MA2019-6

MARINE ACCIDENT

INVESTIGATION REPORT

June 27, 2019

JTSB Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board is to determine the causes of an accident and damage incidental to such an accident, thereby preventing future accidents and reducing damage. It is not the purpose of the investigation to apportion blame or liability.

Nobuo Takeda
Chairman
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

MARINE ACCIDENT INVETIGATION REPORT

Vessel type and name:	Container vessel NYK VENUS
IMO number:	9312793
Gross tonnage:	97,825 tons
Vessel type and name:	Container vessel SITC OSAKA
IMO number:	9638329
Gross tonnage:	9,566 tons
Accident type:	Collision
Date and time:	Around 07:02:49, May 4, 2018 (local time, UTC+9 hours)
Location:	Hanshin Port, Kobe Area, South off the coast Around 218 ° true bearing, 350 m from Kobe Rokko Island East Waterway in the vicinity of center floating lighted buoy (approximately 34° 37.7 'N, 135° 18.4'E)

May, 29, 2019

Adopted by the Japan Transport Safety Board

Chairman Nobuo Takeda
Member Yuji Sato
Member Kenkichi Tamura
Member Yoshiko Kakishima
Member Makiko Okamoto

SYNOPSIS

< Summary of the Accident >

While container vessel NYK VENUS, the Master ,26 other crew, 3 other persons and a pilot were on board, was turning toward the south entrance of Rokko Island East Coast of Kobe Area of Hanshin Port from the north-eastward under escort by the Pilot, while container vessel SITC OSAKA, the Master and 17 other crew were on board, was proceeding toward in the direction of north west for the south entrance of Kobe Chuo Passage, both vessels collided at around 07:02:49 on May 4,2018 in the vicinity of Kobe Rokko Island East Waterway Central Floating Lighted Buoy.

NYK VENUS caused damage at the starboard side bow, and SITC OSAKA caused damage at the accommodation spaces on the port side stern, but there were no casualties in both vessels.

< Probable Causes >

It is probable that the accident occurred because, while NYK VENUS(hereinafter referred to as "Vessel A") was traveling northeastward and turning left toward the south entrance of East Waterway and SITC OSAKA(hereinafter referred to as "Vessel B") was traveling northwestward toward the south entrance of the Kobe Chuo Passage, Pilot of Vessel A thought that Vessel A was able to pass by the stern side of Vessel B and thus continued to navigate while turning left, while Master of Vessel B, thinking that Vessel B was able to pass by the bow side of Vessel A, continued to proceed northwestward, as a result of which both vessels collided.

It is probable that the Pilot thought that Vessel A was able to pass by stern side of Vessel B and continued to navigate while turning left because, Vessel A was slowing down even though turning left, in addition, by observing the relative orientation of Vessel A and B with his eyes, the Pilot overestimated that Vessel A would be able to pass by Vessel B's stern side and was not aware of the risk of collision with Vessel B.

It is probable that Master of Vessel B continued to proceed northwestward, thinking that the Vessel B would be able to pass by the bow side of Vessel A because, by observing Vessel A's traveling direction and from the radar’s predicted course, he thought Vessel A would maintain the course of travel.

It is probable that the fact that Vessel A and B were not communicating information by VHF in early stage of the encounter, for example letting each other know the course their own vessel was taking, contributed to the occurrence of this accident.

It is considered somewhat likely that the fact that the Pilot and Vessel A's crew were not having verbal communication in regard to maneuvering their own vessel and the movement of the other vessel and Master of Vessel A did not keep to lookout because of focusing his attention on the meeting about entering the port, also contributed to the occurrence of the accident.

1 PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident

While container vessel NYK VENUS, the Master ,26 other crew, 3 other persons and a pilot were on board, was turning toward the south entrance of Rokko Island East Coast of Kobe Area of Hanshin Port from the northeastward under escort by the Pilot, while container vessel SITC OSAKA, the Master and 17 other crew were on board, was proceeding toward in the direction of northwest for the south entrance of Kobe Chuo Passage, both vessels collided at around 07:02:49 on May 4,2018 in the vicinity of Kobe Rokko Island East Waterway Central Floating Lighted Buoy.

NYK VENUS caused damage at the starboard side bow, and SITC OSAKA caused damage at the accommodation spaces on the port side stern, but there were no casualties in both vessels.

1.2 Outline of the Accident Investigation

1.2.1 Set up of the Investigation

The Japan Transport Safety Board (JTSB) appointed an investigator-in-charge and six other marine accident investigators to investigate this accident on May 7, 2018.

1.2.2 Collection of Evidence

May 8, 2018: On-site investigations and interviews

May 9, June 27, June 28 and July 6, 2018: Interviews

May 17, 22, 24, 25, and 30, June 8, July 12, 17, 20, 25, and 31, August 2 and 27, October 4, 5 and 22, all through 2018: collection of questionnaire.

1.2.3 Tests and Research by Other Institutes

In the investigation of this accident, the JTSB entrusted the National Institute of Maritime, Port and Aviation Technology, National Maritime Research Institute for the evaluation of collision risk level, analysis of the navigation situation based on the port entry records, and human factor analysis following to CREAM method which is a tool of human reliability analysis.

1.2.4 Comments of Parties Relevant to the Cause

Comments were invited from parties relevant to the cause of the accident.

1.2.5 Comments from the Flag State

Comments were invited from the flag states of NYK VENUS and SITC OSAKA.

2. FACTUAL INFORMATION

2.1. Events Leading to the Accident

2.1.1 The Navigation Track according to the Automatic Identification System

According to the records of the Automatic Identification System (AIS)*1 data (hereinafter referred to as "the AIS record") received by a data company in Japan, the navigation tracks of "NYK VENUS" (hereinafter referred to as "Vessel A") and "SITC OSAKA" (hereinafter referred to as "Vessel B") from 06:30 to 07:05 on November May 4, 2018 were as shown in Table 2.1-1 and Table 2.1-2 below.

The positions of Vessel A and Vessel B are the position of the GPS antenna mounted above the bridge respectively. The course over the ground and the heading were the truth bearings (same as hereinafter).

Table 2.1-1 AIS Record of Vessel A (abstract)

Time (HH: MM: SS)	Vessel position		Course Over the Ground (°)	Heading (°)	Speed Over the Ground*2 (Knots)
	North latitude (°-′-″)	East longitude (°-′-″)			
6:31:22	34-31-16.1	135-12-38.7	040.6	040	18.0
6:40:05	34-33-07.1	135-14-34.3	041.5	040	15.6
6:45:05	34-34-04.5	135-15-35.3	040.8	040	15.1
6:50:05	34-35-02.2	135-16-33.4	040.3	040	14.9
6:55:05	34-35-59.4	135-17-30.8	040.1	040	14.6
6:55:23	34-36-02.9	135-17-34.5	041.2	039	14.5
6:56:05	34-36-10.7	135-17-42.1	035.0	034	14.1
6:57:05	34-36-21.5	135-17-52.3	034.7	032	13.8
6:58:05	34-36-33.1	135-18-00.8	030.5	030	13.5
6:59:05	34-36-45.2	135-18-08.2	026.7	024	13.2
7:00:05	34-36-57.0	135-18-14.4	019.7	015	12.8
7:01:09	34-37-10.3	135-18-18.0	005.9	006	12.3
7:01:29	34-37-14.2	135-18-18.5	006.5	006	12.2
7:01:49	34-37-18.4	135-18-19.1	005.3	005	12.0
7:02:09	34-37-22.2	135-18-20.2	004.3	004	11.8
7:02:29	34-37-26.0	135-18-19.9	005.1	003	11.5
7:02:49	34-37-29.9	135-18-21.0	005.0	001	11.3
7:03:09	34-37-33.5	135-18-21.3	003.3	354	10.5
7:04:09	34-37-42.8	135-18-20.0	348.3	342	9.1

*1 The "Automatic Identification System" (AIS) is a device that each vessel used to automatically transmit receive information such as Vessel identification code, ship type, name, position, course, speed, destination, and conditions of navigation, and to exchange information with other vessels or land-based navigation aids.

*2 "Speed over the ground" refers to the speed of a vessel as measured against one point on the earth's surface. The speed of a vessel as measured against the water in which the vessel is traveling is called " speed over water".

7:05:09	34-37-51.1	135-18-16.9	341.5	343	8.4

Table 2.1-2 AIS record of Vessel B (abstract)

Time (HH:MM:SS)	Vessel position North latitude (°-′-″)	East longitude (°-′-″)	Course Over the Ground (°)	Heading (°)	Speed Over the Ground* (knots)
6:40:07	34-38-34.5	135-23-53.3	236.6	237	13.8
6:45:11	34-37-55.3	135-22-42.3	234.4	235	14.0
6:50:05	34-37-14.9	135-21-33.8	235.1	235	14.2
6:52:23	34-36-56.0	135-21-01.5	233.9	236	14.2
6:55:11	34-36-53.3	135-20-18.2	291.0	293	13.8
6:56:05	34-36-57.9	135-20-04.2	291.0	293	13.8
6:57:03	34-37-02.8	135-19-48.8	290.0	294	13.8
6:58:03	34-37-08.3	135-19-33.3	293.2	295	13.8
6:59:03	34-37-13.9	135-19-17.6	293.5	295	13.9
7:00:03	34-37-19.4	135-19-02.4	293.2	295	13.9
7:01:03	34-37-24.9	135-18-47.0	292.2	297	13.8
7:01:23	34-37-27.0	135-18-41.7	297.1	301	13.7
7:01:44	34-37-29.2	135-18-36.8	299.9	303	13.7
7:02:03	34-37-31.5	135-18-32.3	302.1	306	13.7
7:02:23	34-37-34.1	135-18-27.8	305.4	309	13.6
7:02:34	34-37-35.4	135-18-25.6	307.7	311	13.5
7:02:44	34-37-37.0	135-18-23.3	311.0	313	13.5
7:03:03	34-37-40.6	135-18-20.3	326.8	284	13.5
7:04:03	34-37-40.1	135-18-11.3	230.8	240	8.7
7:05:03	34-37-36.2	135-18-01.1	264.0	274	9.8

2.1.2 Information on voice etc. recorded by Voyage Data Recorder

According to the records of the Voyage Data Recorder (hereinafter referred to as "VDR") installed in vessel B, the information concerning voice communication and other inside the bridges of the vessel B between 06:52:25 and 07:02:52 on May 4, 2018 was as shown in Table 2.1-3 below.

The voice communication of the Chinese crew in Chinese language are written down in italicized letters.

Table 2.1-3 Information on voice, etc. (abstract)

Time	Voice, etc.	Main engine remote control device
6:52:25	Vessel B Master: *Rudder starboard 10 °.* Vessel B Steering officer: *Rudder starboard 10 °. 10°, starboard.*	Full ahead
6:52:56	Vessel B Master: *Rudder starboard 10 °.* Vessel B Steering officer: *Rudder starboard 10 °.*	
6:52:59	Vessel B Master: *5°, starboard.*	
6:53:15	Vessel B Master: *Rudder midship.* Vessel B Steering officer: *Rudder midship.*	
6:53:19	Vessel B Master: *5°, starboard.* Vessel B's Steering officer: *Rudder starboard 5 °.*	
6:53:50	Vessel B Master: *290°.* Vessel B Steering officer: *290°.*	
6:54:24	Vessel B Master: *293°.* Vessel B Steering officer: *Course 293 °.*	
6:56:47	Vessel B Master: *295°.* Vessel B Steering officer: *295°. Course 295 °.*	
	[Voice unclear]	
7:00:45	Vessel B Master: *Rudder starboard 10 °.* Vessel B Steering officer: *Rudder starboard 10 °. 10°, starboard.*	
7:00:55	Vessel B Master: *Rudder midship.* Vessel B Steering officer: *Rudder midship.*	
07:00:59～ 07:01:02	[Voice unclear]	
7:02:10	Vessel B Navigational officer: NYK VENUS NYK VENUS. SITC OSAKA SITC OSAKA. Whistle: One long sound (about 10 seconds) Vessel B Navigational officer: NYK VENUS NYK VENUS. SITC OSAKA SITC OSAKA.	
7:02:30	Vessel B Navigational officer: *Super close.* Vessel B Master:[Voice unclear] Buzzer sound: (about 10 seconds)	
7:02:40	[Voice unclear] Vessel B Master: *Rudder port10 °.* Vessel B Steering officer: *Rudder port 10 °.*	
7:02:43		Nav. Full ahead
7:02:49～ 7:02:52	(sound of impact)	

In addition, according to the reply to the questionnaire by NYK SHIPMANAGEMENT PTE LTD (hereinafter referred to as "Company A"), which is the management company of vessel A, with respect to the VDR that was installed in vessel A, Master of Vessel A (hereinafter “Master A”) wanted the VDR recording and ordered the recording work, but the work was not done properly, the record at the time of this accident was lost, and we could not get it. The manual related to the procedure of recording work was posted in the bridge.

2.1.3 Event Leading to the Accident according to Statements of crew, etc.

According to the statements by Master A, Navigational officer of Vessel A (hereinafter, “Officer A1“), Steering officer of Vessel A (hereinafter, “Steering Officer A”), Trainee of Vessel A (hereinafter, “Trainee A”), and Pilot of Vessel A (hereinafter, “Pilot A”), as well as, Master of Vessel B (hereinafter “Master B”), Navigator officer of Vessel B (hereinafter, “Officer B”), Steering officer of Vessel B (hereinafter, “Steering officer B”), the Operational Report of the Kobe Port Radio [*3] (hereinafter referred to as "Port Radio") and the reply to the questionnaire by Company A.

(1) Vessel A

On April 28, 2018, Vessel A departed from Port of Singapore, Republic of Singapore bound for Rokko Island Quay RC-7 in Kobe Area of Hanshin Port, with Master A (Republic of Croatia nationality), 26 other crews (3 Croatian citizens, 2 Russian federals, 16 Republic of the Philippines, 2 Indian citizens, 1 Romanian citizen and 2 citizens of the People's Republic of China) and 3 other persons (all nationality of India) on board.

At around 05:00 on May 04, Pilot A got on board Vessel A at the Pilot station [*4] off to the south of Tomogashima Island, Wakayama city Wakayama Prefecture, after exchanging information with Master A about Vessel A and entering to the port, and started the Pilotage operating of Vessel A.

Vessel A set the course to 040° (true azimuth, hereinafter the same) toward Hanshin Port Kobe Area and sailed off Kansai International Airport at a speed of about 18 knots (ground speed, hereinafter the same) under the pilotage of Pilot A, with Master A conning the vessel, other navigational officer who is different from the Officer A1 (hereinafter referred to as "Officer A2") assigned to the operation of main engine remote control device, the Steering officer A assigned to hand steering, and the Trainee A assigned to the lookout.

During Pilotage of Vessel A, Pilot A felt that crews of Vessel A have been educated for

*3 "Kobe Port Radio" refer to a coastal broadcasting station which is entrusted from the port administrator, Kobe City, to communicates using VHF with vessels entering and leaving the port, in order to provide port schedules, ensure the navigational safety of vessels as necessary, inform the vessel of the state of the inside of the route and the inside of the port (presence or absence of entering or exiting vessels, presence or absence of encountering vessels, and construction situation inside of the port.) In addition, Kobe Port Radio is not authorized to conduct traffic control, traffic restrictions, prohibitions, etc. of vessels carried out by the harbormaster under the provisions of the Act on Port Regulations.

*4 "Pilot station" refers to a waters area that was set up for a Pilot to join a Pilot-requesting vessel and onboard the vessel.

BRM[*5] well, so he thought that the crew members on board would be reliable, and also thought that the perception of vessel maneuvering was able to beshared with Master A.

Pilot A ordered the crew of the bridge to gradually lower the speed to the harbor speed at around 06:35, and at around 06:44, communicate with Port Radio by No. 2 'VHF radio telephone' (hereinafter referred to as "VHF") in Japanese, and told that Vessel A arrived outside of Hanshin Port Kobe Area and would navigate through the No.7 breakwater of the Hanshin Port Kobe Area at around 07:20. Then, Pilot A heard the information of a vessel proceeding ahead of Vessel A and that the vessel B were scheduled to enter to Kobe Chuo Passage at around 07:15, and watched Vessel B.

Officer A1 rose up to the bridge at around 06:52 and took over the watch with the Officer A2 who had been watching and operating the main engine remote control device.

Master A watched Vessel B at a distance of about 3M ahead to starboard at around 06:53, checked the numerical value of the closest approach distance (hereinafter referred to as "DCPA") with Vessel B on No. 1' Electronic Chart Information Display Device '(hereinafter referred to as "ECDIS"), and confirmed that the value of Vessel B was 0.84 M (about 1,556m). Because Master A thought that Vessel B would proceed southwest toward and Vessel A was going to proceed to the left, he thought that Vessel B would go away from the starboard side of Vessel A. Therefore Master A did not tell the Pilot A about Vessel B. In addition there was no talk about Vessel B from Pilot A. So Master A started to talk about the entry to the port with Officer A2 near the chart table.

Because Master A was watching with the radar, Pilot A continued the watch on Vessel B with his own eyes without using the radar near the No. 2 VHF with which communicated with Port Radio, and at around 06:55 felt there was no bearing change in the relative with Vessel B.

Pilot A thought that Master A and Officer A2 were watching on Vessel B with radar and ECDIS. Then Pilot A thought that crew of Vessel A were conscious of the movement of Vessel B because Pilot A pointed at Vessel B with his finger, and ordered the Steering officer A to turn the left toward Rokko Island East Waterway (hereinafter referred to as "East Waterway").

Pilot A could not predict how Vessel B would proceed immediately after her right turn, however, from the relative relationship with Vessel B which he saw at around 06:57, thought that Vessel B might pass through the bow side of Vessel A, so continued to order the left turn with slowing down.

Pilot A thought that the instructions concerning the vessel maneuver that he had done to enter the port were understood by the Master A, therefore continued to maneuver Vessel A.

Although Trainee A, confirming by the radar, felt the fear of collision against Vessel B and reported that to Pilot A, Pilot A did not notice that there was a report of Trainee A.

Vessel A gradually turned left to the East Waterway while slowing down.

As Vessel A approached the entrance of the East Waterway at around 07:01, Pilot A ordered Officer A1 to make the main engine half ahead, then check the positional

---

*5 "BRM" is an abbreviation for Bridge Resource Management, which means effectively manage all the resources available on the bridge such as crews, facilities and information for safe operation of the ship.

relation with Vessel B with his eyes, and felt the risk of collision with Vessel B, therefore ordered the Steering officer A hard port.

Because Master A listened to "half-ahead" and "hard port" which were ordered by Pilot A, he looked back from nearside of the chart table and saw the bow. It seemed that the bow of Vessel A and the bow of Vessel B were overlapping. Therefore, at the same time Master A ordered Officer A1 to change the slow ahead of the main engine, moved to near the main engine remote control device, and shifted the driving of the main engine from the dead slow ahead to the full astern, however at around 07:03, the starboard bow of Vessel A collided with the accommodation spaces on the port side stern of vessel. B.

Pilot A felt, after the accident, that he had not fully considered the length of Vessel A from the bridge to the bow for the passing distance with Vessel B.

(2) Vessel B

At around 06:10 on May 4,Vessel B departed from the Osaka Area of Hanshin Port bound for Rokko Island Quay RC-4 in Kobe Area of Hanshin Port, with Master B (nationality of People's Republic of China) and 17 other crew (all nationality of People's Republic of China) on board.

Vessel B continued navigation, under the command of Master B, with Officer B assigned to the lookout and Steering officer B assigned to the hand steering respectively.

Officer B informed Port Radio with VHF at around 06:31 that Vessel B was planning to enter the Kobe Chuo Passage at around 07:15 and heard from Port Radio the information about two vessels anchoring in the anchorage.

Master B confirmed Vessel A with his eyes at around 4 M away in the direction of bow at around 06:50 and started watching with No.2 radar and visual observation.

Master B ordered right turn towards the Kobe Chuo Passage near the south off the Osaka Landfill Disposal Site in Hanshin Port Osaka Area, No.6 district at around 06:52.

Master B recognized that it was in crossing situation with Vessel A at around 06:54 and was concerned about the decrease in the DCPA value at around 06.57, but from the predicted course of Vessel A by the radar, thought that Vessel B was able to pass the bow of the Vessel A without problems, and he also thought Vessel B would enter the port at faster speed if the speed up here around.

Watching Vessel A which was turning left at around 07:00, Master B felt the danger, and ordered starboard 10 ° to try to leave a distance from Vessel A.

After that, Officer B called Vessel A twice with VHF, but there was no response from Vessel A. Then Master B sounded the whistle and Officer B called Vessel A for two times similary, however there was no response from Vessel A too.

Master B thought that the whistle could not be heard even if it sounded too far.

Master B ordered Officer B to change the movement of the main engine from full ahead to navigation full ahead in order to increase the speed so that it could pass before the bow of Vessel A, however, at around 07:03 the accommodation spaces etc. on the port side stern of Vessel B collided with the starboard bow of Vessel A.

The date and time of occurrence of this accident was around at around 07:02:49 on May

04, 2018, and the location was around 218 ° true bearing 350 meters from the Kobe Rokko Island East Waterway Central Light Buoy (hereinafter referred to as the "Central Buoy").

(See Annex Figure 1: Navigation path diagram of Vessel, Annex Figure 2: Navigation path diagram (enlarged), Annex Table 1: Table of the progress of this accident)

2.2 Injuries to Persons

According to the statements of Master A and Master B, there were no casualties or injuries.

2.3 Damage to Vessels

(1) Vessel A got a bend damage in the bulwark and others of the starboard bow, abrasion on the shell plate of the starboard bow, and a concave damage in the bulbous bow.

(2) Vessel B was damaged in the accommodation spaces etc. on the port side stern, and according to the statement by the SITC SHIPS MANAGEMENT CO., LTD., the management company of Vessel B (hereinafter referred to as "Company B"), Vessel B occurred cracks in the port bottom shell.

(See Photo 2.3-1 and Photo 2.3-2)

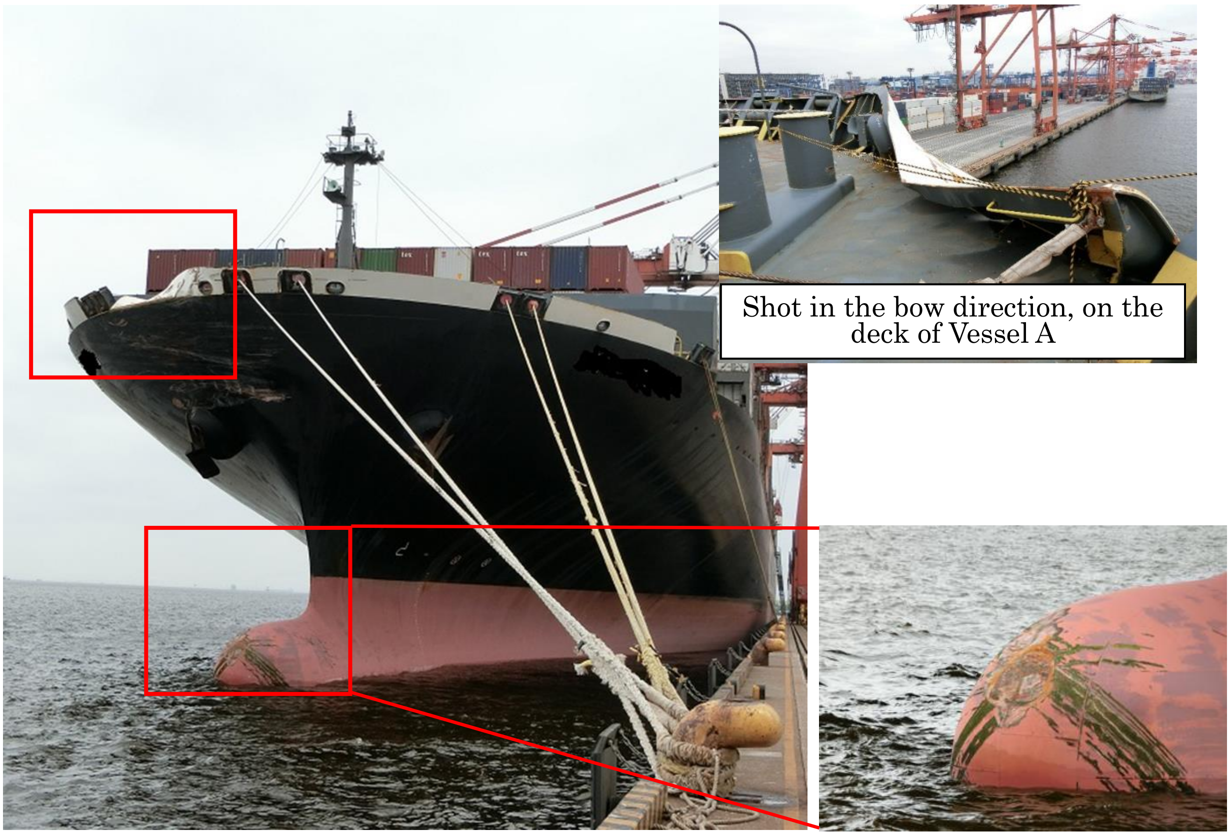


Photo 2.3-1 Damage status of Vessel A

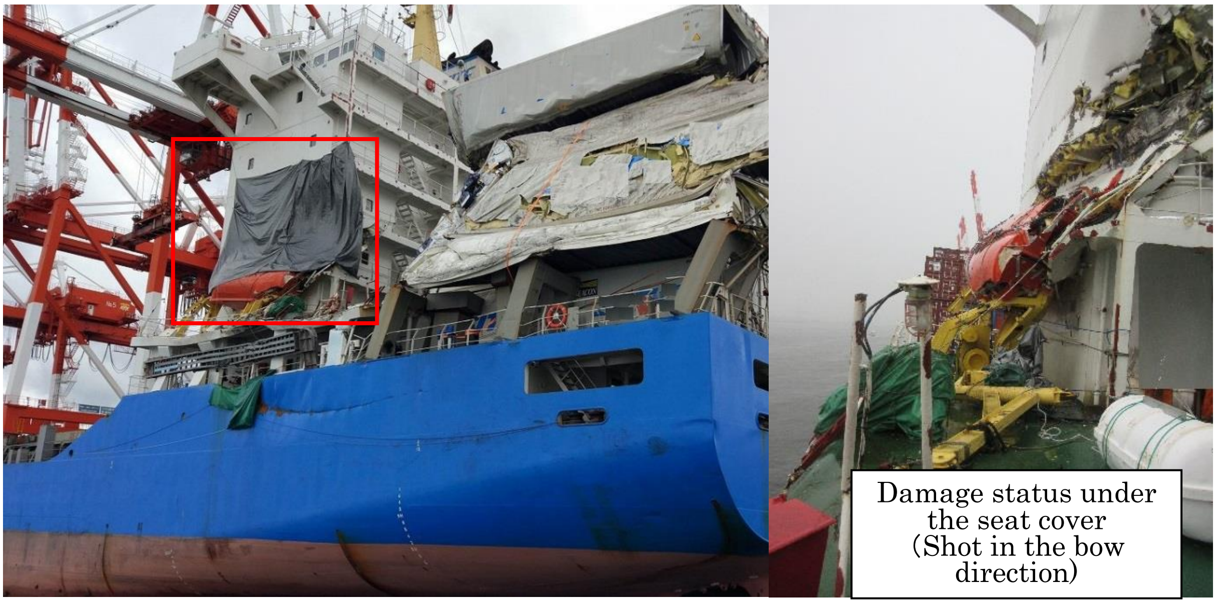


Photo 2.3-2 Damage status of Vessel B

2.4 Crew Information

(1) Gender, Age, Certificate of Competence

Master A: Male 54 years old, Nationality: Republic of Croatia

Endorsement attesting the recognition of certificate under STCW regulation I/10: Master (issued by the Republic of Panama)

Date of Issue: December 12, 2016

(Valid until September 28, 2021)

Officer A1: Male 24 years old Nationality Republic of the Philippines

Endorsement attesting the recognition of certificate under STCW regulation I/10: Second officer (issued by the Republic of Panama)

Date of Issue: March 6, 2018

(Valid until July 26, 2021)

Officer A2 : Male 54 years old Nationality Republic of Croatia

Endorsement attesting the recognition of certificate under STCW regulation I/10: Master (issued by the Republic of Panama)

Date of Issue: December 22, 2014

(Valid until October 17, 2019)

Trainee A: Male 25 years old Nationality People's Republic of China

No seamen's competency certificate

Pilot A: Male 71 years old

Osaka Bay Pilot District First Grade Pilot's License

Date of Issue: December 25, 2001

Date of Revalidation: December 24, 2015

Date of Expiry: December 24, 2018

Master B: Male 45 years old Nationality People's Republic of China

Master's License (issued by the People's Republic of China)

Date of Issue: November 27, 2017
(Valid until June 16, 2021)

(2) Sea-going Experience, etc.

