvering performance of HSC	To construct a maneuvering model that represents turning, accelerating and decelerating performance and wind effect based on tank tests, etc., and to install it in the simulator.
(3) Maneuvering interface	To realize appropriate interfaces that display necessary information of HSC and other ships and have necessary functions HSC should be equipped in the simulator.
(4) Sight from navigation bridge	To display other ships' maneuver, landscape and remarkable objects for navigation on the screen of the simulator.
(5) Simulation Scenario	To estimate ship traffic pattern and time of day in HSC service area and navigation watch system of HSC and to set the most severe condition scenarios to the simulator experiments.
After (1) to (5) have been done:	
(6) Confirmation of adequacy of the simulator experiments	To confirm that requirements on (1) to (6) are fulfilled.
(7) Safe Maneuver (Not only HSC's safety, but not to disturb other ships)	To evaluate resulting maneuver from viewpoints of time to start collision avoidance maneuver, wind effect, navigation support, navigation watch system, etc..
(8) Clear identification of HSC by other ships	To confirm the clear identification from other ships by replaying the experiment results and changing own ship to other encountered ships.

3. SAFETY ASSESSMENT ACCORDING TO THE PROPOSED PROCEDURE

A series of simulator experiments has been executed with an existing HSC performance and Tokyo Bay as a congested sea area using the Sea Traffic Simulation (SEATRAS). (Numano, et. al., 2001) (Numano, et. al., 2003). Scenarios are listed in Table 3. and HSC performances are shown in Figure 3.. Figure 4. shows planned routes used in the simulator experiments as navigation environment.

Expert mariners were invited as examinees of the experiments

3.1 Simulator Experiment Results And Discussion

According to Table 1. and 2., adequacy of the experiments and the resulting maneuver to be safe were confirmed by examinees' subjective evaluation, and clear identification of HSC by other ships is confirmed with replay of the simulation results.

Table 3. Scenarios of Simulator Experiments.

Mission	After appropriate pre-tests, examinees are said to handle their own ship without speed change		
Maneuvering performance *	Model-I	Model-II	
	Performance A : T=0.5, K=1.0 Performance B : T=1.0, K=0.5	Performance C : T=0.5, K=1.0 Performance D : T=2.0, K=0.5	
Sea area model	Southbound in Tokyo Bay	Southbound in Tokyo Bay	
Time of day	Day	Day	Night
Watch	2 persons	2 persons	3 persons
Max. speed	40.0 KNOTS	37.6KNOTS / 15.0KNOTS	37.6 KNOTS
Wind	No	No	No・15 m/s W
Emergency maneuver	Done	Done（37.6 Knots）	
Analysis	Subjective evaluation by expert mariners, confirmation with objective indices		

* T: delay time in seconds, K: gain in turning force.
Mode1-I : extrapolation of a half size model performance. (A; original, B; degraded.)
Mode1-II: based on full size model performance tank tests. (C; original, D; degraded.)

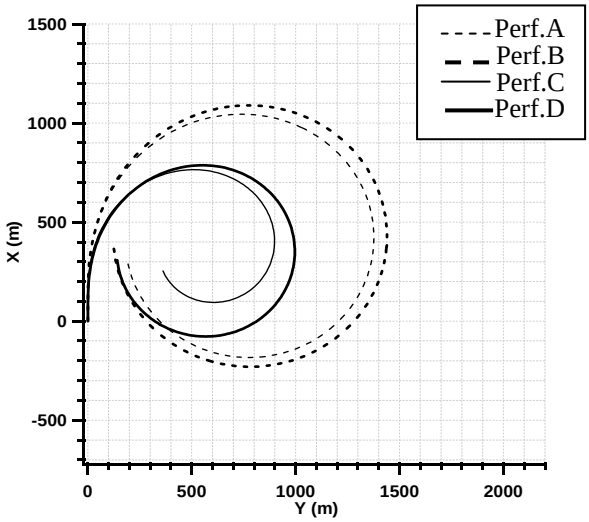

Figure 3. Turning performance:
Set rudder angle to starboard 35 at X=0

Figure 4. Planned routes used in the simulator experiments as navigation environment.