According to the statement of Master A, Master B and Pilot A, these were as follows:

(i) Master A

Since 2003 Master A took office as a Master, as a Master of Vessel A he had been on board since March 2018, and he had experienced entering the Kobe Area of Hanshin Port as Master for eight times.

At the time of this accident, he was in good health.

(ii) Pilot A

He got a job in a shipping company in 1969, he had the experience of getting on large crude oil tankers, LNG vessels, and container vessels, etc. as master, and started working as a pilot in Osaka Bay in February 2002 , and had been doing Pilot work for about fifteen times a month.

At the time of this accident, he was in good health.

(iii) Master B

Since 2002 Master B took office as a Master, as a Master of vessel B he had been on board since November 2017, and he had experienced entering the Kobe Area of Hanshin Port as Master for more than a hundred times in total.

At the time of this accident, he was in good health.

2.5 Vessel Information

2.5.1 Principal of the vessels

(1) Vessel A

IMO No.:	9312793
Port of registry:	Republic of Panama, Panama
Owner:	NYK VENUS CORPORATION (Republic of Panama)
Management company:	Company A (Singapore)
Classification Society:	Nippon Kaiji Kyokai
Gross tonnage:	97,825 tons
L x B x D:	338.17m x 45.60m x 24.60m
Hull material:	Steel
Engine:	Diesel engine x 1
Output:	64,033kW
Propulsion:	6-blade fixed pitch propeller x 1
Date of launch:	December 29, 2006

(See Photo 2.5-1)

Photo 2.5-1: Vessel A

Vessel A had been engaged in a regular route between Japan, Singapore and Europe, and had entered the Kobe Area of Hanshin Port once every two and a half months.

(2) Vessel B

IMO No. :	9638329
Port of Registration:	Hong Kong Special Administrative Region, Peoples Republic of China, Hong Kong
Owner:	SITC OSAKA SHIPPING COMPANY LTD. (Hong Kong Special Administrative Region of China)
Management company:	Company B (Peoples Republic of China)
Classification Society:	Nippon Kaiji Kyokai
Gross tonnage:	9,566 tons
L x B x D:	141.03m x 22.50m x 11.40m
Hull material:	Steel
Engine:	Diesel engine x 1
Output:	8,280kW
Propulsion:	5-blade fixed pitch propeller x 1
Date of launch:	March 31, 2012

(See Photo 2.5-2)

Photo 2.5-2: Vessel B

Vessel B had been engaged in a regular route between Japan and People's Republic of China, and had entered the Kobe Area of Hanshin Port twice a month.

2.5.2 Load conditions

(1) Vessel A

According to the reply to the questionnaire by Company A, the 20-foot equivalent container loading capacity of Vessel A was 9,012 unit. At the time of the accident, Vessel A had 1,360 of 20-foot containers and 2,441 of 40-foot containers, while the draft was about 12.85m at bow and about 13.35m at stern.

(2) Vessel B

According to the statement and reply to the questionnaire by Master B, the 20-foot equivalent container loading capacity of Vessel B was 1,103 unit. At the time of the accident, Vessel B had 195 of 20-foot containers and 208 of 40-foot containers, while the draft was about 5.19m at bow and about 7.05m at stern.

2.5.3 Navigation equipment, etc.

(1) Vessel A

Vessel A had a gyro- compass repeater and two VHF handsets at the center of the bow window side of the bridge and a steering device behind them, and No. 1 ECDIS, No. 1 radar, No. 2 radar and No. 2 ECDIS at the starboard side of the bow window side, the main engine remote control device and No. 1 radar display unit on the port side near the bow window, and in addition, the chart table etc. behind the radar, VDR remote control unit on the work console at the rear of the main engine remote control device, respectively.

According to the reply to the questionnaire by Company A, at the time of the accident, Officer A1 had set the range of the No. 1 radar to 6 M and the No. 2 radar to 3 M respectively, and was monitoring them both.

(See Figure 2.5 - 1)

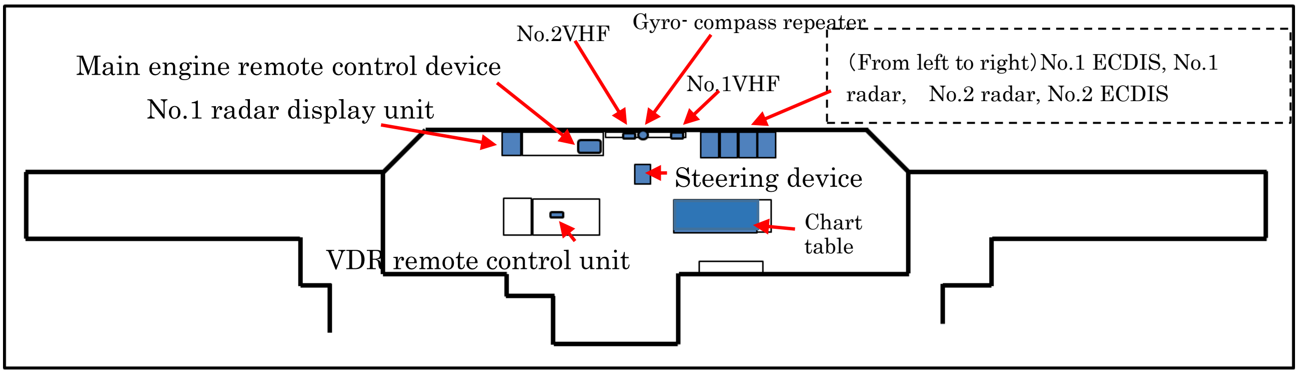


Figure 2.5-1: Bridge of Vessel A

(2) Vessel B

Vessel B had a gyro-compass repeater and two VHF handsets at the center of the bow window side of the bridge and a steering device behind them, and the main engine remote control unit, No. 1 radar, etc. at the starboard side, No. 2 radar at the port side, the whistle operation unit near the window on the bow (around port side and center) respectively.

According to the statements of Master B, at the time of the accident, Master B had set the range of No. 2 radar to 3M, monitor it, and used the left whistle operation unit, and Officer B was using No. 1 VHF.

(See Figure 2.5 - 2)

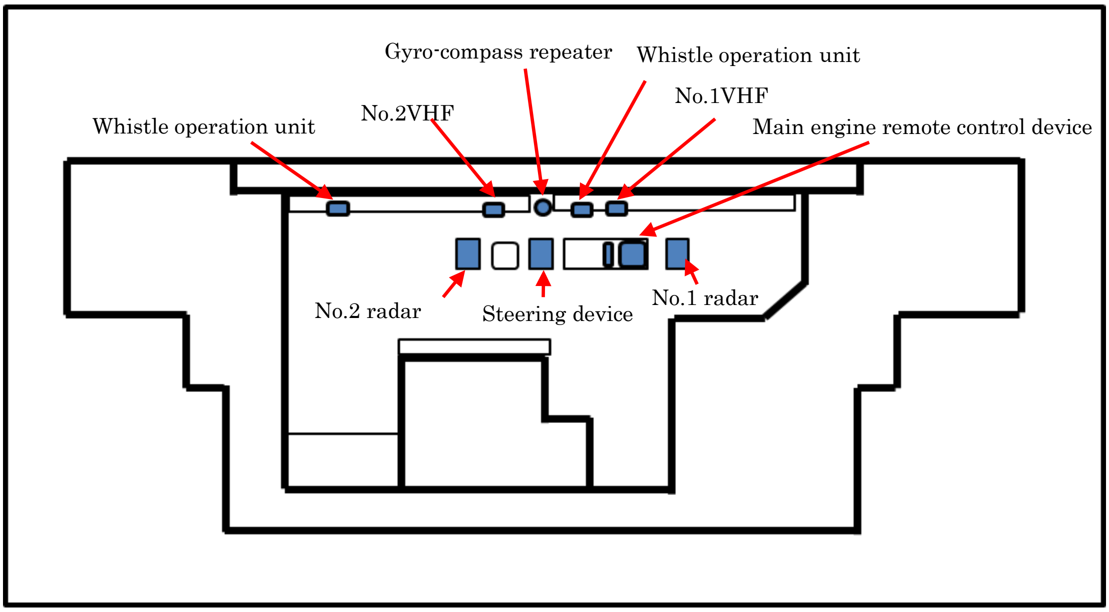


Figure 2.5-2: Bridge of Vessel B

2.5.4 View from the Bridge

There was no structure that caused a blind spot on the starboard bow of Vessel A and on the portside bow of Vessel B.

2.5.5 Information about the Maneuverability

(1) Vessel A

According to the maneuverability characteristics table of Vessel A, her maneuverability was as follows.

(i) Main engine revolutions and speed

Type	Main engine revolutions per minute (rpm)	Speed with load (kn)	Speed without load (kn)
Navigation full ahead	93.5	25.0	27.0
Full ahead	46.0	12.0	12.9
Half ahead	39.0	10.0	11.1
Slow ahead	31.0	8.0	9.4
Dead slow ahead	25.0	6.0	7.8

(ii) Time and distance needed until stopping at speed full astern

	With Load		Without load	
State when astern order issued	Time (seconds)	Distance (M)	Time (seconds)	Distance (M)
Navigation full ahead	660	2.3	450	1.7
Half ahead	264	0.4	186	0.3

(iii) Steerageway

With Load	4.7 knots
Without load	6.8 knots

(iv) Turning characteristics with load

	Main engine revolutions per minute (rpm)	Advance*6 (m)	Time (sec)	Tactical diameter*7 (m)	Time (sec)
Starboard turn	93.5	994.5	108	1357.5	294
	39.0	770.4	270	1172.3	654
Port turn	93.5	913.0	96	1150.1	264
	39.0	789.0	246	998.2	654

(v) Turning characteristics without load

	Main engine revolutions per minute (rpm)	Advance (m)	Time (sec)	Tactical diameter (m)	Time (sec)
Starboard turn	96.0	1059.3	120	1446.4	246
	44.0	820.4	228	1248.2	456

*6 "Advance" means the distance by which the center of gravity of the hull advances in the direction of the present course when turning 90° from the center of gravity of the hull at the time of vessel turning.

*7 The "turning diameter" means the distance by which the center of gravity of the hull advances in the direction of the present course when turning 180 ° from the center of gravity of the hull at the time of vessel turning.

Port turn	96.0	972.3	114	1224.2	222
	44.0	840.8	228	1063.0	438

(2) Vessel B

According to the maneuverability characteristics table of Vessel B, her maneuverability was as follows.

(i) Main engine revolutions and speed

Type	Main engine revolutions per minute (rpm)	Speed with load (kn)	Speed without load (kn)
Navigation full ahead	124.5	18.0	19.5
Full ahead	85.0	13.0	13.5
Half ahead	77.0	11.5	11.5
Slow ahead	55.0	7.5	7.5
Dead slow ahead	40.0	5.5	7.8

(ii) Time and distance needed until stopping at speed full astern

	With Load		Without load	
State when astern order issued	Time (sec)	Distance (M)	Time (sec)	Distance (M)
Navigation full ahead	377	1661	295	1455
Half ahead	316	933	197	665

(iii) Turning characteristics with load

	Main engine rotational speed per minute (rpm)	Advance (m)	Time (sec)	Turning radius*8 (m)
Starboard turn	124.5	544.0	79	287.0
	77.0	503.0	110	280.0
Port turn	124.5	544.0	79	287.0
	77.0	503.0	110	280.0

(iv) Turning characteristics without load

	Main engine revolutions per minute (rpm)	Advance (m)	Time (sec)	Turning radius (m)
Starboard turn	124.5	523.0	74	256.0
	77.0	483.0	108	249.0
Port turn	124.5	523.0	74	287.0
	77.0	483.0	108	249.0

2.5.6 Other Relevant Vessel Information

*8 The "turning radius" means the lateral movement distance of the center of gravity of the hull from the present course when turning 90 degrees from the center of gravity of the hull at the time of turning.

According to the statement of Master B and the reply to the questionnaire by Company A, at the time of the accident, there were no malfunctions or failures in the hulls, engines and equipment of Vessel A and Vessel B.

2.6 Weather and Sea Conditions

2.6.1 Weather and Sea Observations

(1) Weather observations

The observations at the Kobe Local Meteorological Observatory located to the north-west about 5.4 M to this accident location, was as follows. At around 07:00, the weather was sunny, and the visibility was 30.0 km.

Time	Wind direction	Average wind speed (m/s)	Maximum instantaneous wind speed (m/s)	Precipitation amount (mm)
06:40	WSW	3.8	6.1	None
06:50	SW	4.1	6.7	None
07:00	WSW	4.1	6.6	None
07:10	SW	4.1	6.6	None

(2) Wave observations

The observation values at the NAUFUS*9 of "Kobe" located at approximately 1.9 M north-east of the accident site at the time of the accident were as follows.

07:00, Wave height 0.32 meters, Frequency 3.7 seconds, Wave direction south

07:20, Wave height 0.38 meters, Frequency 3.5 seconds, Wave direction west-south-west

(3) Tide

According to the Tide Table published by the Japan Coast Guard, tides at the time of the accident in Kobe Area of Hanshin Port was at the end of the rising tide.

2.6.2 Observation by crew

According to the reply to the questionnaire by Company A, the weather at the time of the accident was sunny and occasionally cloudy, north-west winds, and the visibility was more than 5 M.

According to the navigation logbook of Vessel B, the weather at 08:00 was sunny, south-west wind, wind grade 4 and visibility was more than 7 M.

2.7 Characteristics of the Area

2.7.1 East Waterway

(1) According to chart W101 (Kobe) published by the Japan Coast Guard, East Waterway was dug down to 16 meters, and the depth on the east side of the waterway was around

*9 The "NAUFUS"(Nationwide Ocean Wave information network for Port and HarbourS – Ports and Harbours Bureau, MLIT), is a wave information network for Japan's coastlines that was built and is operated though a collaborative effort by the Ports and Harbours Bureau, MLIT; Regional Development Bureau, MLIT; Hokkaido Bureau, MLIT: Okinawa General Office, Cabinet Office; National Institute for Land, Infrastructure and Management(NILIM); and Port and Airport Research Institute(PARI).

14.2 to 15.8 meters.

(2) According to the "Sailing Directions for Seto Naikai" published by the Japan Coast Guard, car ferries arriving and leaving from the ferry pier in the northeastern area of Rokko Island travel in and out along the East Waterway.

(3) However, according to the statement by a person in charge of Kobe City Marine Affairs Division, as the day of the accident was a holiday, and there were fewer vessels navigating than on a weekday.

2.7.2 Port Entry Manual

(1) According to the statement by a person in charge of Kobe City Marine Affairs Division, it was as follows.

Kobe City, the port administrator, had prepared the "Port Entry Manual," and requested the vessel agencies to distribute and let equipped of it to the vessels entering and leaving the Kobe Area of Hanshin Port.

Although the “Port Entry manual” was not based on laws and regulations, it was an administrative guideline and the municipal government was trying to make people aware of the items written based on the agreement of maritime officials in Kobe Area, Hanshin Port.

(2) The Port Entry Manual said that vessel entering to and/or moving in the port should display the route using the international signal flags.

(3) According to the statement by Master B and the reply to the questionnaire by Pilot A, at the time of the accident, Vessel A displayed such flags following to the instruction of Pilot A, and Vessel B also displayed them by the crew member.

2.7.3 Forced pilotage area and vessels subject to pilotage

According to Article 35 of the Pilot Act and Article 5 of the Enforcement Ordinance of the Act, the Osaka Bay area, which was the site of this accident, had been designated as a compulsory pilotage area, and the master who carried a vessel with a gross tonnage of 10,000 tons or more must have a pilot on board.

2.7.4 Information on Surrounding Vessels, etc.

According to the AIS records, the situation near the accident area at around 06:30 to 07:00 on May 4, 2018 was as follows.

(1) In the area outside of Hanshin Port, there were two vessels in the southwest of Central Buoy and one vessel in the east northeast all anchored.

(2) A car carrier from Tomogashima heading to East Waterway was sailing through the west side of Central Buoy ahead to Vessel A.

2.8 Information on the Safety Management of Vessel A

The Safety Management Manual of Company A specified the responsibility of the master and the watch officer when a pilot was on board as follows:

(1) The pilot's duty is simply to assist the Master, and even though he is on board, the responsibility for navigation lies with Master;

(2) The Master shall closely monitor the pilot's action and do his utmost to ensure the safety of the vessel;

(3) When the master judges that it is not proper to let the pilot maneuver the vessel, he shall immediately override the pilot's instructions and maneuver the vessel as in deemed necessary.

(4) When the Master and the pilot give conflicting steering or engine operation orders, etc, the Officer of watch and the helmsman shall comply with the Master's directives and orders;

(5) The Master shall respect the pilot's advice and, if necessary, shall revise his passage plan; and

(6) The Officer of the watch, even while the pilot is on board, shall engage in fixing the ship's position and other normal navigating duties.

2.9 Information on BRM Training

(1) According to the reply to the questionnaire by Company A, Master A had undergone BRM training in September 2014.

(2) According to the statement by the person in charge of the Osakawan Pilot's Association (hereinafter referred to as the "Pilot's Association"), Pilot A had undergone BRM training in July 2015.

(3) According to the reply to the questionnaire by Vessel B, Master B had undergone BRM training in June 2016.

2.10 Analysis Survey on Accident Occurrence Factors

A summary of the results of the analysis entrusted to the National Institute of Maritime, Port and Aviation Technology, National Maritime Research Institute on the evaluation of collision risk level for Vessel A and Vessel B, the analysis of navigation situation based on the port entry records, and CREAM **[10] analysis were as follows.
(See Attachment)

(1) Evaluation of collision risk level

In order to quantitatively evaluate the risk of collision of Vessel A and Vessel B, based

*10 The "CREAM (Cognitive Reliability and Error Analysis Method)" means one of the Human Reliability Analysis (HRA) methods that focus on the cognitive aspects of humans, and there is a feature where there are various factors behind an accident, by treating the accident as the ultimate result.

on AIS records, the five assessment indicators of OZT**[11],CJ**[12], SJ**[13], CR**[14] and BC **[15] were used. Also, the reference point for the positions of Vessel A and Vessel B was the GPS antenna position respectively, unless otherwise specified. (For the calculation method of each evaluation value, please see to page 30 to page 35 in Attachment.)

(i) Evaluation of collision avoidance

a. OZT (Obstacle Zone by Target)

The occurrence of OZT means that there is a OZT by another vessel in a range of 10 ° to the left and right of the course (set value in this accident investigation) within 5 minutes, and some action must be taken to avoid the area where OZT has occurred.

The time of occurrence of OZT in Vessel A and Vessel B were at around 06:58 for Vessel A and at around 06:56 for Vessel B, and it was a situation where it was in a dangerous condition below the safety navigation over distance of 259 m (which is the value determined from the lengths of Vessel A and Vessel B) so that within five minutes the distance between Vessel A and Vessel B would become the smallest of the two vessels. (The reference point for the position of Vessel A and Vessel B were corrected to the center position of each hull.)

(See to the attachment page 6)

The OZT of Vessel A occurred on the course that Vessel A was proceeding from around 06:58 to just before the collision, while the OZT of Vessel B occurred on

---

*11 "OZT (Obstacle Zone by Target)" refers to an area expected to be blocked by another vessel in the near future. Specifically, it refers to a water area where one's own vessel and another vessel can approach within the minimum safe navigation distance(within 259 meter is set in this accident investigation) in the future under the condition that the course and speed of another vessel are constant at a certain time. Since it is assumed that the course of own vessel is variable, the own OZT by another vessel will be present only on the course of another vessel. Similarly, the another vessel's OZT by own vessel will be present only on the course of own vessel.

*12 "CJ (Collision Judgment)" is an indicator expressing the collision risk level of two vessels in a one-on-one relationship. It is calculated from the relative distance to another vessel, its rate of change, and the relative orientation and its rate of change. The risk level increases as another vessel approaches.

*13 "SJ (Subject Judgment)" means the evaluation of the subjective collision risk level between two vessels from general operator's point of view, such risk level being changed depending on the combination of the distance from one vessel to another and the rate of change of the relative orientation.

*14 "CR (Collision Risk)" means an evaluation of collision risk level in consideration of vessel characteristics such as maneuverability using the time to closest point of approach and the distance of closest point of approach determined from the relative position and relative speed between two vessels.

*15 "BC (Blocking Coefficient)" is an indicator showing the degree to which a vessel is blocked by vessels present in the vicinity when the vessel is giving way by changing speed and course. It is based on the risk level of collision with other vessels present in the vicinity, multiplied by a weighting factor that express preference for changing course and speed as a means of giving way (desirable for vessel's maneuvering).

Also, at the time of the accident, because the situation was just before entering to the port and the engine could be decelerated, it is assumed that the means for evading the voyage is both a change of course and a deceleration.

Also, at the time of the accident, the situation was just before the arrival at the port, and because the engine could be decelerated, it is assumed that the means of giving way is both a change of course and a deceleration.

the port side of Vessel B except at the time immediately before the collision, and was out of the course that Vessel B was proceeding.
(See attachment Figure 2-6 on page 9)

(ii) Evaluation of dangerous condition between two vessels

a. CJ (Collision Judgement)

The CJ value is an index that indicates the collision risk level of two vessels calculated from the relative relationship, and the range of CJ value is from -∞ to +, with a positive value indicating a danger.

The CJ values of Vessel A began to rise gradually from at around 06:56 with respect to Vessel B, and the CJ values of Vessel B began to rise gradually from at 06:54 with respect to Vessel A.

The time when the CJ value exceeded the danger threshold value*16 (the value at which a collision risk occurred) 0.015 was at around 07:02 or later for both vessels.

(See to the attachment page 9)

b. SJ (Subject Judgement)

The SJ value is an index indicating the collision risk level of two vessels through a filter such as the average value of the operator's experience, and is a value indicating the collision risk level felt by the operator. The range of SJ values is between -3 to +3, with negative values indicating danger.

SJ = -3: Extremely dangerous, SJ = -2: Dangerous,
SJ = -1: Somewhat dangerous, SJ=0: Cannot be said either,
SJ = +1: Slightly safe, SJ = +2: Safe, SJ = + 3: Extremely safe.

The SJ values of Vessel A became negative values indicating dangerous from at around 06:54, and the first indication of -2 was at around 06:54, and then increased temporarily, however, at around 06:57 and at 07:01, the value exceeded -2 again, and Vessel A was in a dangerous state.

As for Vessel B, the SJ value became negative values indicating dangerous from at around 06:58, and became around -2 at around 07:00, indicating a dangerous condition.

(See to the attachment page 9)

c. CR (Collision Risk)

The CR value is an index of the collision between two vessels, taking into account the time to closest point of approach (TCPA), DCPA, and the vessel characteristics such as the maneuverability, etc.

The CR value of Vessel A rose after 06:54, and the value was at the maximum after 6:58, and the CR value of Vessel B rose after at 06:56, it was in the maximum after at 07:01.

(See to the attachment page 10)

(iii) Evaluation of vessel's freedom

*16 "Threshold" refers to the lowest level of stimulation that causes a response.

a. BC(Blocking Coefficient)

The rise in the BC value means that the freedom of maneuvering decreases, and the possible range of the BC value is between 0 to 1.

The BC values evaluated for Central Buoy and vessels around Vessel A and Vessel B were rising after at 06:55 for both vessels. The BC value of Vessel A showed a maximum value of 0.50 at around 07:01, The BC value of Vessel B showed a maximum value of 0.52 at around 07:01, therefore for both vessels continued the freedom of maneuver for giving way remained in a low state.

(See to the attachment page 10)

(2) Evaluation of the effect of ship length on DCPA value

In order to analyze the influence of the ship length, CPA analysis was performed using the position where both vessels collided as a reference point. The DCPA value was evaluated to be smaller by about maximum 200 meters just before the accident than using the GPS antenna position as a reference point. In addition, it was said that the bow which is the collision position of Vessel A is mainly affected by the length of Vessel A, since it was about 240 meters ahead of the antenna position.

Also, the DCPA value displayed on the radar of Vessel B was close to the value when using the GPS antenna position as a reference point.

(3) Analysis of navigational situation

When the navigation situation of Vessel A at the time of the accident was compared with the past 18 times experience of the same type vessels in East Waterway, it could be said that the same type vessels often sailed the east side of Central Buoy in case of entering East Waterway from the position of Vessel A at around 06:55.

In addition, the entering speed of Vessel A at the time of the accident was about 1 knot faster than the average speed of the same type vessels including Vessel A in the past.

(4) CREAM analysis

(i) CREAM analysis is performed in the following procedure.

a. Describe in detail what actually occurred.

b. Identify CPC *[17].

c. Describe the time relationships of major events.

d. Select all actions to be focused on (such as unsafe actions).

e. Identify the error mode **[1818] for each action.

f. Trace back the causes from the relevant results for each error mode and find the underlying factors.

---

*17 "CPC (Common Performance Condition)" is evaluated by three factors of human, organization and technology as the cause of error mode, and ten types are defined (appropriateness of the organization, working environment, appropriateness of man-machine interface and work support, availability of procedures and plans, number of simultaneous goals, available time, time zone, appropriateness of training and experience, and the quality of cooperation of crew, communication and sharing information)

*18 "Error mode" means an action that may lead to an accident, and it can be thought that there is an error mode behind the occurrence of an accident. The error mode is something that can be observed just like "Collision caused by delayed timing. They are defined in eight categories, such as: period (too long / too short); procedure (reverse order, repetition, miss, interruption); object (different behavior / different object); power (too weak / too strong); direction (wrong direction); speed (too fast / too slow); distance (too far / too close) and timing (too early, too late, omitted).

g. Describe the whole matters and find the cause.

(ii) The actions to be focused on (unsafe actions) and the underlying factors of Vessel A and Vessel B were as follows.

a. The actions to be focused on of Vessel A (unsafe actions) were that Pilot A did not inform about Vessel B to the crew of Vessel A, such as Master A, after contacting with Port Radio by VHF (error mode: procedure<miss>), Pilot A did not use either EDICS or the radar after contaction with Port Radio (error mode: procedure<miss>), Pilot A did not recognize the status of Master A and Officer A2 in the watch-out (error mode: timing <omission>), Pilot A, although thinking that the rate of change in the relative relationship with Vessel B was slow, did not communicate with Vessel B (error mode: procedure <miss>), Pilot A ordered to take half ahead for entering the port (error mode: the object < wrong object>), Pilot A ordered hard-port just before the collision (error mode: the direction <wrong direction>), Master A turned behind and talked with Officer A2 about the port entry (error mode: procedure <interruption>), and the astern operation of engine was taken too later so that the speed of Vessel A could not be decreased (error mode: speed <too fast>).

The background factors behind these were that Master A judged that Vessel B was navigating to the opposite side from the location relationship with Vessel B before the change of direction (inappropriate procedure), it was necessary for Master A to talk with Officer A2 about the port entry (habitual practice and over-trust to others), Pilot A performed watch without using the radar or ECDIS (inappropriate procedure and arrangement), Master A and Pilot A over-trusted each other (over-trust to others, experience, and habitual practice).

b. The actions to be focused on of Vessel B (unsafe actions) were that was tried to communicate with VHF and blew a whistle just before the collision (error mode: timing <too late>), and an acceleration was ordered immediately before the collision (error mode: speed <too slow>).

The background factor behind these was that Master B, thinking that Vessel A would travel east side of the Central Buoy, was puzzled by the maneuvering of Vessel A (a preconception about cognition).

3. ANALYSIS

3.1 Situation of the Accident Occurrence

3.1.1 Course of the Events

According to 2.1, the following events occurred.

(1) Vessel A

(i) It is probable that Vessel A departed from Port of Singapore, Republic of Singapore, on April 28, 2018, bound for Rokko Island Quay RC-7 in Kobe Area of Hanshin Port.

(ii) It is probable that Pilot A got on board Vessel A off to the south of Tomogashima Island at around 05:00 on May 04.

(iii) It is considered highly probable that Vessel A navigated about 8.2 M southeast of

Central Buoy at a heading of 40. 6 ° and a speed of 18.0 kn at around 06:31:22 , then navigated decelerating gradually.

(iv) It is considered highly probable that Vessel A started to turn left at around 06:55:23.

(v) It is considered highly probable that Vessel A was navigating at around 07:00:05 at a heading of 19.7 °and a speed of 12.8 kn while continuing to turn left.

(vi) It is probable that Vessel A set the main engine to half ahead at around 07:01 and set the rudder to hard port, and then change the main engine to full astern from dead slow ahead.

(vii) It is probable that Vessel A collided with Vessel B while turning left.

(2) Vessel B

(i) It is probable that Vessel B on May 4 around 06:10 departed from Osaka Area of Hanshin Port bound for Rokko Island Quay RC-4 in Kobe Area of the Hanshin Port.

(ii) It is considered highly probable that Vessel B started to turn right at around 2.2 M southeast of Central Buoy at around 06:52:23.

(iii) It is considered highly probable that Vessel B was navigating at around 06:55:11 at a heading of 291.0 ° and a speed of 13.8 kn.

(iv) It is considered highly probable that Vessel B was navigating at around 06:57:03 at a heading of 290.0 ° and a speed of 13.8 kn.

(v) It is probable that Vessel B set the rudder to starboard 10 ° at around 07: 00: 45, set the rudder to midship at around 07: 00: 55, therefore changed its heading from 295 ° to starboard side.

(vi) It is considered highly probable that Vessel B blew a whistle at around 07:02:10, and changed the main engine from full ahead to navigation full ahead at around 07:02:43.

(vii) It is probable that Vessel B collided with Vessel A while navigating strait in northwest direction.

3.1.2 Date, time and the location of this accident

According to 2.1, the occurrence date and time of this accident was on May 4, 2018 at around 07:02:49 when impact noise was recorded in VDR of Vessel B, and the occurrence location was around 218 ° true bearing, 350 meters from Central Buoy.

3.1.3 Information on casualties or injuries

According to 2.2, there were no casualties or injuries in Vessel A and Vessel B.

3.1.4 Damage to Vessel

According to 2.3, these were as follows.

(1) Vessel A got a bend damage in the bulwark and others of the starboard bow, abrasion on the shell plate of the starboard bow, and a concave damage in the bulbous bow.

(2) It is probable that Vessel B was damaged in the accommodation spaces etc. and cracks occurred in the port bottom shell.

3.1.5 Situation about the collision

According to 2.1.1, 3.1.1, 3.1.2 and 3.1.4, it is probable that the starboard bow of Vessel A collided with the accommodation spaces of the port and stern of Vessel B while Vessel A was sailing at a heading of approximately 1 °and a speed of approximately 11.3 kn, and Vessel B was sailing at a heading of approximately 314 °and a speed of approximately 13.5 kn.

3.2 Causal Factors of the Accident

3.2.1 The situation of the crew, etc.

According to 2.4, the situation of the crew members, etc. were as follows.

(1) Master A and Master B

Master A and Master B possessed legally valid certificates of competence.

It is probable that they were in good health at the time of the accident.

(2) Pilot A

Pilot A possessed a legally valid certificate of competence as a pilot.

It is probable that he was in good health at the time of the accident.

3.2.2 Situation about the vessels

According to 2.5.6, at the time of the accident, there were no malfunctions or failures in the hulls, engines and equipment of Vessel A and Vessel B.

3.2.3 Information on the weather and sea conditions

According to 2.6, it is probable that, at the time of the accident, the weather was fine, the west-south-west wind was blowing at force 3, the visibility was 5 M or more, waves with a height of about 0.3 meters were coming from the south, and the tide was the end of rising tide.

3.2.4 Analysis of communication

According to 2.1 and 2.10, in this accident, the situation of "Communication between Pilot A and Crew members of Vessel A", "Communication between crew members of Vessel B" and "Communication between Vessel A and Vessel B," were as follows respectively.

(1) Vessel A

(i) Communication between Pilot A and Crew members of Vessel A

a. It is probable that Pilot A, during pilotage of Vessel A on which he was borading at around 05:00, felt that crews of Vessel A had been educated for BRM* well, so he thought that the crew members on board would be reliable, and thought that he was able to share the perception of vessel maneuvering with Master A.

b. It is probable that Pilot A, at around 06:44, communicated with Port Radio in Japanese and told that Vessel A arrived outside of Hanshin Port Kobe Area and would navigate through the No.7 breakwater of the Hanshin Port Kobe Area, then, Pilot A heard the information of a vessel proceeding ahead of Vessel A and that Vessel B were scheduled to enter to Kobe Chuo Passage at around 07:15 and watched Vessel B, but the Pilot A did not tell that to Master A.

c. It is probable that Master A watched Vessel B for the first time at around 06:53, but

Vessel B was heading southwest, and as a result of above b, Master A was not informed by Pilot A about the information that Vessel B was going to enter Kobe Chuo Passage, he thought that there was no risk of collision with Vessel A and he had a meeting with Officer A2.

d. It is probable that Pilot A thought that Master A and Officer A2 were both watching Vessel B with the radar and ECDIS and thought that crew members of Vessel A were conscious of the movement of Vessel B because Pilot A pointed at Vessel B, therefore Pilot A was not aware that Master A and Officer A2 started to talk near the chart table.

e. It is probable that Pilot A thought that crew members of Vessel A were aware of Vessel B because he pointed at Vessel B, and then Pilot A ordered Steering officer A to turn left toward East Waterway.

f. It is probable that although Trainee A, feeling the fear of collision against Vessel B, reported Pilot A, who was taking substantial command, Pilot A did not notice that there was a report of Trainee A.

g. It is considered somewhat likely that on Vessel A, according to the above items b to f, Pilot A and the crew members of Vessel A did not communicate sufficiently with each other verbally concerning the vessel maneuvering and the movement of other vessels.

(ii) Communication between Vessel A and Vessel B

a. It is probable that Pilot A thought that Vessel B would pass the bow side of Vessel A from the relative relationship with Vessel B, which was visually identified at 06:57.

b. It is probable that, from the above (ii)-a, Pilot A did not communicate with Vessel B using VHF about information such as the course of Vessel A.

(2) Vessel B

(i) Communication among crew members of Vessel B

a. On Vessel B, there might be insufficient verbal communication between Master B and Officer B on the behavior of Vessel A, between around 06:54 and 07:02. However, it was not possible to clarify this point so that VDR's voice had some unclear points.

(ii) Communication between Vessel A and Vessel B

a. It is probable that, although concerning about the decrease in the DCPA value at around 06:57, Master B thought that Vessel B might be able to pass the bow of Vessel A without problems from the predicted course of Vessel A by the radar.

b. It is probable that Master B instructed Officer B to call Vessel A with VHF at around 07:02 and sounded the whistle.

c. It is probable that, from the above a. and b., Master B did not communicate with Vessel A using VHF until immediately before the collision, thinking that Vessel B could pass the bow side of Vessel A without any problem.

3.2.5 Situation of the watch and maneuvering

According to 2.1, 2.4, 2.5, 2.7, 2.10, 3.1.1 and 3.2.4 were as follows.

(1) Vessel A

(i) It is probable that, while Vessel A was heading north-east toward Rokko Island Quay RC-7 in Hanshin Port, Kobe Area, Pilot A was piloting the vessel while Master A, Officer A2 and Trainee A were keeping lookout by eyesight, radar and ECDIS.

(ii) It is probable that Pilot A, after ordering the crew members to gradually reduce to the harbor speed at around 06:35 and recognizing Vessel B visually for the first time at around 06:44, thought that Pilot A himself did not need to watch using the radar as Master A took a look at the radar, then he stood near No. 2 VHF and observed for Vessel B by eyesight.

(iii) It is probable that Officer A1 rose up to the bridge at around 06:52 and took over the bridge watch with Officer A2 who had been watching and operating the main engine remote control device.

(iv) It is probable that Master A watched Vessel B at a distance of about 3M ahead to starboard of Vessel A at around 06:53, confirmed the DCPA value with Vessel B by ECDIS, and as it was in the distance of 0.84 M, Vessel B was expected to proceed toward southwest, while Vessel A was proceeding to northward from now on, he thought that Vessel B would pass through the starboard side of Vessel A and there was no risk of collision with Vessel A, so Master A started to talk about the port entry with Officer A2 near the chart table.

(v) It is probable that felt there was no bearing change in the relative with Vessel B but as Pilot A pointed at Vessel B with his finger, Pilot A thought that crew members of Vessel A were aware of Vessel B, therefore Pilot A ordered Steering officer A to turn left toward the East Waterway.

(vi) It is probable that although Pilot A could not predict how Vessel B would proceed immediately after her right turn, as Vessel A was slowing down for the port entry and from the relative relationship with Vessel B which he saw at around 06:57, Pilot A thought that Vessel B might pass through the bow side of Vessel A, so ordered to continue left turn.

(vii) It is probable that Trainee A confirmed by the radar and felt the fear of collision against Vessel B.

(viii) It is probable that as Vessel A approached the entrance of the East Waterway at around 07:01, Pilot A after ordering the Officer A1 to make the main engine half ahead, checked the positional relation with Vessel B with his eyes and felt the risk of collision with Vessel B, therefore ordered the Steering officer A hard port.

(ix) It is probable that, as Master A listened to“half-ahead” and ”hard port” which were ordered by Pilot A, he looked back from nearside of the chart table and saw the bow, the bow of Vessel A and the bow of Vessel B seemed overlapping, therefore at the same time Master A ordered Officer A1 to change the slow ahead of the main engine, and Master A himself moved to near the main engine remote control device and shifted the driving of the main engine from the dead slow ahead to the full astern.

(2) Vessel B

(i) It is probable that Master B and Officer B were keeping a lookout by eyesight and the radar.

(ii) It is probable that Master B confirmed Vessel A with his eyes at around 4 M away in the direction of bow at around 06:50 and started watching with No.2 radar and visual observation.

(iii) It is probable that Master B ordered right turn toward the Kobe Chuo Passage at around 06:52.

(iv) It is probable that, although Master B recognized at around 06:54 that it was in crossing situation with Vessel A, he thought Vessel B could pass the bow side of Vessel A without any problem.

(v) It is probable that Vessel B finished turning to the right at around 06:55, and it continued to sailing northeast toward the Kobe Chuo Passage.

(vi) It is probable that Master B was concerned about the decrease in the DCPA value at around 06:57, but from the predicted course of Vessel A by the radar, he thought that Vessel B was able to pass the bow of the Vessel A without problems, and he also thought the Vessel B would enter the port at faster speed if the speed-up here around.

(vii) It is probable that, as Master B felt dangerous when he watched Vessel A which was turning left at around 07:00, although an anchoring ship was existing in the starboard side, he ordered starboard 10 ° to try to leave a distance from Vessel A.

(viii) It is probable that, because Master B tried to pass the bow of Vessel A at around 07:02, he ordered to change from full ahead to navigation full ahead.

3.2.6 Analysis of collision risk level

According to 2.1, 2.10, and 3.2.5 were as follows.

(1) Vessel A

(i) It is probable that, as the BC value had risen since at around 06:55 after Vessel B turned to the right, the freedom of maneuvering for Vessel A began to decline.

(ii) In addition, it is probable that, as the SJ value showed "-2" for the first time at around 06:54 to 06:55, it is consistent with the fact that Pilot A felt that there was no bearing change in the relative with Vessel B at around 06:55.

(iii) It is probable that Vessel A needed to make an escaping action as the SJ value showed "-2" again at around 06:57, OZT by Vessel B occurred at around 06:58, and the distance between Vessel A and Vessel B was becoming less than 295 meters within 5 minutes.

(iv) In addition, it is considered somewhat likely that the risk of collision was high as the CR value showed the maximum value at around 06:58.

(v) According to (iii) and (iv) above, it is probable that Pilot A did not notice those situations although the risk of collision occurred.

(vi) In the background that the Pilot A did not notice the situation of (v) in the above and did not take an escaping action and did not feel the risk of a collision, it is considered somewhat likely that Pilot A thought that it could pass the stern of Vessel B from the relative relationship with Vessel B which he saw at around 06:57, then he did not keep to watch Vessel B carefully.

(vii) It is probable that, as the SJ value for Vessel A showed "-2" again at around 07:01, Vessel A was in a situation where Pilot A should notice dangerous, and it is consistent with the fact that Pilot A noticed a danger of collision.

(viii) It is probable that, Vessel A set the main engine to half ahead at around 07:01 and set the rudder to hard port, and then change the main engine to full astern from dead slow ahead, and then pilot A and Master A noticed a danger of collision, however, as the CJ value had already reached the threshold value at around 07:02, the risk of collision had already been high.

(ix) It is probable that, Vessel A took an escaping action at around 07:01, but since the BC value showed the maximum value at this time, it was in a difficult situation to maneuver, and the time for the evacuation could have been missed.

(x) In addition, it is probable that, at around 07:02, the CJ value exceeded the threshold value, and it is consistent with the fact that Pilot A and Master A took an avoidance action feeling the risk of collision after at 07:01.

(2) Vessel B

(i) It is probable that as the BC value had risen since at around 06:55 after Vessel B turned to the right, the freedom of maneuvering for Vessel B began to decline.

(ii) It is probable that, although OZT by Vessel A occurred at around 06:56, the distance between Vessel A and Vessel B was less than 259 meters within 5 minutes, and it was necessary for Vessel B to take an escape action, OZT occurred on the port side of Vessel B which was out of the course that Vessel B was proceeding, so that it was difficult for Vessel B to feel the fear of a collision.

(iii) It is considered somewhat likely that, according to (ii) above, Master B was in a situation where it was difficult for him to feel the fear of a collision, so he did not take an escape action.

(iv) It is probable that, as the SJ value for Vessel B became to the danger zone at around 06:58, Vessel B was in a situation where Master B should begin to feel the danger of collision, but from the fact (ii) above, it was in a difficult situation for him to feel the fear of a collision.

(v) In addition, it is considered somewhat likely that, because the BC value for Vessel B against the surrounding vessels including Vessel A continued to rise, Vessel B was in a situation which was becoming difficult to take an escaping navigation as time passed.

(vi) It is probable that, the SJ value for Vessel B showed "-2" at around 07:01, it was consistent with the fact that Master B felt a danger of collision.

(vii) It is probable that, the CR value for Vessel B showed maximum value at around 07:01 and CJ value for Vessel B reached the threshold value at around 07:02, so the collision risk was high, it was consistent with the fact that Master B, at around 07:02 ordered to call Vessel A with VHF, and sounded the whistle.

(viii) It is probable that Vessel B was in a situation where it was difficult to maneuver as the BC value showed the maximum value at around 07:01.

3.2.7 Evaluation of watching and maneuvering conditions and collision risk

According to 3.2.4, 3.2.5 and 3.2.6 were as follows.

(1) Vessel A

(i) It is probable that, while Vessel A was heading north-east toward Rokko Island Quay RC-7 in Hanshin Port, Kobe Area, Pilot A was piloting the vessel, while Master A, Officer A_2 and Trainee A were keeping lookout by eyesight, radar and ECDIS.

(ii) It is probable that Pilot A, after ordering the crew members to gradually reduce to the harbor speed at around 06:35 and recognizing Vessel B visually for the first time at around 06:44, thought that Pilot A himself did not need to watch using the radar as Master A took a look at the radar, then he stood near No. 2 VHF and observed for Vessel B by eyesight.

(iii) It is probable that Officer A1 rose up to the bridge at around 06:52 and took over the bridge watch with Officer A2 who had been watching and operating the main engine remote control device.

(iv) It is probable that Master A watched Vessel B at around 06:53, confirmed Vessel B by ECDIS, Vessel B was expected to proceed away passing through the starboard side and there was no risk of collision with Vessel B, so Master A started to talk about the port entry with Officer A2 near the chart table.

(v) It is probable that, as the BC value had risen since at around 06:55 after Vessel B turned to the right, the freedom of maneuvering for Vessel A began to decline.

(vi) It is probable that, as the SJ value showed "-2" for the first time at around 06:54 to 06:55, it is consistent with the fact Pilot A felt that there was no bearing change in the relative Vessel B at around 06:55, however Pilot A thought that the crew members of Vessel A was aware of Vessel B because Pilot A pointed at Vessel B with his finger, and ordered Steering officer A to turn left toward the East Waterway.

(vii) It is probable that although Pilot A could not predict how Vessel B would proceed immediately after her right turn, as Vessel A was slowing down for the port entry and from the relative relationship with Vessel B which he saw at around 06:57, Pilot A thought that Vessel B might pass through the bow side of Vessel A, so ordered to continue left turn.

(viii) It is probable that Vessel A needed to make an escaping action as the SJ value showed "-2" again at around 06:57, OZT by Vessel B occurred at around 06:58, and the distance between Vessel A and Vessel B was becoming less than 295 meters within 5 minutes.

(ix) In addition, it is considered somewhat likely that the risk of collision was high as the CR value showed the maximum value at around 06:58.

(x) It is probable that, according to (viii) and (ix) above, the risk of collision occurred, Trainee A confirmed by the radar and felt the fear of a collision against Vessel B, however Pilot A did not notice the situation.

(xi) In the background that the Pilot A did not notice the situation of (x) in the above and did not take an escaping action and did not feel the risk of a collision, it is considered somewhat likely that Pilot A thought that it could pass the stern of Vessel B which he saw at around 06:57, then he did not keep to watch Vessel B carefully.

(vii) It is probable that as Vessel A approached the entrance of the East Waterway at around 07:01, Pilot A after ordering the Officer A1 to make the main engine half ahead, checked the positional relation with Vessel B with his eyes and felt the risk of collision with Vessel B, therefore ordered the Steering officer A hard port.

(xiii) It is probable that, as the SJ value showed "-2" again at around 07:01, Vessel A was in a situation where Pilot A should notice dangerous, and it was consistent with the fact that Pilot A noticed a danger of collision.

(xiv) It is probable that, as Master A listened to "half ahead" and "hard port" which were ordered by Pilot A, he looked back from nearside of the chart table and saw the bow, the bow of Vessel A and the bow of Vessel B seemed overlapping, therefore at the same time Master A ordered Officer A1 to change the slow ahead of the main engine, and Master A himself moved to near the main engine remote control device and shifted the driving of the main engine from the dead slow ahead to the full astern.

(xv) It is probable that, according to (xii), (xiii) and (xiv) above, although Pilot A and Master A took an escape action feeling a danger of collision, the CJ value had already reached the threshold value at around 07:02, the risk of collision had already been high.

(xvi) It is considered somewhat likely that Vessel A took an escaping action at around 07:01, but since the BC value showed the maximum value at this time, it was in a difficult situation to maneuver, and the time for the evacuation could have been missed.

(2) Vessel B

(i) It is probable that Master B and Officer B were keeping a lookout by eyesight and the radar.

(ii) It is probable that Master B confirmed Vessel A with his eyes at around 4 M away in the direction of bow at around 06:50 and started watching with No.2 radar and visual observation.

(iii) It is probable that Master B ordered right turn toward the Kobe Chuo Passage at around 06:52.

(iv) It is probable that, although Master B recognized at around 06:54 that it was in crossing situation with Vessel A, he thought Vessel B could pass the bow side of Vessel A without any problem.

(v) It is probable that as the BC value had risen since at around 06:55 after Vessel B turned to the right, the freedom of maneuvering for Vessel B began to decline.

(vi) It is probable that, although OZT by Vessel A occurred at around 06:56, the distance between Vessel A and Vessel B was less than 259 meters within 5 minutes, and it was necessary for Vessel B to take an escape action, OZT occurred on the port side of Vessel B which was out of the course that Vessel B was proceeding, so that it was difficult for Vessel B to feel the fear of a collision.

(vii) It is considered somewhat likely that Master B was concerned about the decrease in the DCPA value at around 06:57, but under the difficult situation to feel the fear of a collision, from the predicted course of Vessel A by the radar, he thought that Vessel B was able to pass the bow of the Vessel A without problems, and he also thought Vessel B would enter the port at faster speed if the speed-up here around.

(viii) It is probable that, as the SJ value became to the danger zone at around 06:58, Vessel B was in a situation where Master B should begin to feel the danger of collision,, but from the fact (vi) and (vii) above, it was in a difficult situation for him to feel the fear of a collision.

(ix) In addition, it is considered somewhat likely that because the BC value against the surrounding vessels including Vessel A continued to rise, Vessel B was in a situation which was becoming difficult to take an escaping navigation as time passed.