An extent of the obstruction was evaluated with FZN (Free Zone Number). Comparison of the trends of FZN among various HSC speeds is shown in Figure 5., respective traces are shown in Figure 6.. Table 4. shows duration and counts of FZN. Respective OZT displays are shown in Figure 7. and 8.. These figures and table show that a sufficient margin in decision-making to maneuver was held even for Performance model D.

In the expert mariners' subjective evaluation, the turning performance of the model D is said to be acceptable because of easiness in steering control in large control actions.

4. CONCLUSIONS

A study on the safety assessment of a high-speed navigation in congested sea area has been performed and concluded as follows:

1. An effective safety assessment procedure for a high-speed navigation using a ship-handling simulator is proposed, that comprises suitable modeling and installation to the simulator, adoption of the typical and most difficult scenarios and combination of expert

mariners' subjective evaluation and objective evaluation with appropriate indices.

2. An extent of obstruction applying OZT as obstruction by collision danger of other ships is introduced as an index of safety margin for decision-making to collision avoidance maneuver. Other indices of safety margin than FZN based on OZT can be applicable depending on each case.

3. The effectiveness of the proposed procedure has been confirmed through sample experiments on a high-speed navigation with an existing ship performance of HSC and a traffic environment of Tokyo Bay.

Although an actual service of the high-speed marine transportation should need stepwise confirmation of its safety, etc., a basic confirmation can be acquired with the proposed procedure, that is essential at the planning and design stage of services and ships.

5. ACKNOWLEDGEMENTS

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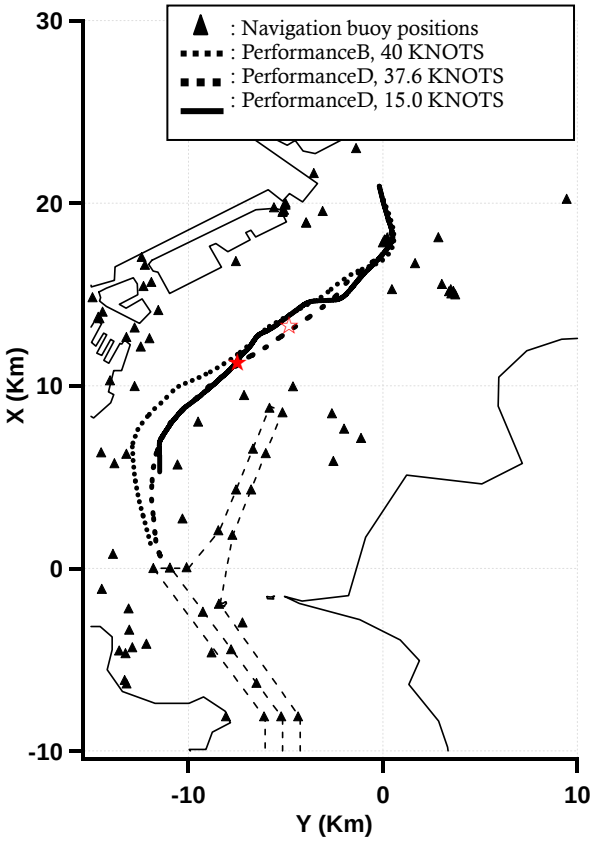

Figure 5. Ship Traces Shown in Figure 6.