(x) It is probable that, as Master B felt dangerous when he watched Vessel A which was turning left at around 07:00, although an anchoring ship was existing in the starboard side, he ordered starboard 10 ° to try to leave a distance from Vessel A.

(xi) It is probable that, the SJ value showed "-2" at around 07:01, it was consistent with the fact that Master B felt a danger of collision.

(xii) It is probable that, the CR value showed maximum value at around 07:01 and the CJ value reached the threshold value at around 07:02, so the collision risk was high, it was consistent with the fact that Master B, at around 07:02 ordered to call Vessel A with VHF, and sounded the whistle.

(xiii) It is probable that Vessel B was in a situation where it was difficult to maneuver as the BC value showed the maximum value at around 07:01.

(See Figure 3: Time-series related to the situation of lookout and maneuvering conditions and collision risk)

3.2.8 Analysis of the effect of vessel length

According to 2.1 and 2.11 above, it is considered somewhat likely that, as the DCPA value displayed by the radar of Vessel B was evaluated value based on the GPS antenna position as a reference point, Master B kept a lookout without recognizing that the DCPA value was not considered the length and width of Vessel A therefore the actual distance between Vessel B and Vessel A was closer than the displayed DCPA values.

3.2.9 Analysis of navigational situation

According to 2.1, 2.4, 2.5, 2.5.5, 2.6,1, 2.7 and 2.10 were as follows.

(1) Vessel A

(i) It is probable that, as Pilot A started working as a Pilot in Osaka bay in February 2002, and had been doing Pilot work for about fifteen times a month, he had sufficient knowledge about entering the port of Kobe Area of Hanshin Port.

(ii) It is considered somewhat likely that, upon entering the East Waterway from the southwestern side of the waterway, a car carrier ahead of Vessel A was heading for the East Waterway had been navigating the west side of the Central Buoy, the water depth of the eastern side of the East Waterway was shallower, and the distance was shorter when navigating west side than the east of the Central Buoy, so that Pilot A selected to navigate west of the Central Buoy.

(iii) It is considered somewhat likely that as Pilot A had seen two vessels anchored in southwest of the Central Buoy, Pilot A ordered to turn left toward the East Waterway at around 06:55.

(iv) It is probable that, when compared with the cases of past 18 times of the same type vessels entering the East Waterway, in the case of entering the East Waterway from the position of Vessel A at around 06:55, in many cases, the east side of the Central Buoy were preferable, and the navigation speed of Vessel A was about 1 knot faster than the average speed of the same type vessels including Vessel A, but it was no problem.

(2) Vessel B

(i) It is considered somewhat likely that Master B, having had a total of 100 times or more of the experience of entering the Hanshin Port, Kobe-Area, had knowledge about entering the same area.

(ii) In accordance with the above (1) and (2)(i), it is considered somewhat likely that Master B also thought that Vessel A would navigate the east side of the Central Buoy because Vessel A has been proceeding the course which many vessels sailed east side of the Central Buoy through.

3.2.10 Analysis of the accident occurrence

According to 2.1.3, 3.1.1, 3.1.5, 3.2.4, 3.2.5, 3.2.6, 3.2.7 and 3.2.9 were as follows.

(1) It is probable that Pilot A, after recognizing Vessel B visually for the first time at around 06:44 hours, thought that Pilot A himself did not need to watch using the radar as Master A took a look at the radar, then he started to observe for Vessel B by eyesight.

(2) It is probable that Master A watched Vessel B at around 06:53, but thought that there was no risk of collision from the confirmed course of Vessel B, and focused his attention on the meeting with Officer A2 about entering the port near the chart table, as a result he did not keep a lookout.

(3) It is probable that Pilot A, without recognizing that Master A was in the meeting, but Pilot A thought that crew members were conscious of Vessel B because Pilot A pointed at Vessel B, and then he ordered to turn left toward East Waterway from the northeast navigation.

(4) It is probable that although Pilot A, as Vessel A was slowing down for the port entry and from the relative relationship with Vessel B, thought that Vessel B might pass through the bow side of Vessel A and did not notice the situation where the risk of collision with Vessel B occurred, so he ordered continued left turn.

(5) It is probable that Master B, although concerning about the decrease in DCPA value at around 06:57, under the situation where it was difficult for Vessel B to feel the fear of collision, from the predicted course by the radar and navigating route of Vessel A, Vessel A might keep to proceed the east side of Central Buoy, Vessel B might be able to pass the bow of Vessel A, so he continued to sailing for the northwest direction.

(6) It is probable that, as Master B felt dangerous when he watched Vessel A which was turning left at around 07:00, he ordered starboard 10 ° to try to leave a distance from

Vessel A.

(7) It is probable that Pilot A was not aware that there was a risk of collision with Vessel B before he ordered hard port, so he ordered continued left turn.

(8) It is considered somewhat likely that Master B did not communicate with Vessel A using VHF until immediately before the collision, thinking that Vessel B could pass the bow side of Vessel A without any problem.

(9) It is considered somewhat likely that on Vessel A, Pilot A and the crew members of Vessel A did not communicate sufficiently with each other verbally concerning the vessel maneuvering and the movement of other vessels.

(10) It is probable that, as VHF was not used to communicate with each other from earlier stage when Vessel A and Vessel B might become close to each other at a short distance, they could not confirm another vessel's maneuvering intention, therefore, it became a situation where two vessels approached each other too close.

3.3 Analysis on Loss of VDR Data of Vessel A

According to 2.1.2 above, it is considered somewhat likely that, although Master A ordered the crew members to save the VDR records after the collision, but the save operation was not properly done and the records at the time of the accident were lost, so the crew members of Vessel A had not fully understood how to operate the VDR at the time of occurrence of an accident.

4. CONCLUSIONS

4.1 Probable Causes

It is probable that the accident occurred because, while Vessel A was traveling northeastward and turning left toward the south entrance of East Waterway and Vessel B was traveling northwestward toward the south entrance of the Kobe Chuo Passage, Pilot A thought that Vessel A was able to pass by the stern side of Vessel B and thus continued to navigate while turning left, while Master B, thinking that Vessel B was able to pass by the bow side of Vessel A, continued to proceed northwestward, as a result of which both vessels collided.

It is probable that Pilot A thought that Vessel A was able to pass by stern side of Vessel B and continued to navigate while turning left because, Vessel A was slowing down even though turning left, in addition, by observing the relative orientation of Vessel A and B with his eyes, Pilot A overestimated that Vessel A would be able to pass by Vessel B's stern side and was not aware of the risk of collision with Vessel B.

It is probable that Master B continued to proceed northwestward, thinking that the Vessel B would be able to pass by the bow side of Vessel A because, by observing Vessel A's traveling direction and from the radar's predicted course, Master B thought Vessel A would maintain the course of travel.

It is probable that the fact that Vessel A and B were not communicating information by VHF in early stage of the encounter, for example letting each other know the course their own vessel was taking, contributed to the occurrence of this accident.

It is considered somewhat likely that the fact that Pilot A and Vessel A's crew were not having verbal communication in regard to maneuvering their own vessel and the movement of the other vessel and Master A did not keep to lookout because of focusing his attention on the meeting about entering the port, also contributed to the occurrence of the accident.

4.2 Other Discovered Safety-Related Matters

It is considered somewhat likely that, as Master A was not informed by Pilot A about Vessel B's plan to enter the Kobe Chuo Passage, he thought that the Vessel B would proceed southwestward to pass by the starboard side of Vessel A, and thus there were no risk of collision with the Vessel B.

It is considered somewhat likely that while keeping a lookout, Master B was not aware that DCPA value was based on the position of the GPS antenna and did not take into account the length and width of Vessel A, thus the actual distance between Vessel A and Vessel B might have been closer than the displayed DCPA values.

It is considered somewhat likely that the crew of Vessel A did not fully understand how to operate a VDR during an accident.

5. SAFETY ACTIONS

It is probable that this accident occurred outside of Kobe Area of the Hanshin Port when Vessel A, which was proceeding northeastward and turning left toward Rokko Island Quay RC-

7 in Kobe Area, collided with the Vessel B, which was proceeding northwestward toward the south entrance of the Kobe Chuo Passage, and Pilot A was only looking out by eyesight and did not notice the situation where there were the risk of collision with Vessel B, thus overestimated that Vessel A was able to pass by the stern side of Vessel B, and continued left turn even though the two vessels were at a close distance, , on the other hand, in Vessel B, Master B believed that Vessel A would proceed to the east of Central Buoy, and thus Master B navigated northwestward, as a result, Vessel B couldn't change its course promptly enough to avoid the collision.

Moreover, it is probable that because Vessel A and Vessel B were not communicating by VHF about each other's course, speed, etc., they were not able to verify each other's maneuvering plan, thus both vessels came very close.

In addition, it is considered somewhat likely that, as Vessel A's VDR recording was not properly saved, and the recording of the accident was lost, Vessel A's crew didn't have enough understanding of VDR operation during an accident.

Accordingly, the following measures should be taken in order to prevent reoccurrence of similar accident.

(1) A pilot should always adequately keep a lookout by using navigation equipment, such as radar and ECDIS, in addition to sight observation.

(2) When there is a risk of approaching another vessel at a close distance, even if the relative orientation of the other vessel may seem to be changing, a pilot of a large vessel should ask for cooperation of the other vessel by using VHF because of the risk of collision.

(3) A pilot should communicate (including verbal communication) maneuvering and the other vessel's movement with crew in the bridge. Also, if local language was used to transmit information, the contents should be conveyed to the Master. They should share information.

(4) A master should communicate (including verbal communication) maneuvering of the vessel and movement of the other vessel with crew and a pilot in the bridge.

(5) Crew, including a master, should be aware that the master is responsible for navigation, even when a pilot is on board, and thus they should continue to keep a lookout.

(6) A master or a pilot should know that CPA, which the position of the GPS is used as a reference point, does not take into account the length and the width of a vessel. Thus they should keep enough distance between other vessels in order to navigate safely.

(7) A master should have the crew understand VDR operation, in order to keep objective data of the time of an accident.

5.1 Safety Actions Taken

5.1.1 Safety Actions Taken by Company A

Company A made an accident investigation report, dated May 25th, 2018. It stated that inadequate navigation and maneuvering, dependence on the pilot, lack of situational judgment, and failure of BTM*[19] were the causes of the accident.

*19 "Bridge Team Management" shares the same purpose with BRM and focuses on tasks of not only a resource manager, but also each member of a bridge team (every crew member including a master). BRM is considered as a part of BTM.

Also, Company A sent a document, which called to re-acknowledge the importance of safe navigation, to masters and officers of the Company A's vessels including the Vessel A. In addition, the Company A revised its briefing check list, reviewed the BRM/BTM training, and conducted VDR operation training.

5.1.2 Countermeasures by the Osakawan Pilots' Association

The Osakawan Pilots' Association, which Pilot A is a member of, took the following countermeasures after the accident.

(1) With a simulator machine, Pilot A took a day of simulated training, which assumed the same type of vessel with the same maneuvering capability as the Vessel A.

(2) Shared overview of the accident with the association members, created a trouble report, and made it available for members.

5.1.3 Countermeasures by Company B

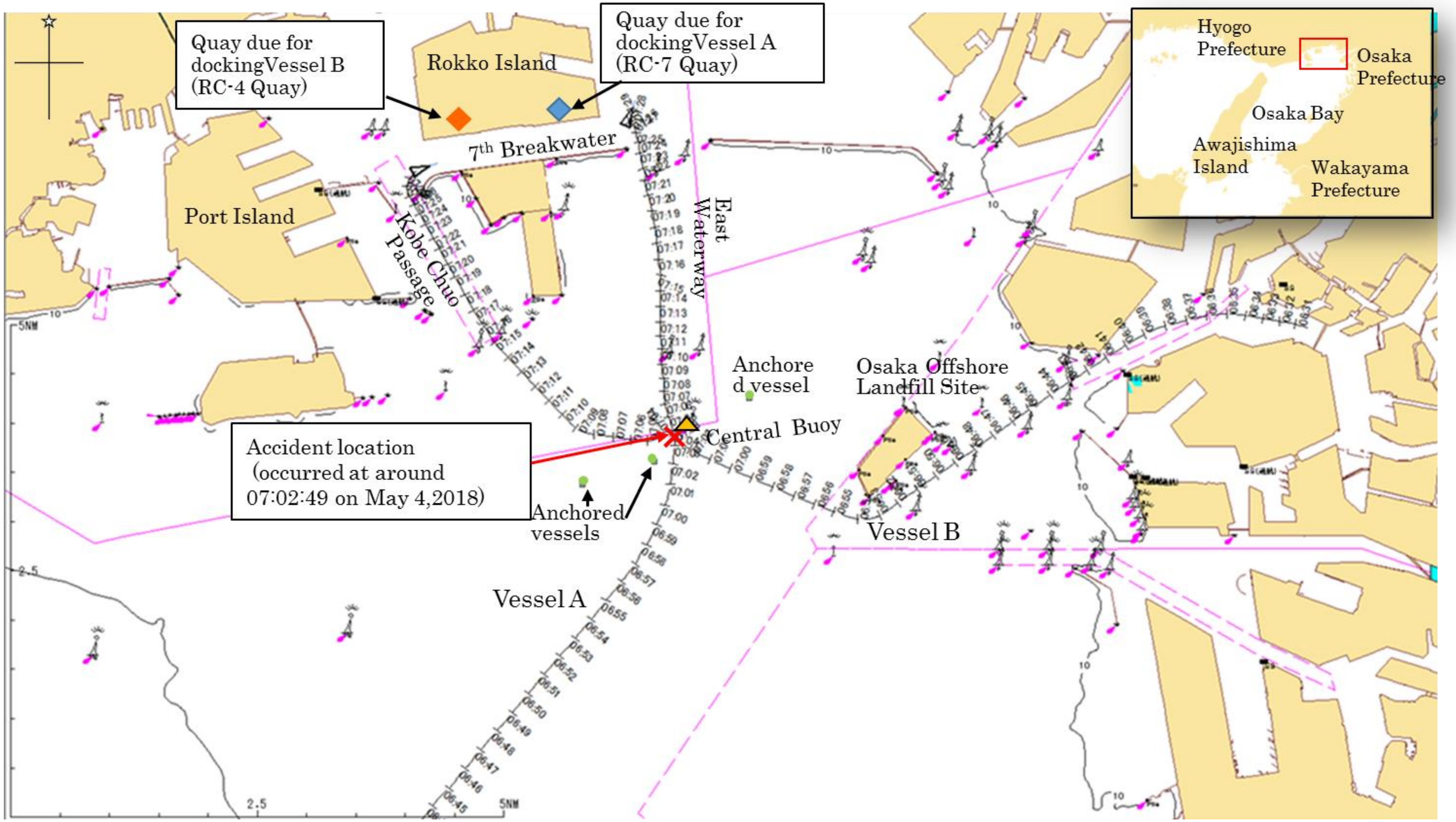
Company B listed the causes of the accident as: the Vessel A didn't maintain a proper lookout, both vessels didn't slow down until right before the accident, and they couldn’t cooperatively avoid the accident because the Vessel A was not maneuvering adequately. Based on the lessons learned from the accident, Company B established a safety action month for all company vessels, in order to check safety awareness, watch conditions, adherence of the company rules, in addition to reviewing a pre-boarding training for the masters and officers.

5.2 Safety Actions Required

5.2.1 Osakawan Pilots' Association

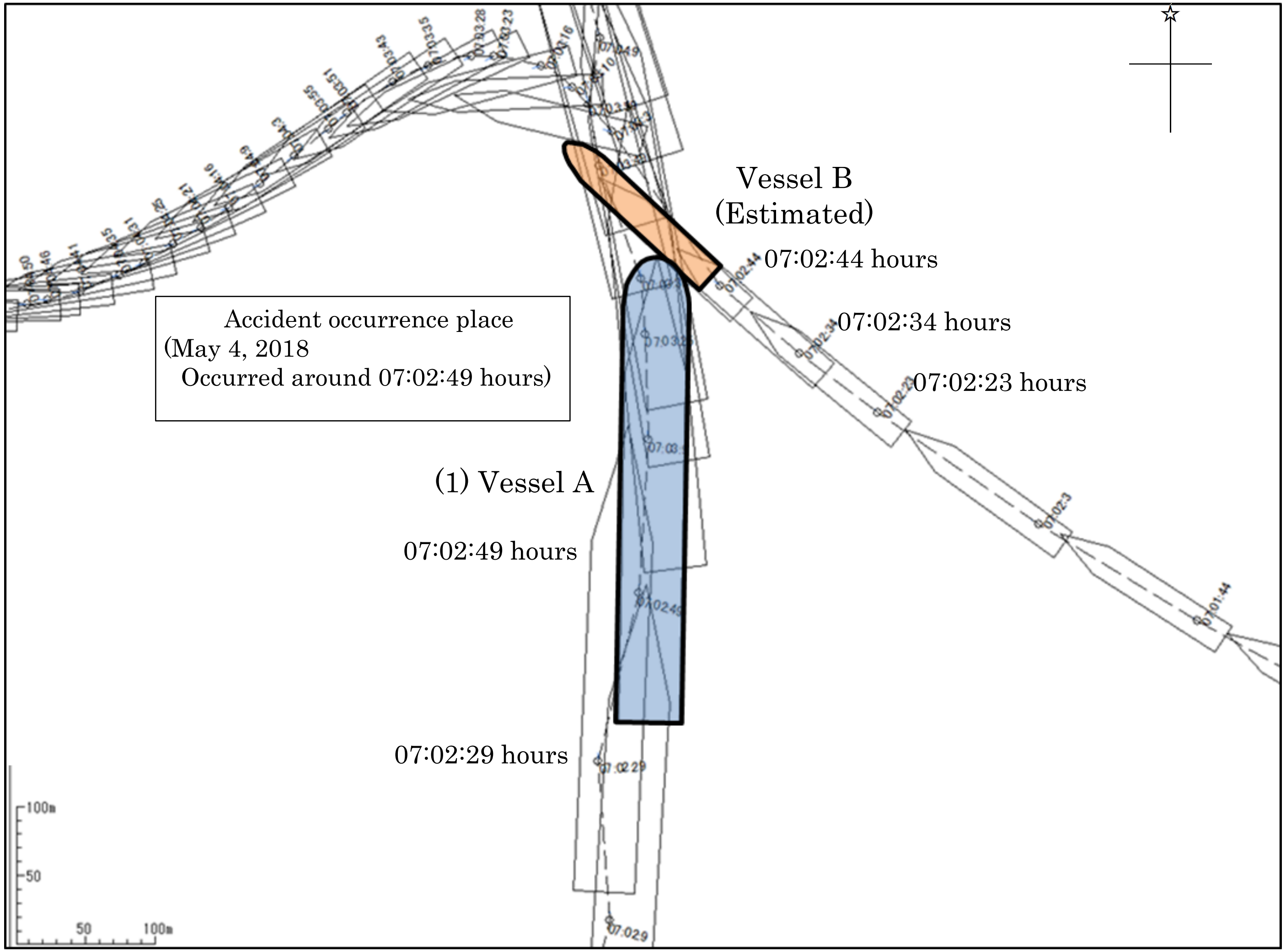
It is recommended that the Osakawan Pilots' Association should have all members acknowledge this report. In addition, the association should instruct members to use navigation equipment, such as radar and ECDIS, to keep a proper lookout at all times, verbally communicate manuvering and movement of other vessels between crews, and share information, such as their own vessel's course, with other vessels and a port radio when manuvering in close distance to other vessels.

Figure 1: Navigation path



－ 37 －

Figure 2: Navigation path (Enlarged)

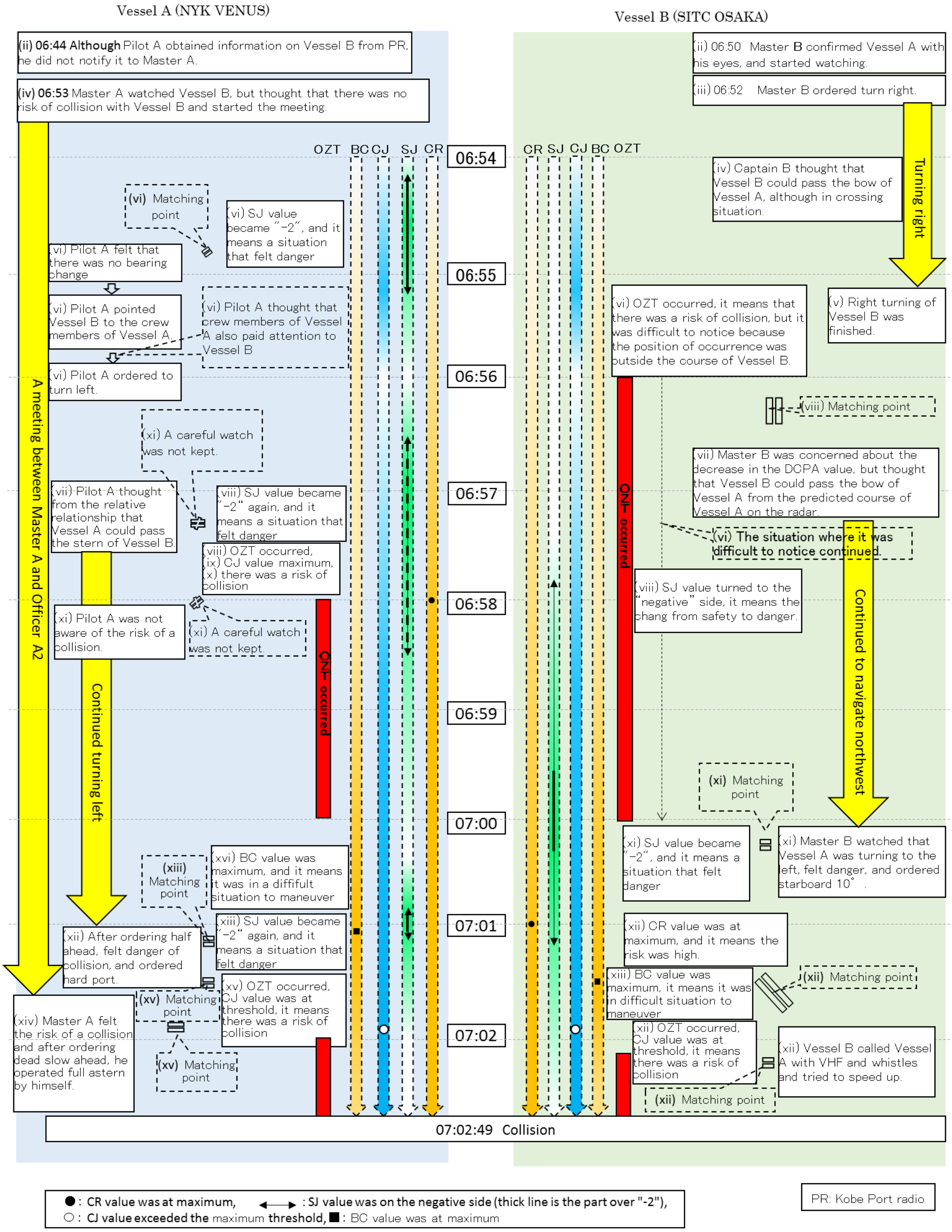


1. Process and Progress of the Accident Table

Time (Hours: Minutes: Seconds)	Vessel A		Vessel B	
	Pilot A	Master A	Master B	Officer B
At round 05:00	Pilot A got on board and had a meeting with Master A. Started the Pilotage operating. During Pilotage, Pilot A thought that the crew members of Vessel A were reliable, and he thought he could share the perception of vessel maneuvering with Master A.			
At round 06:10			Vessel B departed from Hanshin Port Osaka Area bound for Rokko Island RC-4 Quay of the Hanshin Port Kobe Area.	
At round 06:31				Told the Port Radio about the expected arrival time to Kobe Chuo Passage and obtained information on other vessels.
At round 06:35	Ordered the crew members to gradually lower the speed to the harbor speed.			
At round 06:44	Told the Port Radio about the expected arrival time to the breakwaters and obtained of information on other vessels. Recognized Vessel B for the first time.			
At round 06:50			Confirmed Vessel A (4 M away in the bow direction) and started watching with radar and visual observation.	
At round 06:52	Officer A1 rose up to the bridge and took over the watch with Officer A2.		Ordered right turn towards the Kobe Chuo Passage.	
At round 06:53		Watched Vessel B at a distance of about 3M ahead to starboard, confirmed it with ECDIS, and Vessel B seemed to be going away. Master A started to talk about the port entry Officer A2 near the chart table.		
At round 06:54			Recognized that it was in crossing situation with Vessel A.	
At round 06:55	Felt that there was no bearing change in the relative with Vessel B. Pilot A thought that Master A and Officer A2 were watching Vessel B with radar and ECDIS. After thinking that crew of Vessel A were conscious of Vessel B because Pilot A pointed at Vessel B, ordered to turn the left.			

At round 06:57	Pilot A, from the relative relationship with Vessel B thought that Vessel B might pass through the bow side of Vessel A, so continued left turn with slowing down of Vessel A. Although Trainee A felt the fear of collision against Vessel B and Pilot A reported that, Pilot A was not aware of it.		Although concerning about the decrease in DCPA value, Master B thought that Vessel B was able to pass the bow of Vessel A without problems from the predicted course of Vessel A by the radar.	
At round 07:00			Watching Vessel A which was turning left, Master B felt the danger of collision, so ordered starboad 10 °.	
At round 07:01	Ordered Officer A1 to make the main engine half ahead as Vessel A approached the East Waterway. Checked the positional relation with vessel B with his eyes, and felt collision with Vessel B, therefore ordered Steering officer A hard port.	Hearing the instructions of Pilot A, Master A looked at the bow and felt the danger of a collision.		
At round 07:02		Ordered Officer A1 to make the main engine half ahead. Captain A operated the main engine remote control device by himself and change it to full astern.	Sounded the whistle Ordered to increase the speed	Called Vessel A with VHF. Called Vessel A with VHF.
At around 07:02:49	The collision			

Figure 3: Time-series related to watching and maneuvering conditions and collision risk



Attachment

Analytical Investigation of a Collision Accident Involving Container Ships

REPORT

February 2019

National Maritime Research Institute

National Institute of Maritime, Port and Aviation Technology

Table of Contents

1 Introduction

1.1 Purpose of the Investigation

The purpose of this investigation was to contribute to the investigation into the collision accident between the container ship NYK VENUS (hereinafter referred to as “Vessel A”) and the container ship SITC OSAKA (hereinafter referred to as “Vessel B”) that occurred near a point located 350 m southwest from the center floating lighted buoy of the Kobe Rokko Island East Waterway in the Kobe Area of Hanshin Port at around 07:02:49 on May 4, 2018. To this end, situational awareness concerning the behavioral status of both vessels leading to the collision was evaluated based on AIS data, the navigational status was analyzed based on the past record of port entry by large vessels, and factors leading to the accident were analyzed by means of CREAM (Cognitive Reliability and Error Analysis Method).

This investigation was commissioned by the Japan Transport Safety Board.

1.2 Outline of the Investigation

(1) Evaluation of situational awareness

To quantify the risk of collision between the two vessels that collided (Vessel A and Vessel B), the level of collision risk between the two vessels was assessed using five evaluation indicators (OZT [Obstacle Zone by Target], CJ [Collision Judgement], SJ [Subjective Judgment], BC [Blocking Coefficient] and CR [Collision Risk] values) based on AIS data at the time of the accident. Additionally, for BC, the level of collision risk when navigating vessels and anchored vessels in the vicinity are included was also assessed and the situation at the time of the accident was objectively analyzed.

Finally, the result of CPA (Closest Point of Approach) analysis using the positions of the GPS antennas as datum points were compared with the result of CPA when the sizes of the vessels were taken into account, and assessment of the level of collision risk was studied, taking account of vessel length.

It should be noted that the investigation’s analysis focused the time starting at 06:54, which was after Vessel B changed course to head toward the Kobe Chuo Passage. Unless otherwise stated, the datum point for calculation is antenna position (the position received with AIS data) and the quantitative status and level of collision risk at ten second intervals were assessed using values interpolated to one-second values achieved by synchronizing the AIS data of each vessel. Additionally, the rate of change of compass bearing (to be described later) and rates of change of relative distance and relative bearing, used as variables in CJ and SJ indicators for the level of collision risk, are established as differences in individual measured values occurring at times before and after each ten seconds.

(2) Navigational status based on past records of port entry by large vessels

Navigational tracks and speeds were analyzed in terms of navigational status when passing several gate lines, using a total of 18 port entry records by large vessels of similar types as those involved in the accident that were supplied by the Japan Transport Safety Board.

(3) CREAM analysis

Cognitive factor analysis was carried out using the CREAM method, based mainly on interview research with ship handlers and others supplied by the Japan Transport Safety Board.

2 Evaluation of Situational Awareness

2.1 Navigational Tracks Around the Time of the Accident

Fig. 2-1 provides a navigational track chart for Vessel A and Vessel B around the time of the accident and the positions of vessels existing in the vicinity. Table 2-1 shows the specifications of the two vessels (Vessel A and Vessel B).

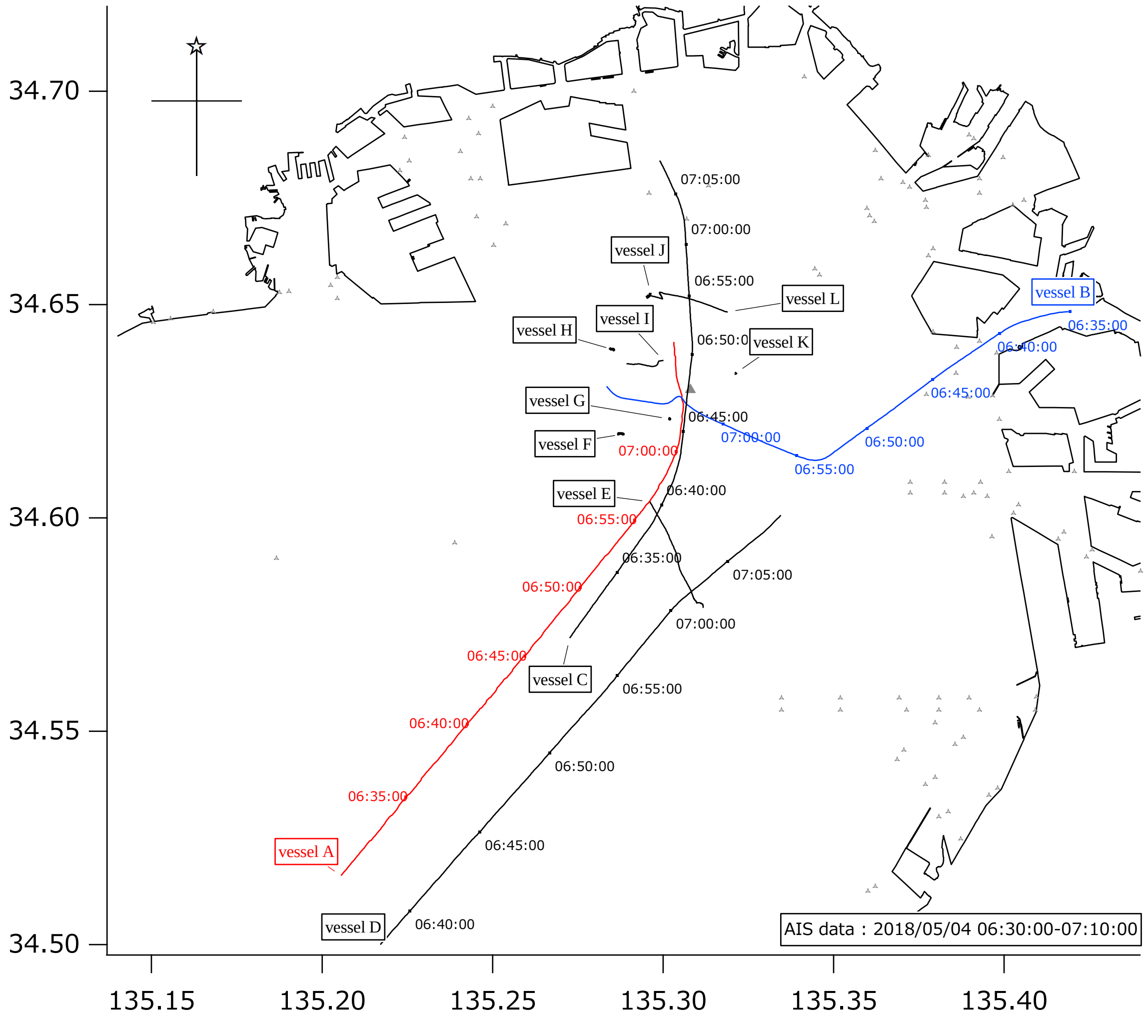


Fig. 2-1 Navigational track chart around the time of the accident

Table 2-1 Vessel specifications

	Gross tonnage	L×B×D

Vessel A	97,825 tons	338.17×45.60×24.60 [m]
Vessel B	9,566 tons	141.03×22.50×11.40 [m]

2.2 Time-related Changes in the Quantitative Status of Vessel A and Vessel B

Time-related changes in the quantitative status of the two vessels that collided were analyzed based on AIS data at the time of the accident. Fig. 2-2 and Fig. 2-3 show changes in the quantitative status of Vessel A and Vessel B. The top part of Fig. 2-2 shows the rate of change in compass bearing, while the bottom part shows the distance between the vessels. The top part of Fig. 2-3 shows the Time to Closest Point of Approach (TCPA), the middle part shows the Distance of Closest Point of Approach (DCPA), and the bottom part shows the Bow Crossing Range (BCR).

Rate of compass bearing change

As is seen in Fig. 2-2, compass bearing changes begin at around 06:54, when Vessel B finished changing course; however, the maximum value of rate of compass bearing change during the time period between 06:54 and around 07:01, when Vessel B conducted steering, was approximately 4 degrees/minute. According to literary sources,[1) 2)] "human ability to visually detect rate of change is one or two degrees/minute when there is a reference point." Considering the rate of compass bearing change at the time of the accident, it is possible there were times when changes in compass bearing could not be recognized.

DCPA

As is seen in Fig. 2-3, DCPA was temporarily almost nil at around 06:54, when Vessel B finished changing course, and then remained small afterwards. After 06:54, the highest DCPA value came at around 06:55, when it was approximately 0.3NM.

BCR

As is seen in Fig. 2-3, beginning at 06:54, when Vessel B completed her turn, Vessel A's BCR shows positive and it means that Vessel B is passing Vessel A's bow side. Even after 06:55, when it is at its largest, Vessel A's BCR is 0.57NM (approximately 0.44NM from the bow's end), and it gradually grows smaller after 06:55, when Vessel A began making a turn. On the other hand, Vessel B's BCR is on the negative side and it means that Vessel A is passing Vessel B's stern side. After 06:55, after Vessel B completed her turn, Vessel B's BCR is 0.43NM (approximately 0.42NM from the stern's end), and it gradually grows smaller after 06:55.

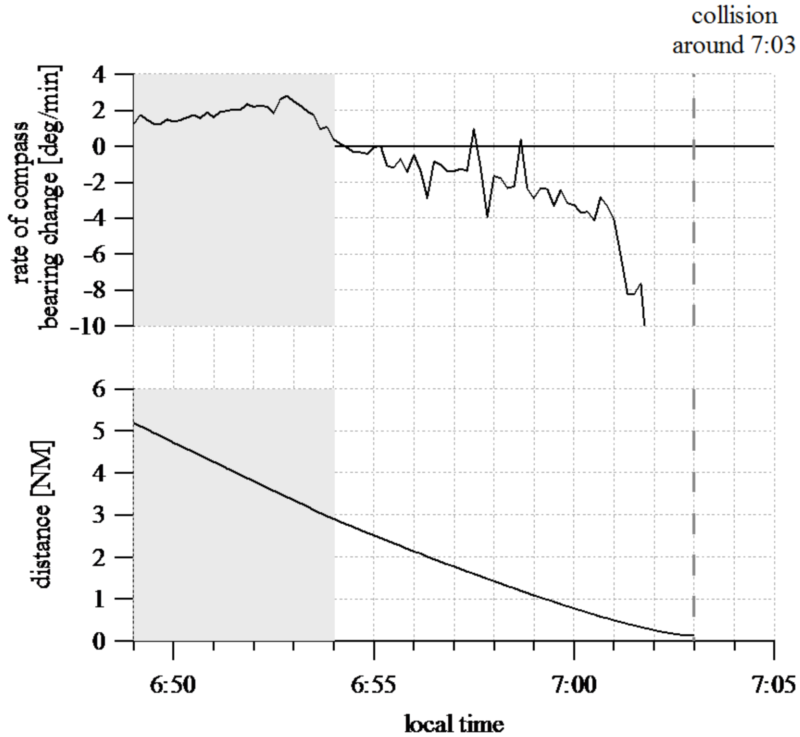


Fig. 2-2 Time-related changes in rate of compass bearing change and relative distance

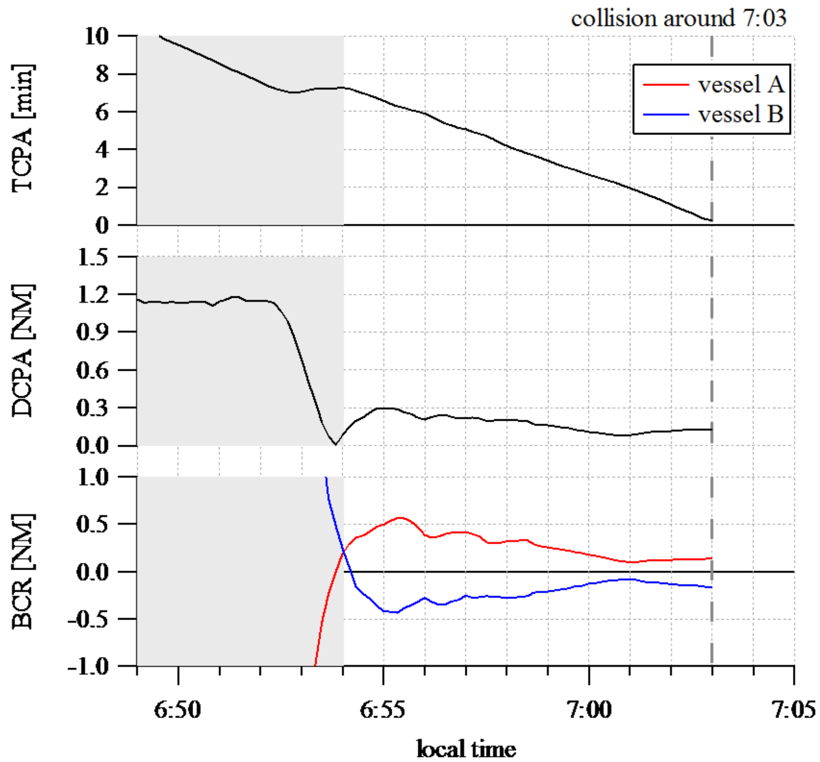


Fig. 2-3 Time-related changes in TCPA and DCPA

2.3 Location of OZT Occurrence

OZT[3] indicates an area that is likely to be obstructed by another vessel (the "target ship") in the near future. When this area exists ahead when seen from a vessel (the "own ship"), it becomes an element that impacts the maneuvering behavior of the own ship. If the area is right in front when seen from the own ship, some kind of action must be taken to avoid the area. Based on this concept, the conditions for OZT areas regarded as causing maneuvering difficulty above a certain level were set as shown below.

Conditions for OZT evaluation

- ✓ Evaluation shall apply to vessels approaching within 3NM.
- ✓ An area whose minimum safe navigating distance between two vessels is determined by the following equation to be within L_g = 259 [m] shall be the OZT (Fig. 2-4 (a)). It should be noted that L_g in the following equation is the length that determines the size of an exclusive area into which the entry of the target ship is not permitted in order to eliminate the danger of collision.[4)]

$$L_g = \left\{ \frac{L_o{}^2 + L_t{}^2}{2} \right\}^{1/2} \quad [\mathrm{m}]$$

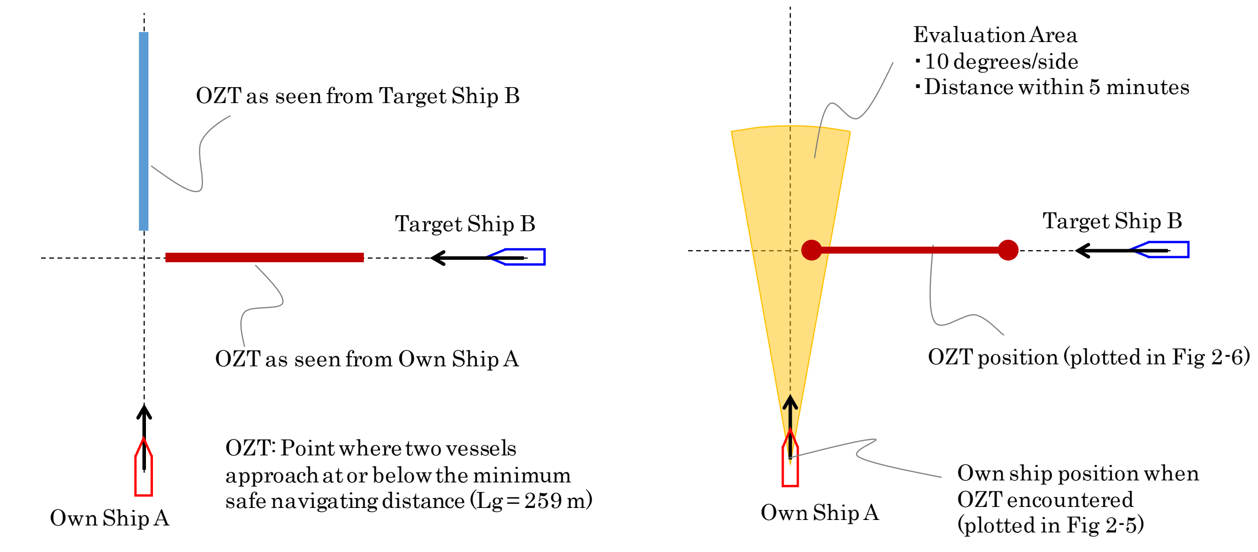
Where, L_o is the own ship's length [m] and L_t is the target ship's length [m].

- ✓ The focus of evaluation shall be an OZT that is within 10 degrees to port and starboard of the own ship's course and in which the time until arrival at the OZT point is five minutes or less (the fan-shaped area of Fig. 2-4 (b)).
- ✓ Furthermore, the datum point for calculation was corrected to the midship. This was done based on consideration of the fact that OZT evaluation will view as hazardous a state whereby the distance between the two vessels falls under the minimum safe navigating distance, and in accordance with the view that evaluation should be made using the approach status of the two vessels based on the midship.

Example of OZT evaluation

For example, let us consider a situation in which Own Ship A and Target Ship B are navigating as shown in Fig. 2-4 (a). The point at which the two vessels will approach below the minimum safe navigating distance (Lg) at the arbitrary time shown in the figure is the OZT. Regarding this point, the OZT seen from Own Ship A is the red line on the path of the target ship, and the OZT seen from Target Ship B is the blue line on the path of Own Ship A. Because a portion of Own Ship A's OZT enters the evaluation area (the yellow fan-shaped area of Fig. 2-4 (b)), Own Ship A's OZT becomes subject to evaluation.

For the purpose of visualizing time and hull position when encountering the OZT, the position of Own Ship A when it encountered the OZT that is represented in the figure corresponds to Fig. 2-5. Additionally, for the purpose of visualizing the OZT occurrence points that Own Ship A encountered, the movement of the position of the entire OZT, with both endpoints clarified with ●, corresponds to Fig. 2-6.



(a) OZT as seen from the two encountering vessels (b) Example of OZT evaluation for Ship A

Fig. 2-4 The concept of OZT

Analysis of the OZT occurrence point

Fig. 2-5 shows the positions of the vessels superimposed on their navigational track chart when the course of the own ship has been obstructed by the OZT.

The time at which the course of the own ship is first obstructed by the OZT is around 06:57:50 for Vessel A and around 06:56:10 for Vessel B. That is, when the course and speed are constant, the vessels will be falling into a dangerous situation within five minutes of those times.

Additionally, Fig. 2-6 provides the position of the OZT encountered by both vessels together with a navigational track chart. The OZT encountered by Vessel A occurred on the path that Vessel A intended to take from the time that she first encountered the OZT until just prior to the collision. On the other hand, with the exception of the time just prior to the collision, the OZT encountered by Vessel B occurred at places on the port side that were removed from the path that she intended to take.

Let us observe Vessel A in detail. When she first encountered the OZT, her speed was approximately 13.6 kt and the distance from Vessel A to the OZT was approximately 1.1NM. It is probable that, at this point, she was not in a state whereby there was no room to avoid danger. Furthermore, the OZT occurred in roughly the same position. It is probable that this was because there was little change in Vessel B's course.

Subsequently, Vessel A approached the OZT until the time that Vessel A was temporarily not encountering the OZT (i.e., the OZT was not in the evaluation area). At around 06:59:50, the distance became approximately 0.6NM at approximately 12.9 kt, and it is probable that Vessel A was gradually losing leeway for avoiding danger. At around 07:02:10, when Vessel A again encountered the OZT just prior to the accident, she had approached to approximately 0.2NM at approximately 11.8 kt.

Let us observe Vessel B in detail. When she first encountered the OZT, her speed was approximately 13.9 kt and the distance from Vessel B to the OZT was approximately 1.1NM. However, Vessel B was not in a state in which her course was obstructed. The OZT's position of occurrence gradually moved to the northwest until the time when she was temporarily not encountering the OZT. Although it is probable that this was an effect of Vessel A's altering course, Vessel B's course was not obstructed during this time. Vessel B subsequently approached the OZT and, at around 06:59:50, she was gradually approaching the OZT at a distance of 0.6NM and speed of approximately 13.9 kt. At around 07:02:10, when Vessel B again encountered the OZT just prior to the accident, the OZT occurred at a distance of approximately 0.2NM directly ahead of Vessel B (approximately 13.7 kt).

It should be noted that the distance from each vessel to the OZT is the distance from the own ship's datum point for calculation to the OZT endpoint nearest from the own ship.

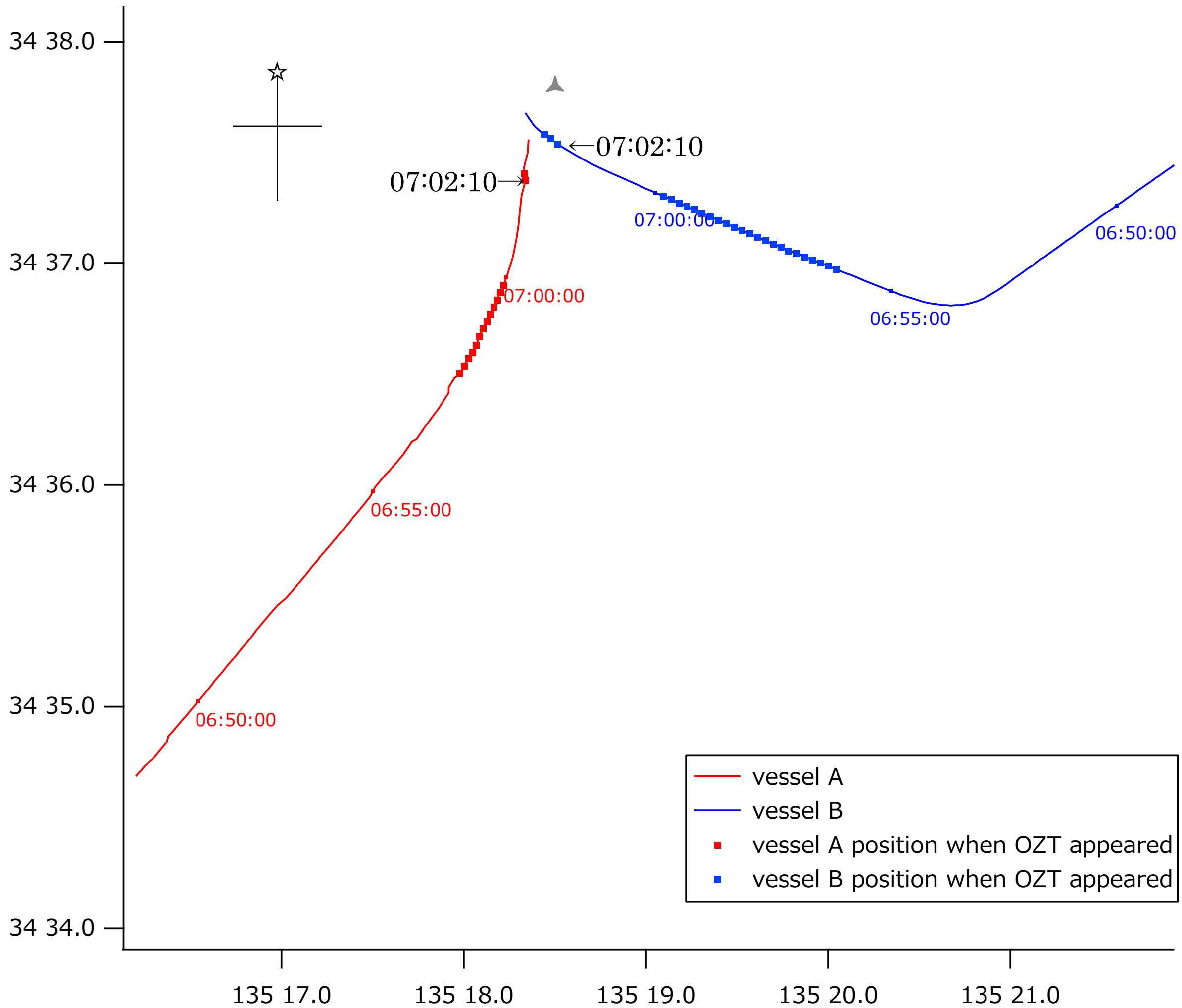


Fig. 2-5 Own ship's position when its course is obstructed by other vessel

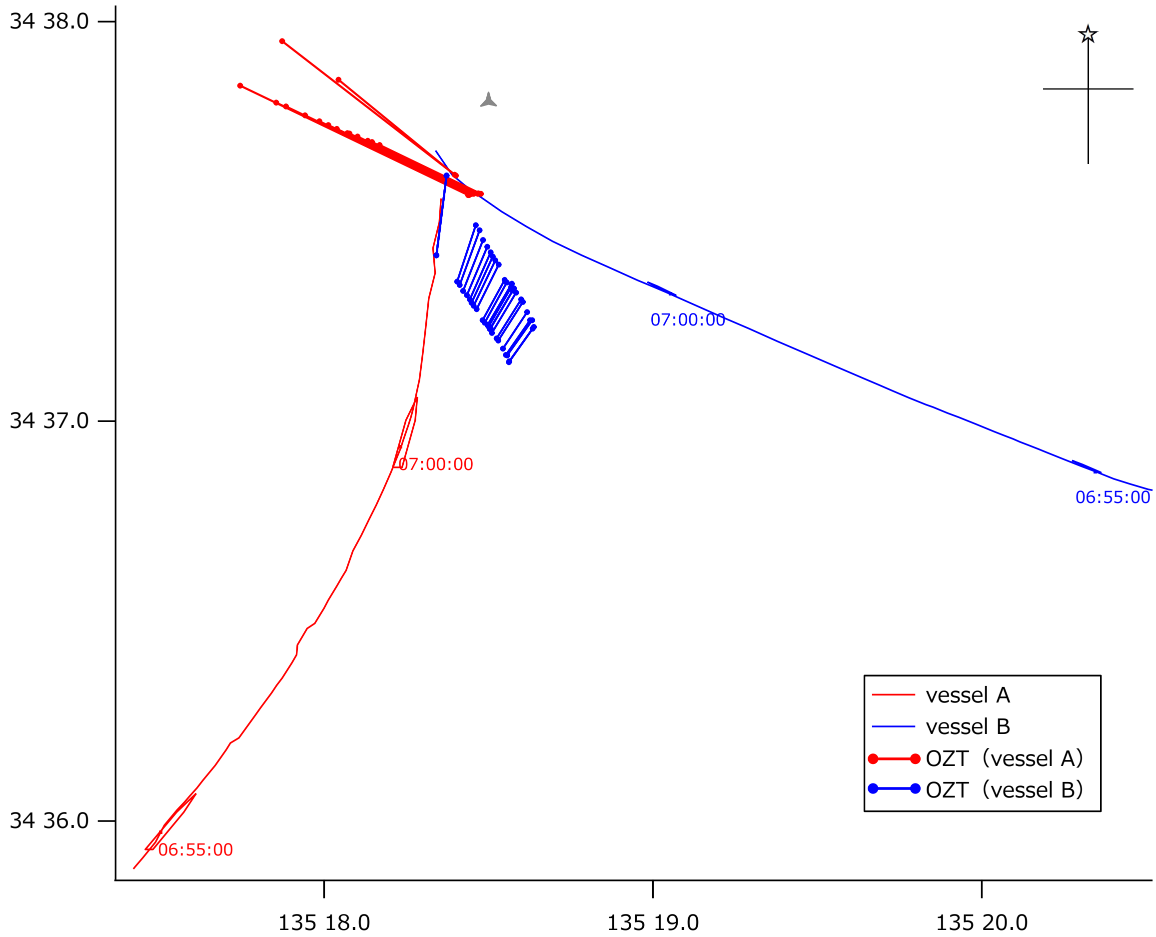


Fig. 2-6 OZT position when encountered by each vessel

2.4 Time-related Changes in Collision Risk Level

Time-related changes in collision risk level were analyzed using indicators published in past literature and based on AIS data at the time of the accident.