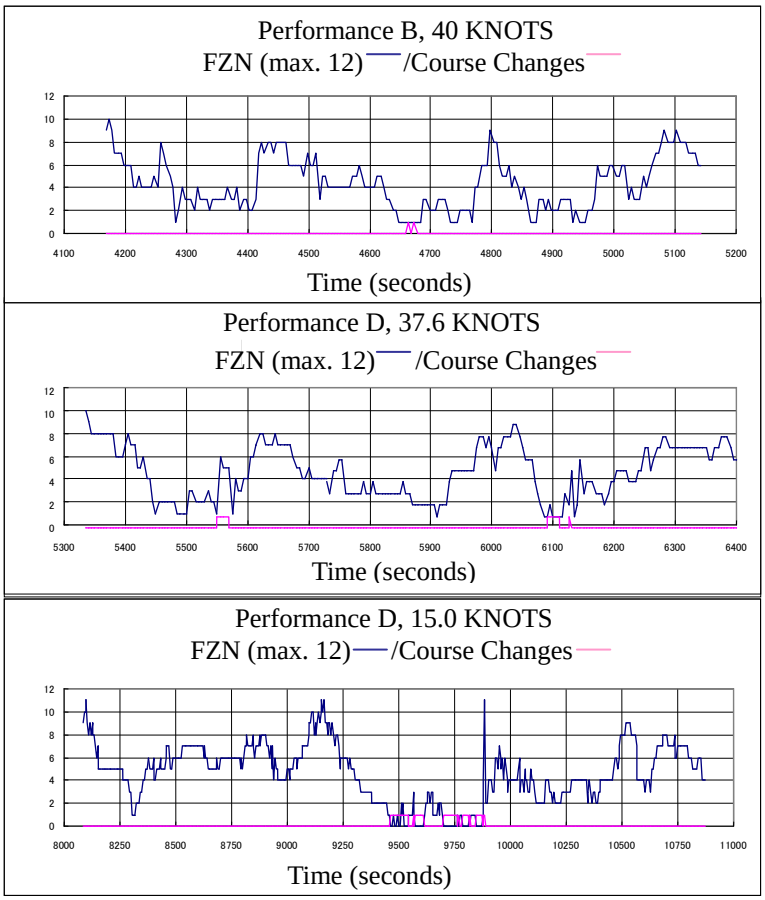

Figure 6. Trend of free zone number (FZN); at day time.

Table 4. Maximum duration and counts of obstructed condition (FZN=0): at day time.

Speed	Max. Duration	Counts
40 KNOTS	0	0
37.6 KNOTS	0	0
15 KNOTS	65 seconds	10

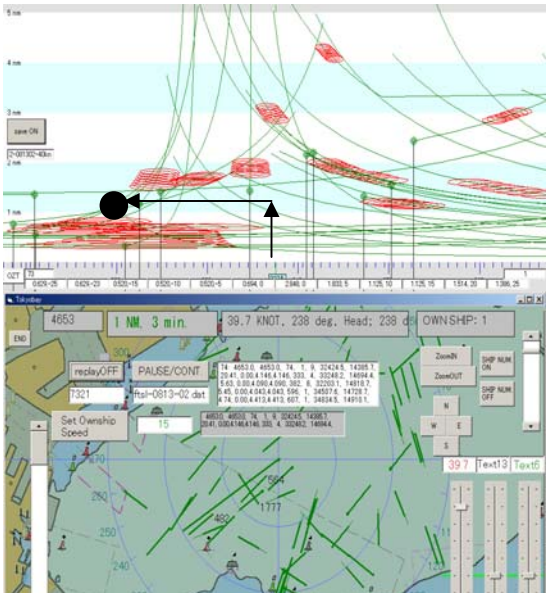

Figure 7. OZT display (Performance D, 40 Knots). Sufficient space at 1 NM ahead with –20 degrees horizontally,(●)

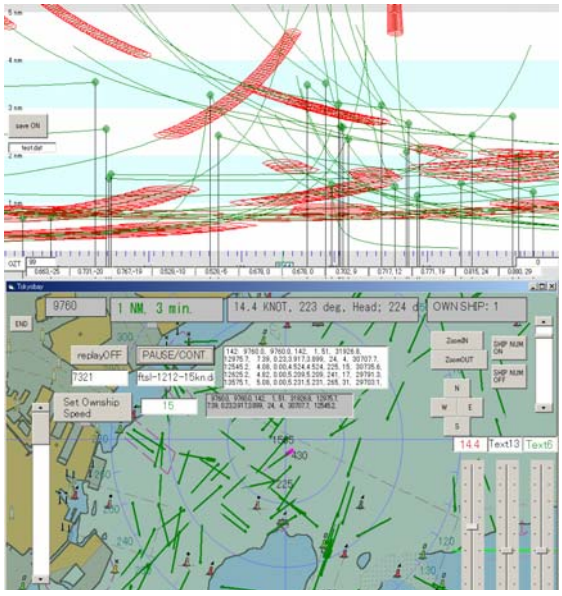

Figure 8. OZT display (Performance D, 15 Knots). No clear spaces ahead due to overlap of OZT.