General description of indicators

(1) What is CJ (Collision Judgment)[5)]

CJ is an indicator showing the level of collision risk between two vessels in a one-on-one matching relationship. The collision risk level is calculated from the distance relative to the other vessel and the rate of change in it, as well as change in the bearing relative to the other vessel and the rate of this change. CJ can be within the range from $-\infty$ to ∞, with a negative CJ indicating safety.

(2) What is SJ (Subjective Judgment)[6)]

SJ uses the distance from one vessel to another vessel and the rate of change in relative bearing as variables.

These variables are expressed with fuzzy representation in three stages with consideration for the meeting relationship. SJ evaluates the level of collision risk between the two vessels by changing weighting factors in accordance with combinations of both. SJ can be within the range of -3 to 3, with meanings as follows.

Very dangerous	SJ=-3	Very safe	SJ=+3
Dangerous	SJ=-2	Safe	SJ=+2
Somewhat dangerous	SJ=-1	Somewhat safe	SJ=+1
Neither safe nor dangerous	SJ=0		

(3) What is CR (Collision Risk)[7) 8)]

CR evaluates the level of collision risk based on fuzzy inference with consideration for maneuverability and other vessel characteristics using Time to Closest Point of Approach (TCPA) and Distance of Closest Point of Approach (DCPA), which are determined from the relative positions and relative speeds of the two vessels. CR can be in the range of -1 to 1. Larger absolute values of numerical values indicate a higher degree of danger. A negative CR expresses a state in which the vessels have gone past the closest point of approach.

(4) What is BC (Blocking Coefficient)[9)]

BC is used to calculate the degree to which the own ship is blocked by the risk of collision with other vessels existing in the vicinity. Specifically, it uses the risk level of collision with vessels existing in the vicinity when the own ship is giving way by changing speed and course, multiplied by a weighting factor that expresses preference for changing speed or changing course as a means of giving way. BC can be in the range of 0 to 1. When BC is 1, it means that the TCPA is extremely small and cannot be avoided by any maneuvering.

It should be noted that, in this investigation, the time of the accident was immediately prior to entering port and that slowing by engine was possible. Thus, it is assumed that changing course and changing speed were both available as means of giving way. As for the ranges of the means of giving way, changing course is at set five-degree increments up to 60 degrees to port and starboard from the current course, and changing speed is set at 20% increments from 20% increase in speed to 60% decrease in speed, using current speed as the base point. BC is evaluated by calculating the degree of danger with the other vessel at each change-of-course angle and speed and based on weighted averages with the above-mentioned weighting factors.

Results of evaluation

Fig. 2-7 shows time-related changes in collision risk level. The results of evaluation with each indicator are provided below.

(1) Evaluation based on CJ

Vessel A's CJ begins rising gradually from around 06:56. Vessel B's negative CJ indicates safety; however, CJ begins rising gradually from 06:54, when it completed her course change, and thus danger is gradually rising. The time that CJ used as the danger threshold in the previous investigation[1] exceeded 0.015 is around 07:02 for both Vessel A and Vessel B.

(2) Evaluation based on SJ

Vessel A's SJ moves to the negative side, indicating danger, from before 06:54, when Vessel B completed her course change. SJ becomes -2 for the first time at around 06:54. Although SJ increases from 06:55, the dangerous situation remains. SJ exceeds -2 and is in a dangerous state after 07:01, immediately prior to the accident.

Vessel B's SJ is on the dangerous side from around 06:58 and approaches -2 at around 07:00.

(3) Evaluation based on CR

Vessel A's CR rises from 06:54, when Vessel B completed her course change, and reaches the state of maximum danger from 06:58. Vessel B's CR rises from 06:56 and reaches the state of maximum danger from 07:01.

(4) Evaluation based on BC

The solid lines of Fig. 2-7 indicate only course change as the means of giving way and the dashed lines indicate both course change and speed reduction. Regardless of whether the means of giving way is course change only or both course change and speed reduction, Vessel A's BC increases on the whole from around 06:55 and Vessel B's BC increases from 06:55, although it decreases temporarily at around 06:58. Looking at the degree of ship maneuvering by the means of giving way for each vessel, Vessel A's course change only values (solid line) have high BC values, while, conversely, Vessel B's course change and speed reduction values (dashed line) have high BC values. From this, it is probable that, in the circumstances of just these two vessels (Vessel A and Vessel B), ship maneuvering would have been comparatively less difficult if Vessel A had used both course change and speed reduction as her means of giving way and Vessel B had used only course change as her means of giving way.

Additionally, the solid lines of Fig. 2-8 indicate time-related changes of BC value for all vessels shown in Fig. 2-1 when Vessel A's means of giving way are both course change and speed reduction and Vessel B's means of giving way is course change only. The BC of both Vessel A and Vessel B rise from 06:54 and their maximum values are more than double the two-vessel scenario due to the presence of anchored vessels, etc., meaning that ship maneuvering becomes difficult (Vessel A's BC of 0.19 becomes 0.47, or roughly 2.5 times higher, and Vessel B's BC of 0.23 becomes 0.52, or roughly 2.4 times higher). The level of maneuvering

[1] Collision accident involving container ships that occurred on June 7, 2016 (see the marine accident report of the Japan Transport Safety Board).

difficulty was about the same for both vessels.

Furthermore, the Kobe Rokko Island East Waterway's center floating lighted buoy is present in the sea area in which the two vessels were navigating, and it is probable that the buoy had an effect on maneuvering. The dotted lines of Fig. 2-8 show time-related changes of BC values when the light buoy is considered. The maximum value of Vessel A is 0.50 and that for Vessel B is 0.52. BC increases for both vessels when compared to the scenario in which only vessels are considered (solid lines). In particular, Vessel A's BC increases greatly from 07:00, and thus it could be said that the light buoy's presence affects her maneuvering.

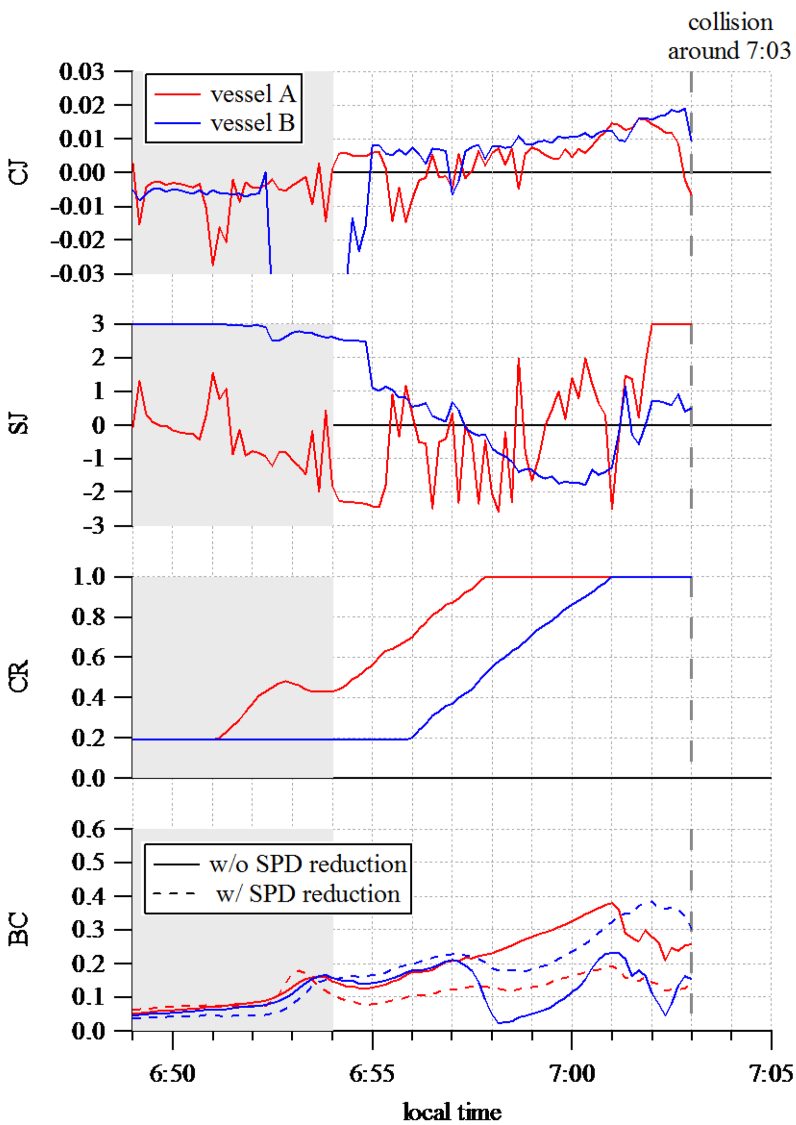


Fig. 2-7 Time-related changes in collision risk level

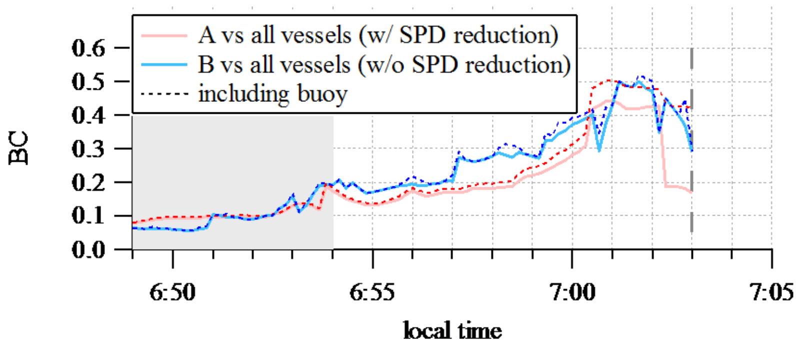


Fig. 2-8 Time-related changes in BC value when vessels in the vicinity are included

2.5 CPA Analysis Taking Account of Vessel Length

To analyze the impact when taking account of vessel size, CPA analysis was carried out using the points where the vessels collided as the datum points for calculation at one-minute intervals from 6:55. Table 2-2 shows the collision points, while Fig. 2-9 shows a comparison with CPA analysis when antenna position and collision points are used as datum points. The DCPA values of Vessel B's VDR record, which was provided by the Japan Transport Safety Board, are marked with Xs in Fig. 2-9. Additionally, Table 2-3 shows the smallest DCPA and TCPA values and their datum points for those DCPA and TCPA where the datum points for calculation are contact points at the initial contact or secondary contact.

Evaluation of the impact of vessel length

DCPA of the evaluation time changes with time-related changes because Vessel A is turning. Looking at DCPA, at almost all time points of time, DCPA when the Vessel A's bow tip (point of primary contact) is the datum point for calculation is smaller than DCPA at the fore starboard side (point of secondary contact), with the difference generally being around 20 m. Additionally, when the smallest DCPA values at the two collision points and DCPA at the antenna position are compared, DCPA at the collision points is smaller, with a maximum difference of approximately 200 m appearing immediately before the collision. DCPA observed on Vessel B is close to the numerical value when the antenna position is used as the datum point, and is evaluated to be a maximum of around 210 m in excess of the actual leeway when the lengths of Vessel A and Vessel B are considered. It should be noted that the bow tip that is Vessel A's collision point is around 240 m in front of the antenna position and thus can be said to receive more influence from Vessel A's length than Vessel B's.

In the case of TCPA, there were no large differences among any of the datum points for calculation. TCPA was smaller by around 20 seconds when the collision points were used as datum points for calculation.

Table 2-2 Collision points taken as datum points

	Distance from antenna position [m]					
	Primary contact point (C.P.1)			Secondary contact point (C.P.2)		
	Forward	To starboard	Remarks	Forward	To starboard	Remarks
Vessel A*	243.0	9.5	Bow tip	225.4	23.7	Fore starboard
Vessel B	8.1	-6.7	Aft port	Same point as primary contact point		

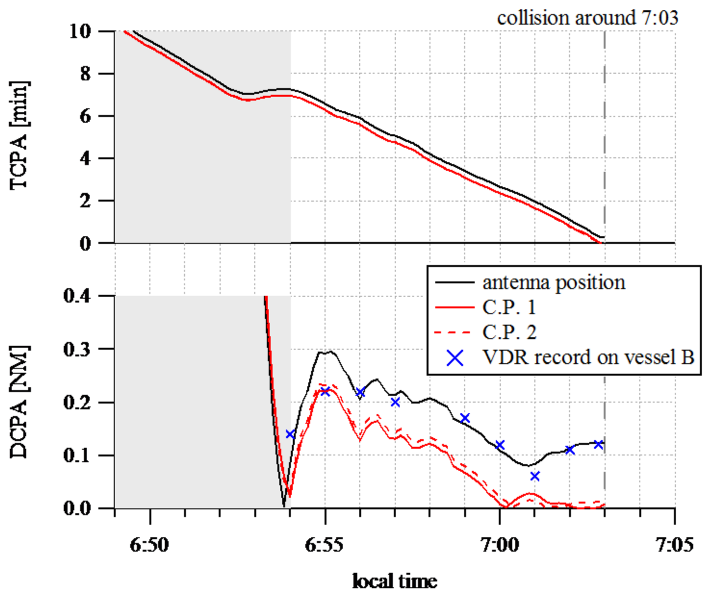


Fig. 2-9 Comparison of CPA analysis when taking vessel length into account

Table 2-3 Comparison of CPA analysis when taking vessel length into account

	DCPA [m]				TCPA [sec]			
	Antenna position	Collision point (*)		Difference	Antenna position	Collision point (*)		Difference
06:55:00	540	407	(C.P.1)	-132	394	376	(C.P.1)	-18
06:56:00	380	236	(C.P.1)	-145	354	336	(C.P.1)	-19
06:57:00	394	242	(C.P.1)	-152	304	285	(C.P.1)	-19
06:58:00	384	225	(C.P.1)	-159	252	233	(C.P.1)	-19
06:59:00	294	124	(C.P.1)	-170	203	185	(C.P.1)	-19
07:00:00	199	14	(C.P.1)	-185	159	141	(C.P.2)	-19
07:01:00	154	26	(C.P.2)	-128	117	98	(C.P.2)	-19
07:02:00	211	8	(C.P.1)	-204	65	47	(C.P.2)	-18
07:03:00	229	15	(C.P.1)	-214	15	-3	(C.P.2)	-18

* The smallest DCPA/TCPA value of DCPA/TCPA at the two collision points. The numerical values in the parentheses indicate the datum point for calculation of that time.

3 Navigational Status Based on Past Records of Port Entry by Large Vessels

3.1 Port Entry Records

Table 3-1 shows past port entry records by Vessel A and a total of three vessels of the same type as Vessel A (Vessel I, Vessel II, and Vessel III), as supplied by the Japan Transport Safety Board.

Table 3-1 Port entry records

	Vessel	Date of port entry
1	Vessel II	7/6/2017
2	Vessel A	7/29/2017
3	Vessel I	8/17/2017
4	Vessel III	9/7/2017
5	Vessel II	9/14/2017
6	Vessel A	10/5/2017
7	Vessel I	10/26/2017
8	Vessel III	11/16/2017
9	Vessel II	11/23/2017
10	Vessel A	12/14/2017
11	Vessel I	1/8/2018
12	Vessel III	1/29/2018
13	Vessel II	2/2/2018
14	Vessel A	2/22/2018
15	Vessel I	4/7/2018
16	Vessel II	4/12/2018
17	Vessel III	4/26/2018
18	Vessel A	5/4/2018 (day of the accident)

3.2 Navigational Track When Entering Port

The navigational tracks of Vessel A when entering the Kobe Rokko Island East Waterway will now be compared. Fig. 3-1 shows the navigational track of Vessel A (red line) on the date of the accident, superimposed together with navigational tracks when Vessel A and other similar vessels entered port in the past (black lines). At the time of the accident, Vessel A was entering the Kobe Rokko Island East Waterway from the port side of the waterway's center floating lighted buoy. Looking at past records, vessels entering the Kobe Rokko Island East Waterway navigated on both sides, port and starboard, of the passage's center floating lighted buoy. Comparing navigation tracks north of 34°36'25"N that pass to the port side of Kobe Rokko Island East Waterway's center floating lighted buoy, as Vessel A did at the time of the accident, reveals that the tracks of past vessels go more to the western side than that of Vessel A at the time of the accident. From this, it can be said that many vessels navigated on the starboard side of Kobe Rokko Island East Waterway's center floating lighted buoy when navigating the route that Vessel A took beginning at 06:55 at the time of the accident.

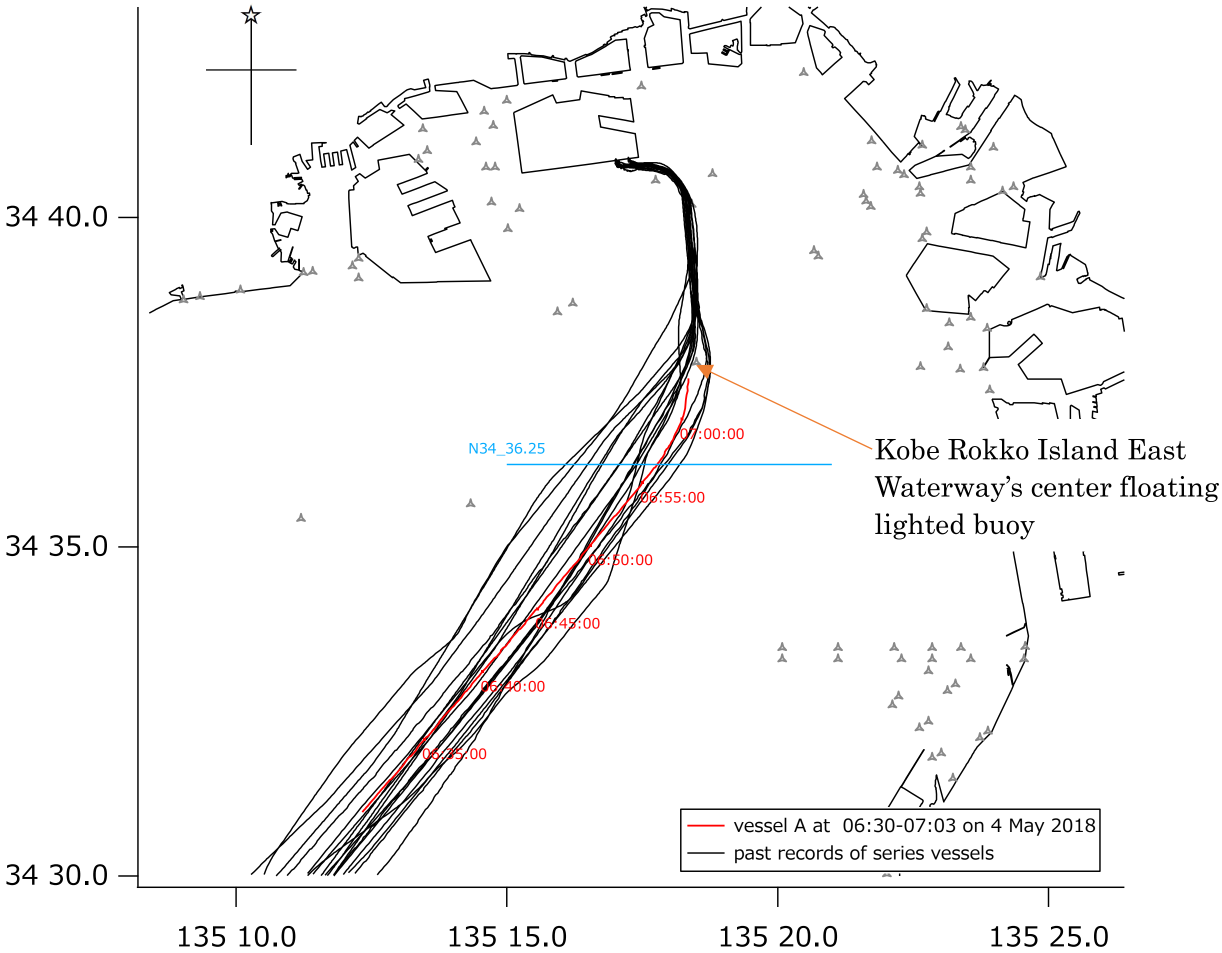


Fig. 3-1 Navigational tracks of Vessel A and similar vessels when entering port

At the time of the accident, numerous anchored vessels were present in the vicinity of the waterway. Fig. 3-2 shows the navigation tracks shown in Fig. 3-1 superimposed with Vessel B's navigation track and the positions of vessels that were anchored at the time of the accident (including some vessels that were not completely anchored at around 06:55). Additionally, according to the literature, separation distance from anchored vessels and buoys is expressed with the following equation.[10] Here, the positions and separation distances of anchored vessels and light buoys that can become obstacles to the paths of both vessels in the sea area around the accident are shown in Fig. 3-2. The light blue circles in the figure indicate separation distance from anchored vessels and the yellow circles indicate separation distance from light buoys.

$$D(\text{Buoy}) = 0.33 \cdot L_o$$
$$D(\text{Anchored vessel}) = 0.89 \cdot L_o$$

Where, D is separation distance vis-à-vis obstacles (m) and Lo is the length of the own ship (Vessel A)

In considering Vessel A's method of entering port at the time of the accident, because the sea area on the port side of Kobe Rokko Island East Waterway's center floating lighted buoy was occupied by numerous anchored vessels, it is somewhat likely that Vessel A took an approach that involved proceeding north at an angle near the waterway's course from a position to the south of the light buoy. On the other hand, it is probable that Vessel B navigated between anchored vessels, which was the shortest path, in order to enter port on the Kobe Chuo Passage.

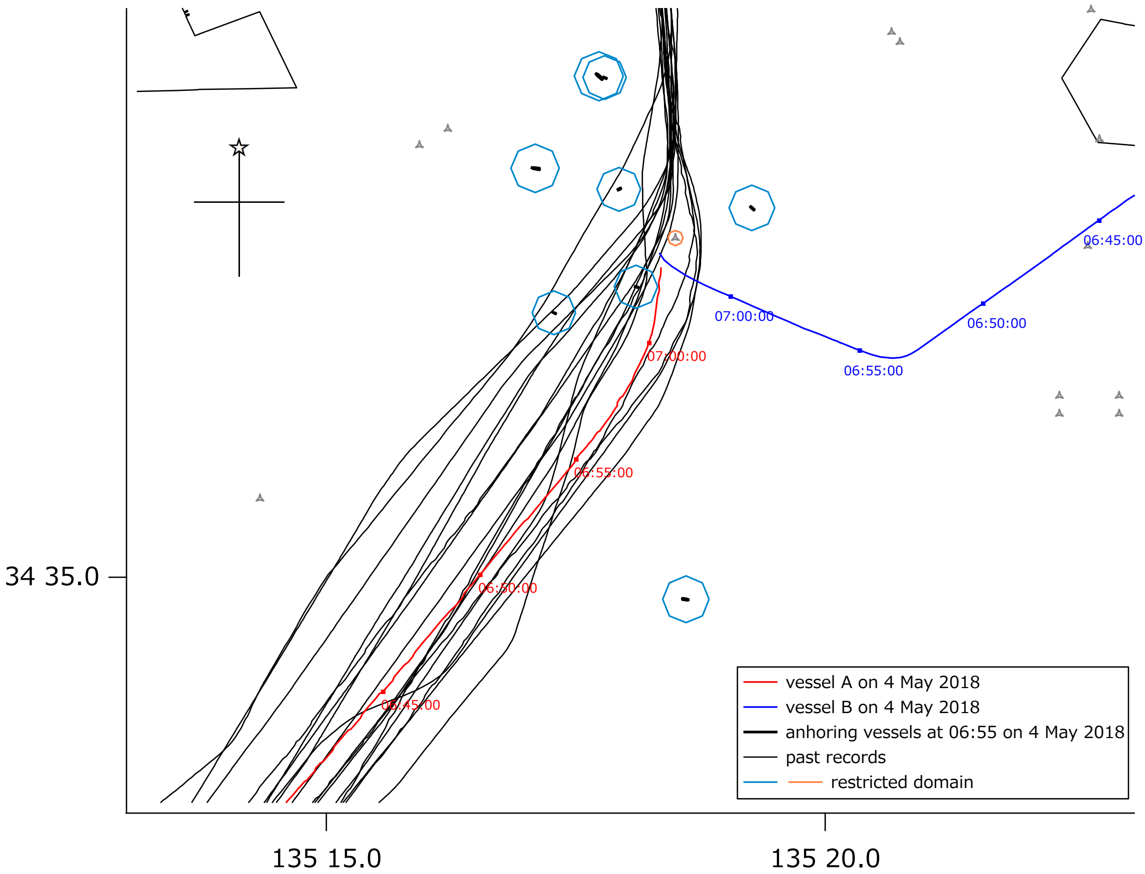


Fig. 3-2　Each vessel's navigation track and positional relationship of anchored vessels at around 06:55

3.3　Speed when Entering Port

Thirteen hypothetical gates were established as shown in Fig. 3-3 and Table 3-2 between 34°35'00"N and the area near the collision points, and the speeds of vessels when passing the gates were analyzed. The results are shown in Table 3-3 and Fig. 3-4. The red line of Fig. 3-4 indicates Vessel A's speed at the time of the accident and the thick blue line indicates the average speed.

It is probable that the speed at which Vessel A was navigating at the time of the accident was a standard speed compared to the speeds of vessels when entering port in the past, albeit slightly faster than the average. The diagonal line section between No. 11 and No. 13 is when Vessel A is passing gates after the collision points.

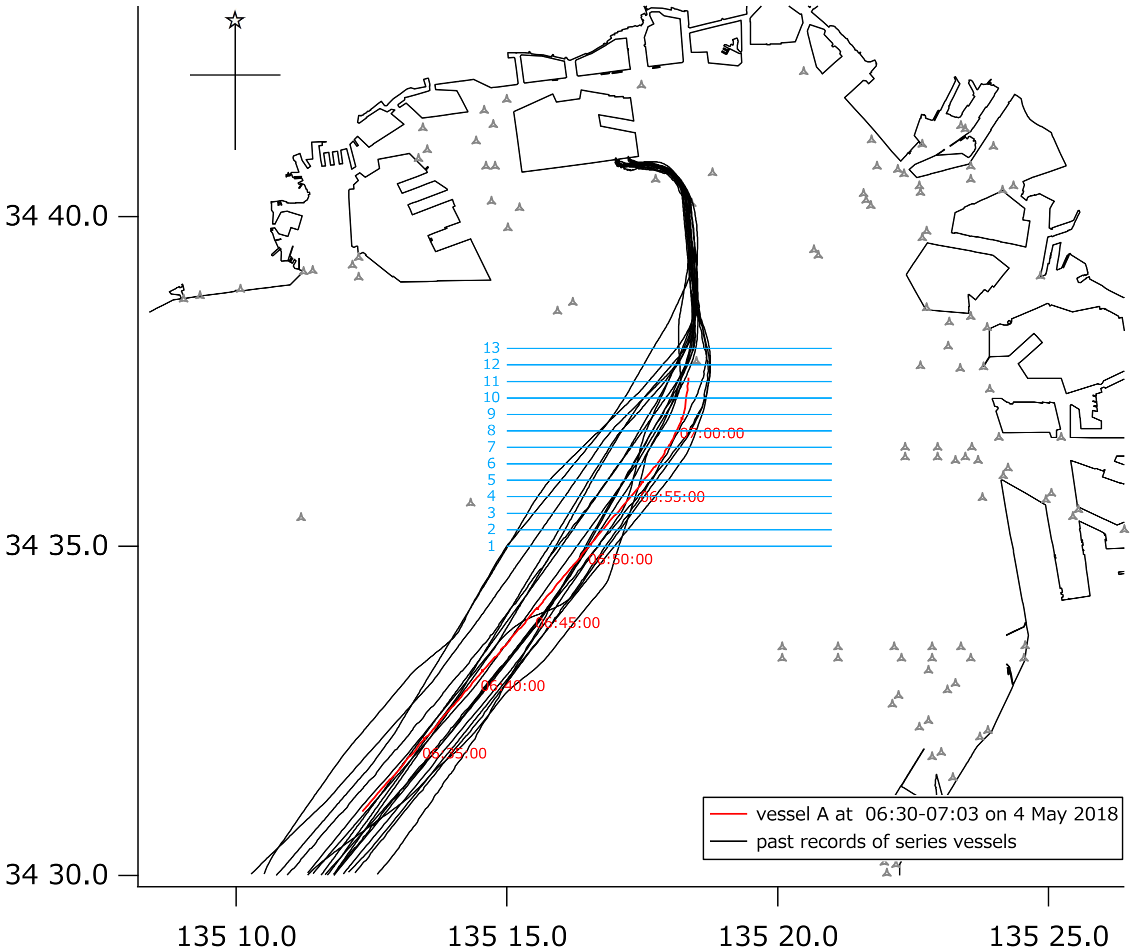


Fig. 3-3 Gate positions

Table 3-2 Gate settings

Gate No.	Start point		End point	
	Lat	Lon	Lat	Lon
1	135 15.0 E	34 35.00 N	135 21.0 E	34 35.00 N
2	135 15.1 E	34 35.25 N	135 21.0 E	34 35.25 N
3	135 15.2 E	34 35.50 N	135 21.0 E	34 35.50 N
4	135 15.3 E	34 35.75 N	135 21.0 E	34 35.75 N
5	135 15.4 E	34 36.00 N	135 21.0 E	34 36.00 N
6	135 15.5 E	34 36.25 N	135 21.0 E	34 36.25 N
7	135 15.6 E	34 36.50 N	135 21.0 E	34 36.50 N
8	135 15.7 E	34 36.75 N	135 21.0 E	34 36.75 N
9	135 15.8 E	34 37.00 N	135 21.0 E	34 37.00 N
10	135 15.9 E	34 37.25 N	135 21.0 E	34 37.25 N
11	135 15.10 E	34 37.50 N	135 21.0 E	34 37.50 N
12	135 15.11 E	34 37.75 N	135 21.0 E	34 37.75 N
13	135 15.12 E	34 38.00 N	135 21.0 E	34 38.00 N

Table 3-3　Comparison of the speeds of past entry records and at the time of the accident

Gate No.	Speed at the time of the accident [kt]	Past entry records	
		Average [kt]	Standard deviation [kt]
1	15.0	13.5	2.1
2	14.9	13.1	2.1
3	14.8	13.0	2.1
4	14.8	12.7	2.1
5	14.6	12.5	2.0
6	13.9	12.4	1.9
7	13.6	12.3	1.8
8	13.2	12.1	1.6
9	12.7	11.9	1.5
10	12.3	11.7	1.5
11	11.7	11.3	1.5
12	9.1	10.8	1.5
13	8.0	10.3	1.6

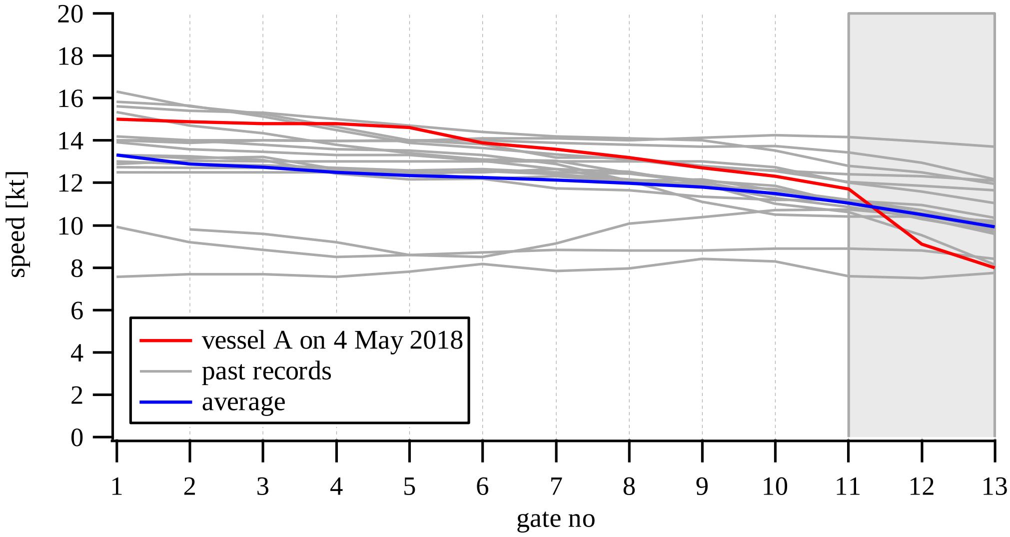


Fig. 3-4　Speed when passing gates

4　Summary

The results of situation analysis on the elements concerning situational awareness and navigational status are shown below.

Situation analysis based on time-related changes in quantitative status

It is probable that, between 06:54 and 07:01, the rate of change in compass bearing never exceeded approximately 4 degrees/minute, making this period a time when changes in compass bearing could not be recognized. For DCPA, given that, from 06:54, DCPA was approximately 0.3NM even at around 06:55, when it was at its largest, and was gradually decreasing, it is probable that recognizing danger was possible.

For BCR, given that Vessel B was passing ahead of Vessel A and Vessel A's BCR was 0.57NM (approximately 0.44NM from the bow's end) even after 06:55, when it was at its largest, and then gradually grew smaller from 06:55, when Vessel A began making her turn, it is probable that recognizing danger was possible. On the other hand, given that, although Vessel A was passing Vessel B's stern side and Vessel B's BCR value was gradually growing smaller, BCR was approximately -0.43NM (approximately 0.42NM from the stern's end) after 06:55, it is somewhat likely that Vessel B did not yet recognize danger at this time.

Situation analysis based on indices of collision risk level

OZT first occurred within 20 degrees dead ahead for Vessel A at around 06:57:50 and for Vessel B at around 06:56:10, and the vessels were falling into a dangerous situation whereby the distance between them would close within five minutes of those times. However, looking at the locations where OZT appeared, while OZT appeared on the path Vessel A intended to take from the time she first encountered it, OZT appeared to the port side and away from the path Vessel B intended to take, with the exception of the time just prior to the collision. From this, it can be said that Vessel B was navigating by avoiding OZT, although ultimately OZT appeared dead ahead of her, while Vessel B was proceeding in the direction in which OZT had existed from a time prior to the accident.

Looking at the indicators of collision risk level, all indicators were showing a tendency to rise from 06:55, and thus it is probable that recognizing danger was possible by both vessels at any time point. From the evaluation based on BC, it is probable that both Vessel A and Vessel B were in circumstances whereby their freedom of maneuvering was limited by anchored vessels and vessels navigating around Vessel A, and that, in the relationship of just these two vessels (Vessel A and Vessel B), ship maneuvering would have been comparatively less difficult if Vessel A had used both course change and speed reduction as her means of giving way and Vessel B had used only course change as her means of giving way. Additionally, when the light buoy is considered, it can be said that the light buoy has an influence on ship maneuvering because the BC value is increasing.

Situation analysis based on the impact of vessel length

When evaluating CPA, and particularly DCPA, the calculation results differ significantly between cases where the hulls' collision points were used as datum points and those when antennas or similar points were used for this purpose. CPA was evaluated to be small at a maximum of around 200 m just prior to the accident when the collision points were used as datum points. Additionally, DCPA observed on Vessel B was close to the numerical value when the antenna position was used as the datum point, and was evaluated to be a maximum of around 210 m in excess of the actual leeway when the length of Vessel A and of Vessel B were considered.

Situation analysis based on navigational status

It was confirmed that there are differences with past records in the navigational track when entering port. It can be said that many vessels navigated on the starboard side of Kobe Rokko Island East Waterway's center floating lighted buoy when navigating the route that Vessel A took beginning at 06:55 at the time of the accident. The speed at which Vessel A was navigating at the time of the accident was a standard speed compared to the speeds of vessels when entering port in the past, albeit slightly faster than the average.

5 CREAM Analysis

5.1 The CREAM Analysis Method

CREAM (Cognitive Reliability and Error Analysis Method) is a method of HRA (Human Reliability Analysis) that focuses on cognitive aspects of human beings. In the classic HRA method, the cognitive processes of workers are not taken into account, and analysis is directed instead at skill-based and rule-based actions. As such, errors by workers who cause accidents are identified as the cause of the accidents. By contrast, a characteristic of CREAM, as the 2nd generation method of HRA, is that it takes an accident as merely the ultimate result, and examines various background factors lying behind it [11)].

First, this method focuses on unsafe actions and others observed in the process of accident occurrence, and makes these the starting point of analysis as actions requiring attention. To initiate a search for background factors, these actions requiring attention are matched with types of deviation, otherwise known as "error modes." The following eight are defined as general error modes.

- Duration (too long or too short)
- Sequence (reverse order, repetition, failure, interruption)
- Wrong object (wrong action, wrong object)
- Force (too weak, too strong)
- Direction (wrong direction)
- Speed (too fast, too slow)
- Distance (too far, too short)
- Timing (too soon, too late, omitted)

Besides these, three elements are seen as causative factors lying behind error modes, namely "Individuals (general functions, specific functions)", "Organizations (organization, communication, training, ambient conditions, working environment)", and "Technology (equipment, procedures, interfaces)." These are evaluated under the concept of Common Performance Conditions (CPC). The following ten types of CPC have been defined.

- Adequacy of organization
- Work environment

- Adequacy of man-machine interface (MMI) and operational assistance
- Availability of procedures/plans
- Number of simultaneous goals
- Available time
- Time of day (circadian rhythm)
- Adequacy of training and experience
- Quality of crew cooperation
- Communication and information sharing

Conclusions about the cause of the accident subject to analysis are reached by combining the result of CPC evaluation with background factor analysis based on error modes.

Next, the steps undertaken in CREAM analysis are as shown below.

1) Describe in detail the events that actually occurred.
2) Specify CPC.
3) Describe temporal relationships between major events.
4) Identify all actions that require attention.
5) Specify error modes for each action.
6) Find a cause-and-effect link related to each error mode.
7) Describe the whole and find the cause.

5.2 Accident Progression

The temporal relationships regarding the occurrence of the accident will now be described.

5.2.1 Outline

Fig. 5-1 shows the movements of the vessels based on AIS data at around the time when the accident occurred. The figure also shows steering and engine operations, awareness of other vessels, and the time and vessels' positions when a risk of a collision was sensed.

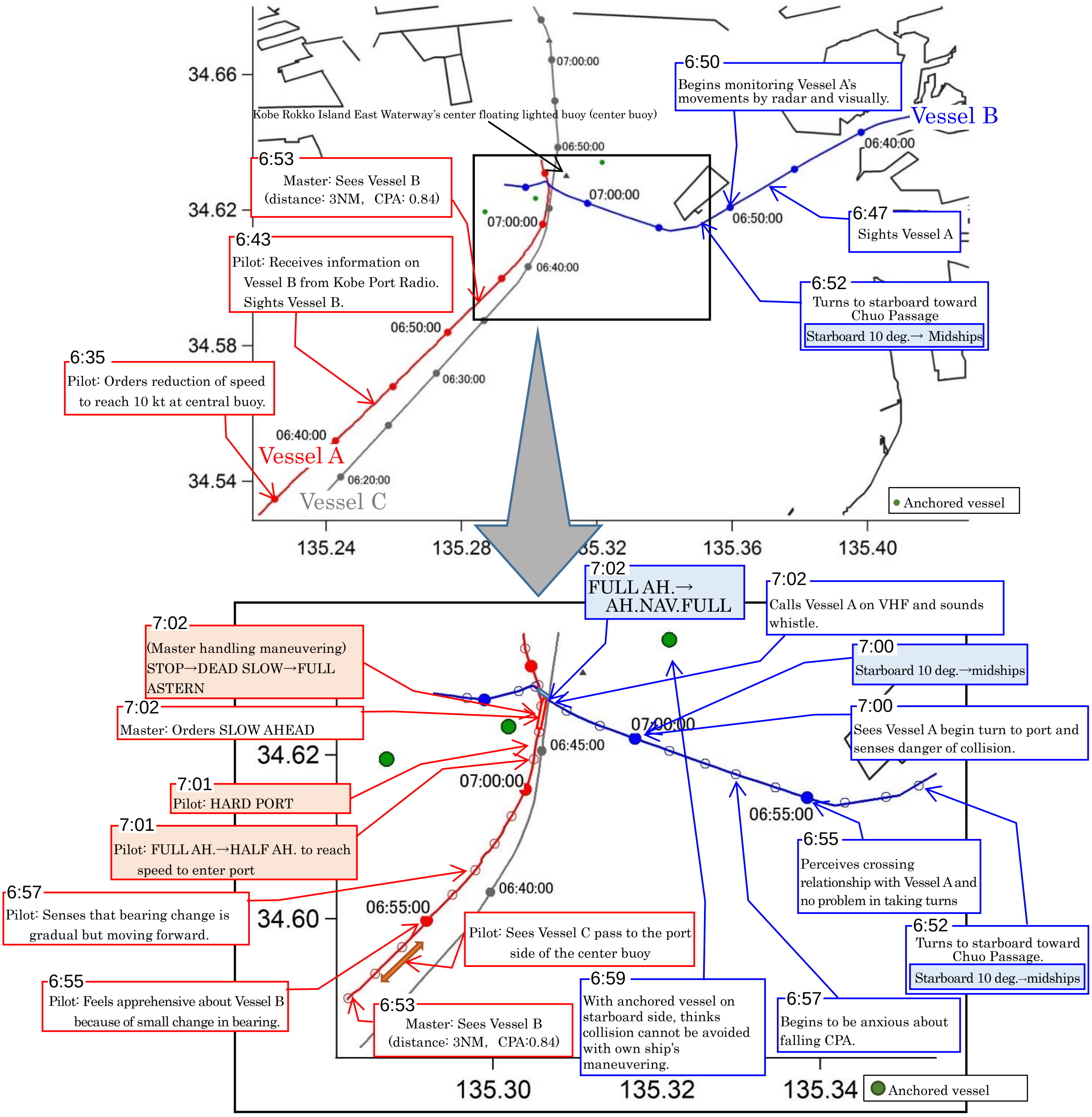
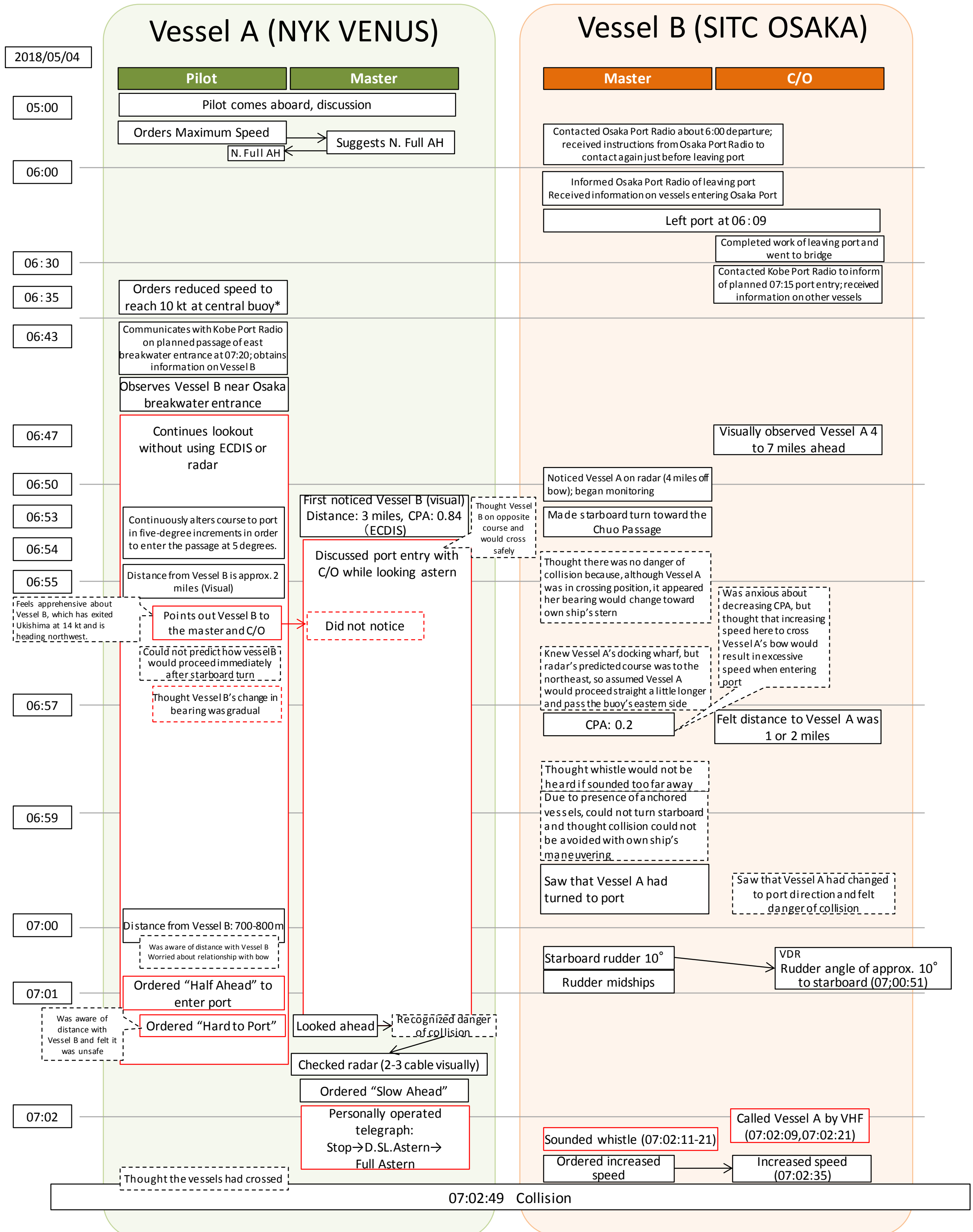


Fig. 5-1 Movements of vessels at the time of the accident

5.2.2 Temporal

Progression

Table 5-2 shows the progression of the accident compiled on the basis of statements and VDR. The boxes made by solid lines indicate situations confirmed from statements and VDR, and boxes made by broken lines indicate the awareness of ship handlers and others based on statements.



*Center buoy: Kobe Rokko Island East Waterway's center floating lighted buoy

Fig. 5-2 Accident progression

5.3 CPC Evaluation

The ten Common Performance Conditions (CPC) will now be evaluated on the effect for actions of ship handlers and others and the reasons for the evaluation explained.

5.3.1 Result of CPC Evaluation of Vessel A

Summarized evaluations of the Pilot, Master, and Chief Officer, who were on the bridge at the time of the accident, are shown in Table 5-1.

Table 5-1 Result of CPC evaluation of Vessel A

<table>
<tr><th></th><th>Operating environment with positive effect</th><th colspan="2">Operating environment with no effect</th><th colspan="2">Operating environment with adverse effect</th><th>Reason for CPC Evaluation</th></tr>
<tr><td>Adequacy of safety management system</td><td>Very efficient</td><td colspan="2">Efficient</td><td>✔ Inefficient</td><td>Deficient</td><td>The master and C/O were conversing prior to entering port and not keeping lookout.</td></tr>
<tr><td>Navigation and watch environment</td><td>Advantageous</td><td colspan="2">✔ Compatible</td><td colspan="2">Incompatible</td><td>The inside of the bridge was tidy, and there was nothing that would cause noise or restrict visibility. The vessel is a 100,000-ton class container ship and therefore the bow is not visible from the bridge.</td></tr>
<tr><td>Adequacy of MMI</td><td>Supportive</td><td colspan="2">✔Adequate</td><td>Tolerable</td><td>Inappropriate</td><td>Equipment was substantial.</td></tr>
<tr><td>Availability of procedures/plans</td><td>Appropriate</td><td colspan="2">Acceptable</td><td>✔ Inappropriate</td><td>Deficient</td><td>There was no radio communication with Vessel B.
The pilot kept visual watch only after communicating with Kobe Port Radio.
The pilot did not provide information on Vessel B to crew members.</td></tr>
<tr><td>Number of simultaneous goals</td><td></td><td>Fewer than capacity</td><td>Current capacity</td><td colspan="2">✔ More than capacity</td><td>The master and C/O were discussing the port entry and not keeping watch.</td></tr>
<tr><td>Available time</td><td>✔Adequate</td><td colspan="2">Temporarily inadequate</td><td colspan="2">Continuously inadequate</td><td>The vessel was navigating according to plan.</td></tr>
<tr><td>Time of day</td><td></td><td colspan="2">✔ Day-time (adjusted)</td><td colspan="2">Night-time (unadjusted)</td><td>Around 7:00 a.m.</td></tr>
<tr><td>Resources of ship handlers</td><td>Very good</td><td colspan="2">Good</td><td colspan="2">✔ Not good</td><td>The pilot had plentiful experience.
The master had experienced entering Kobe Port eight times as master and four times as C/O.
Radar and other equipment were not used, and understanding of CPA was insufficient.</td></tr>
</table>

Quality of crew cooperation	Very efficient	Efficient	✔Inefficient	Deficient	There was cooperation, as, for example, the master suggested changes to the pilot's orders. However, the pilot later thought that the master was keeping watch, and the master and C/O were conversing prior to port entry and not keeping watch.
Communication	Very efficient	Efficient	✔ Inefficient	Deficient	The pilot was not aware of the lookout status of the master and C/O. There was no communication by radio, whistle, etc., with Vessel B. The master, C/O, and others did not receive information on Vessel B from the pilot.

5.3.2 Result of CPC Evaluation of Vessel B

Summarized evaluations of the Master, Chief Officer and Quartermaster, who were on the bridge at the time of the accident, are shown in Table 5-2.

Table 5-2 Result of CPC evaluation of Vessel B

	Operating environment with positive effect	Operating environment with no effect	Operating environment with adverse effect		Reason for CPC Evaluation
Adequacy of safety management system	Very efficient	✔Efficient	Inefficient	Deficient	The master, C/O, and quartermaster were aware of their roles and fulfilled their duties.
Navigation and watch environment	Advantageous	✔ Compatible	Incompatible		The inside of the bridge was tidy, and there was nothing that would cause noise or restrict visibility.
Adequacy of MMI	Supportive	✔ Adequate	Tolerable	Inappropriate	Two radars were installed, the master and C/O were using them, and equipment was efficiently laid out. The master and C/O thought that Vessel A would pass the eastern side of the central buoy based on the radar's predicted course.
Availability of procedures/plans	Appropriate	Acceptable	✔ Inappropriate	Deficient	The crew had a port entry manual for Kobe Port and were checking it. A call was made to Vessel A by VHF immediately before the collision.
Number of simultaneous goals		✔Fewer than capacity Current capacity	More than capacity		No workload exceeding capacity was generated.

Available time	✔Adequate	Temporarily inadequate	Continuously inadequate		The vessel was navigating according to plan.
Time of day		✔ Day-time (adjusted)	Night-time (unadjusted)		Around 7:00 a.m.
Resources of ship handlers	Very good	Good	✔ Not good		The master had plentiful experience, having entered Kobe Port more than 100 times. Understanding of CPA was insufficient.
Quality of crew cooperation	Very efficient	✔ Efficient	Inefficient	Deficient	The master and C/O shared information on Vessel A.
Communication	Very efficient	✔ Efficient	Inefficient	Deficient	The master, C/O, and quartermaster all spoke the same language and thus communication among them was easy. There was no communication by radio with Vessel A. There was no information on Vessel A in communications with Kobe Port Radio.

5.4 Analysis of Background Factors

Error modes were identified and background factors analyzed with regard to the Pilot of Vessel A, the Master of Vessel A, and the Master of Vessel B.

5.4.1 Pilot of Vessel A

The following error modes were identified and background factors for each mode were analyzed with regard to the Pilot of Vessel A.

○ Identified error modes

Sequence (failure)

・06:44 After communicating with port radio by VHF, he conducted lookout without returning to the front of the ECDIS or radar.

Timing (omission)

・06:44 After communicating with port radio by VHF, he did not give information on Vessel B to the master.

・06:55 He was not aware of the lookout status of the master and chief officer.

Sequence (failure)

・06:57 He thought Vessel B's change in bearing was gradual but did not communicate with Vessel B.

Wrong object (wrong object)

・07:01 He set the speed to half ahead in order to enter port.

Direction (wrong direction)

・07:01 He ordered hard to port.

5-3(a)(b) show the results of background factor analysis. The pilot thought that the master or others would mention any questions they had concerning ship handling, and that the lack of questions was because they were keeping watch with thinking that was in agreement with his own. Because the pilot did not give the master the information on Vessel B that the pilot received from the port radio, the master judged that Vessel B would take a course away from Vessel A. He was therefore engaged in a discussion on port entry with the chief officer without keeping lookout and was not paying attention to the pilot's ship maneuvering. However, the pilot did not notice this because communication was inadequate. Additionally, after communicating with Kobe Port Radio, the pilot was keeping watch without using the radar or ECDIS and did not notice that Vessel A was approaching Vessel B in a manner that would lead to a collision. Additionally, although he was slightly apprehensive because Vessel B's change in bearing was gradual, he did not communicate with Vessel B by VHF. Subsequently, he visually observed the other vessel's bearing change and saw her moving forward against the background and therefore thought Vessel B would pass the bow of Vessel A. He was not aware of the danger of collision until just prior to the collision, and ordered the speed reduced in preparation for entering port.

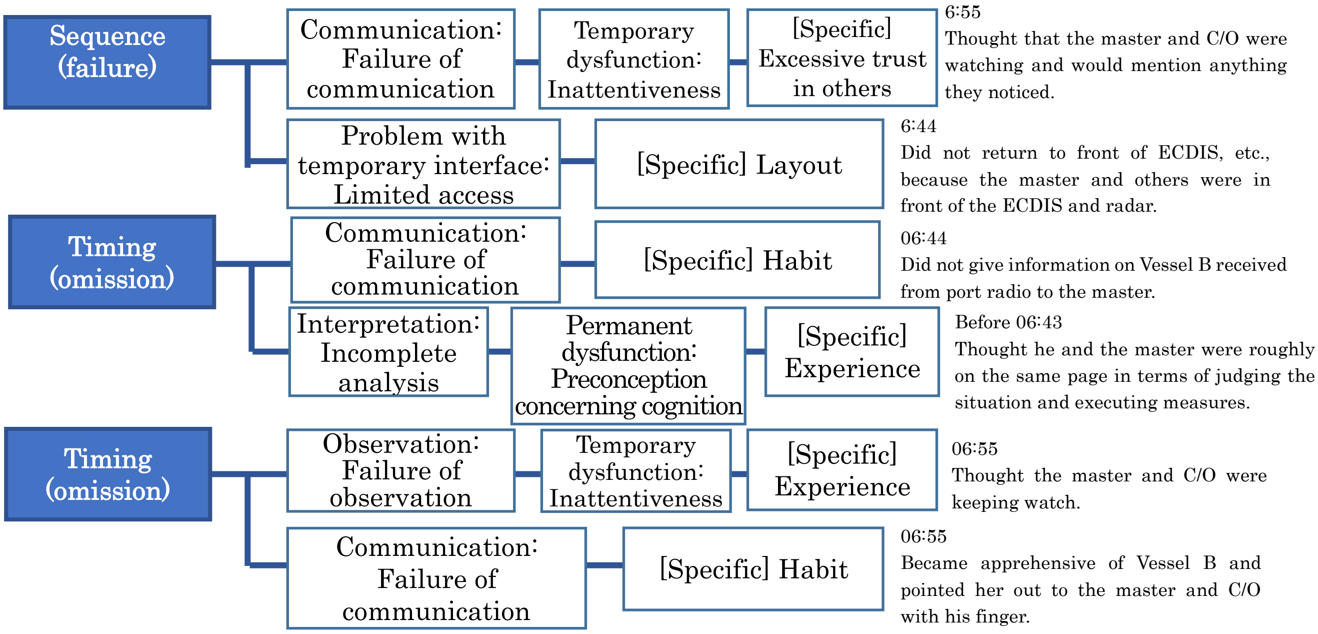


Fig. 5-3(a) Result of background factor analysis on the Pilot of Vessel A

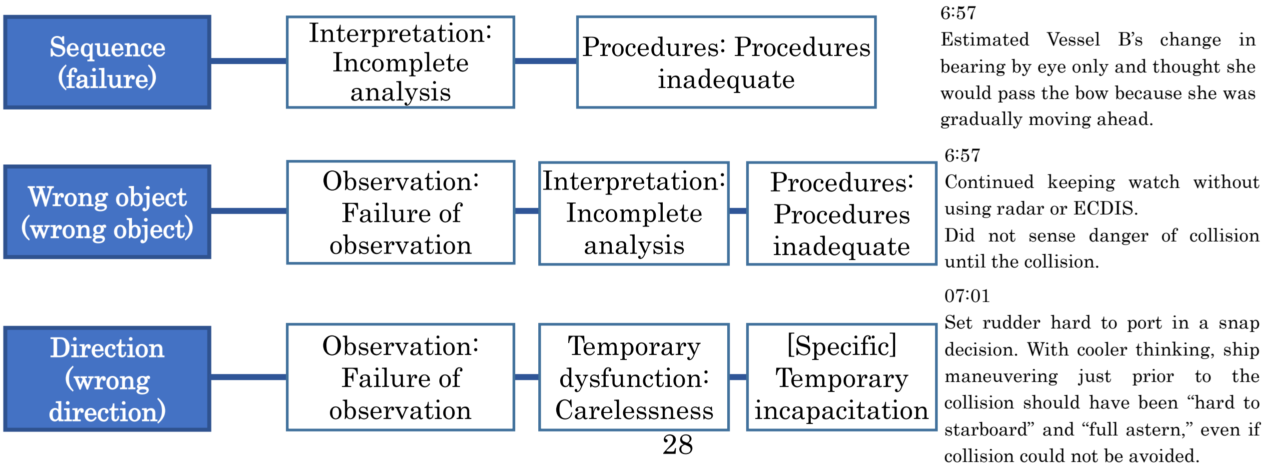


Fig. 5-3(b) **Result of background factor analysis on the Pilot of Vessel A**

5.4.2 Master of Vessel A

The following error modes were identified and background factors for each mode were analyzed with regard to the Master of Vessel A.

○ Identified error modes

<u>Sequence (interruption)</u>

- 06:53 He was discussing port entry with the C/O while facing astern, as he thought Vessel B was on the opposite course and could be crossed safely.

<u>Speed (too fast)</u>

- 07:02 He was personally operating the telegraph and set it to Full Astern; however, he was too slow in setting it to Astern and was not successful in reducing the vessel's speed.

Fig. 5-4 shows the result of background factor analysis. Vessel A's master had to simultaneously keep watch and discuss matters prior to entering port. Vessel B began a starboard turn toward the central passage from around 06:52. However, Vessel A's master had judged that Vessel B was on the opposite course before she changed course and was discussing the port entry with the chief officer while facing astern. Consequently, he did not notice that Vessel A was navigating in a manner that posed the danger of a collision with Vessel B until immediately before the collision.

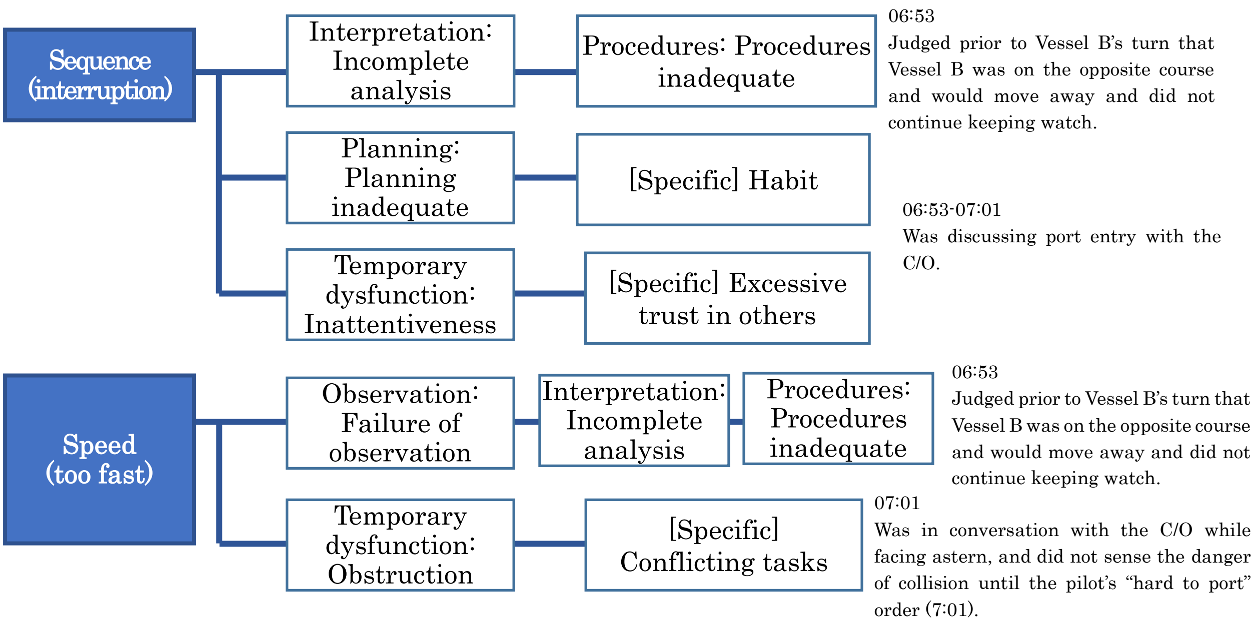


Fig. 5-4 **Result of background factor analysis on the Master of Vessel A**

5.4.3 Master of Vessel B

The following error modes were identified and background factors for each mode were analyzed with regard to the Master of Vessel B.

○ Identified error modes

Timing (too late)

・07:02 He communicated by VHF immediately prior to the collision.

Timing (too late)

・07:02 He sounded the whistle immediately prior to the collision.

Timing (too late)

・07:02 He ordered increased speed.

Fig. 5-5 shows the result of background factor analysis. Based on the radar's predicted course, Vessel B's master thought that Vessel A would pass the eastern side of the central buoy. However, at around 07:00, it appeared that Vessel A was beginning a port turn and he questioned Vessel A's maneuvering. He sensed the danger of collision, as he could not make a large starboard turn due to the presence of anchored vessels; however, he did not confirm Vessel A's intentions by VHF or sound an alarm using the whistle or other means until immediately prior to the collision. Additionally, he needed to communicate with Vessel A at 06:57, when he became anxious about the falling CPA. Since whistle signals are used for vessels that are within visible range, he was required to alert Vessel A using the whistle if he could not understand Vessel A's maneuvering intentions after observing her.

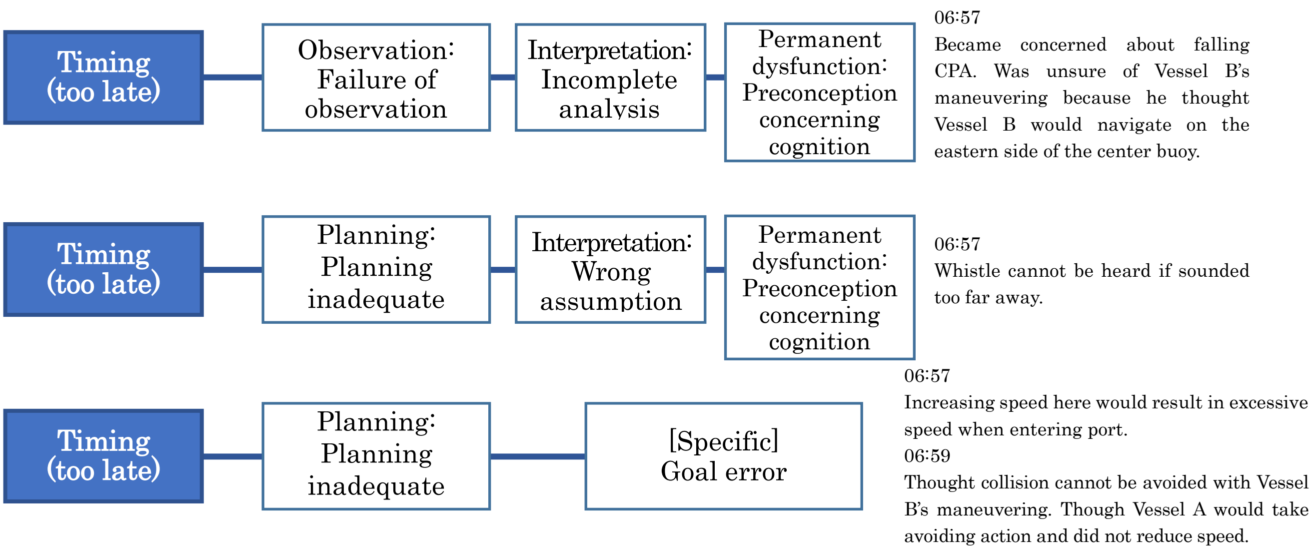


Fig. 5-5 Result of background factor analysis on the Master of Vessel B

5.5 Discussion

Here, the connection between causative factors obtained from the CPC evaluation results concerning Vessel A and Vessel B and the analysis of background factors will be discussed.

5.5.1 Vessel A

According to the CPC evaluation results, the following six topics were identified as elements of an operating environment with adverse impact.

- Validity of safety management system (non-execution of lookout [master])
- Availability of procedures/plans (non-use of radar and other equipment [pilot], absence of radio communication with Vessel B)
- Number of simultaneous goals (lookout and discussion of port entry [master])
- Resources of ship handlers (non-use of radar and other equipment [pilot], understanding of CPA (pilot)
- Quality of crew cooperation (ascertainment of master's work situation [pilot])
- Communication (absence of communication between the master and pilot and with Vessel B)

The direct causes targeted in the analysis of background factors and the background factors that caused them were as follows. Here, the analysis of the Pilot and the Master will be shown collectively. As direct causes, the following five were identified.

1) The master was in discussion with the chief officer and was not keeping lookout.
2) The pilot was not aware of the lookout status of the bridge.
3) The pilot did not provide information on Vessel B to the master.
4) No communication was made with Vessel B.
5) The timing of the change to astern was too late, and speed was not sufficiently reduced.

The background factors were as follows. Parentheses show the relevant direct cause.

- Prior to Vessel B's course change, it was judged that Vessel B was on the opposite course and thus no danger of collision existed. (⇒ 1), 3), 5))
- A discussion prior to entry into port was necessary. (⇒ 1), 5))
- The master and pilot placed too much trust in each other. (⇒ 1), 2), 3))
- Lookout was kept without using the radar or ECDIS. (⇒ 4), 5))

These four points cited as background factors were consistent with the topics deemed to have an adverse impact in the CPC evaluation. The master had to simultaneously discuss port entry and keep lookout. Because he had not been provided information on Vessel B from the pilot, he judged that there was no danger of collision prior to Vessel B's course change and engaged in discussion on port entry with the chief officer. Additionally, the pilot kept lookout without using the radar or ECDIS. Furthermore, the pilot and master did not notice the danger of collision until immediately prior to the collision, partly as a result of inadequate communication that arose because the pilot and master placed too much trust in each other.

5.5.2 Vessel B

According to the results of CPC evaluation, the following two topics were identified as elements of an operating environment with adverse impact.

- Availability of procedures/plans (timing of VHF communications)
- Resources of ship handlers (understanding of CPA and whistle, judgment of Vessel A's course)

The direct causes targeted in the analysis of background factors and the background factors that caused them were as follows. As direct causes, the following three were identified.

1) The vessel communicated by VHF immediately prior to the collision.
2) The vessel sounded the whistle immediately prior to the collision.
3) The master ordered increased speed immediately prior to the collision.

The background factors were as follows. Parentheses show the relevant direct cause.

- The master was unsure of Vessel A's maneuvering because he thought Vessel A would navigate on the eastern side of the center buoy. (⇒ 1), 2))
- The master thought sounding the whistle would be ineffective when Vessel A was far away. (⇒ 2))
- Priority was put on not having excessive speed when entering port by taking cooperative action to avoid collision. (⇒ 3))

These three points cited as background factors were consistent with the topics deemed to indicate an operating environment having an adverse impact in the CPC evaluation. Around three minutes passed between the master's sensing the danger of collision and his making a VHF communication and using the whistle. He needed to alert Vessel A faster than this. Moreover, it was mentioned in the statements that Vessel B was navigating by maintaining a CPA of around 0.1NM near the central passage. However, attention must be given to the danger of collision when CPA with a large vessel such as Vessel A is 0.1NM.

5.6 Summary

The CREAM method was used to conduct CPC evaluation, identify error modes and analyze background factors. Several causative factors were identified for both Vessel A and Vessel B.

In the case of Vessel A, it is highly probable that the point that the master had to simultaneously keep lookout and engage in discussion and the point that the danger of collision with Vessel B was not noticed until just prior to the collision due to inadequate communication on the bridge were the main factors. In the case of Vessel B, it is highly probable that the point that the master did not communicate by VHF or other means when he questioned Vessel A's maneuvering and the point that he was slow to alert Vessel A were the main factors.

Reference Bibliography

1) Kiyoshi HARA: (Provisional title) A Study on Collision Avoidance for Ships, 1983.
2) Keisuke TSUJI, Takayuki ITO: A Study on Altering Rate of Azimuth Bearing, Journal of Japan Institute of Navigation, pp. 67-73, 2007.
3) Hayama IMAZU, Junji FUKUTO, Masayoshi NUMANO: Obstacle Zone by Target and its Expression, Journal of Japan Institute of Navigation, No. 107, pp.191-197, 2002.
4) Akira NAGASAWA: Marine Traffic Simulation Including Collision Avoidance, Navigation, pp. 28-34, 1984.
5) Hiroaki KOBAYASHI: Analysis of Collision Avoiding Action of Ship: From Viewpoint of Man-Machine-System Analysis, Journal of Japan Institute of Navigation, No.56, pp. 101-109, 1976.
6) Kiyoshi HARA: Proposal of Maneuvering Standard to Avoid Collision in Congested Sea Area, Journal of Japan Institute of Navigation, No. 86, pp. 33-40, 1991.
7) Kazuhiko HASEGAWA, Akihiko KOZUKI: Automatic Collision Avoidance System for Ships Using Fuzzy Control, Journal of the Kansai Society of Naval Architects, Japan, No. 205, pp. 1-10, 1987.
8) K. HASEGAWA, et al.,: An Intelligent Ship Handling Simulator With Automatic Collision Avoidance Function Of Target Ships , Proc. of International Navigation Simulator Lecturers' Conference (INSLC 17), Warnemünde, Germany, 2012.
9) Akira NAGASAWA, Kiyoshi HARA, Kinzo INOUE, Kuniji KOSE: The Subjective Difficulties of the Situation of Collision Avoidance-II: Toward the Rating by Simulation, Journal of Japan Institute of Navigation, No. 88, pp. 137-144, 1993.
10) Kinzo INOUE, Shigeru USAMI, Tokiko SHIBATA: Modelling of Mariners' Senses on Minimum Passing Distance between Ships in Harbour, Journal of Japan Institute of Navigation, No. 90, pp. 297-306, 1994.
11) Takahiro TAKEMOTO, Nobuo MITOMO, Kenjiro HIKITA, Kenji YOSHIMURA: A Study on Human Factors Analysis for Possible Factors of Marine Accident: Modifying CPC for Marine Accident Analysis, Journal of Japan Institute of Navigation, No. 127, pp. 95-101, 2012.

Appended Material: Methods for Calculating Evaluation Indicators

The methods for calculating the evaluation indicators are as follows when the speeds of own ship O and other ship T are represented as V_O and V_T, respectively, and the lengths as L_O and L_T, respectively.

i. OZT (Obstacle Zone by Target) [1)]

OZT can be obtained using the following geometrical procedure as shown in Appended Material Fig. 1.

1) Draw a circle having own ship O at the center and radius r representing minimum safe navigating distance.
2) Draw tangent lines AA' and BB' of this circle from target ship T.
3) Let the position of $-V_T$ having the starting point of target ship T's position be point C.
4) Draw a circle with point C at the center and whose radius becomes the own ship's speed vector V_O.
5) Let the intersections of this circle C and the tangent lines obtained in step 2) be E and F.

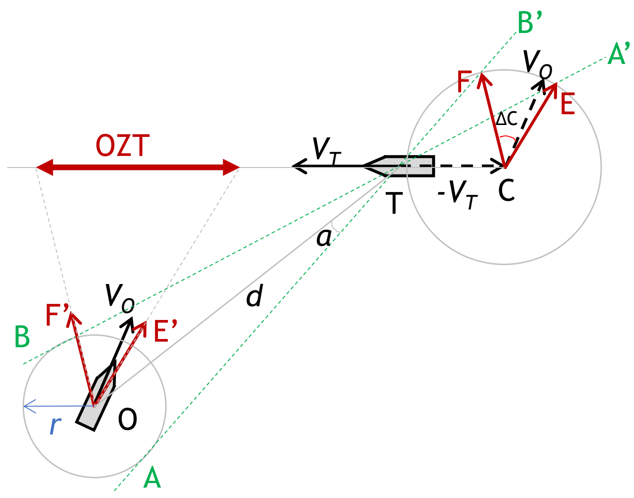
At this time, CE and CF become the own ship's course such that DCPA = r, and ΔC, which is between these two courses, becomes the collision course range. When the other ship's bearing is made AZ, the other ship's course is made CT, and ∠OTA is made α, collision course Co (the courses of the segments CE and CF) are expressed with equation (Appended Material 1) using the speed triangle formula.

$$C_O = A_Z \pm \alpha - sin^{-1}\left\{\frac{V_T}{V_O} sin(A_Z \pm \alpha - C_T)\right\} \qquad \text{Equation (Appended Material 1)}$$

Here, the condition under which the collision course exists is equation (Appended Material 2).

$$\left|\frac{V_T}{V_O} sin(A_Z \pm \alpha - C_T)\right| \leq 1 \qquad \text{Equation (Appended Material 2)}$$

6) Let the portion of parallel translation be OE' and OF' so that the starting points of CE and CF become own ship O. Extend this segment along the extension of the target ship's course. The range that is cut off by OE' and OF' becomes OZT.



Appendix Material 1　Method for geometrical calculation of OZT

ii.　CJ (Collision Judgment)

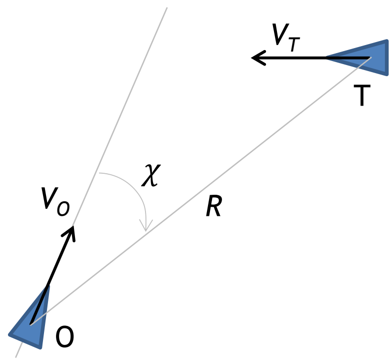
When, as shown in Appended Material Fig. 2, the distance between the two vessels is R, the relative bearing is χ, and the rate of time-related change of each are を$\dot{R}$ and $\dot{\chi}$, respectively, CJ is expressed using equation (Appended Material 3).

$$\mathrm{CJ} = -\frac{\dot{R}}{R} - aR|\dot{\chi}| + b\chi$$ Equation (Appended Material 3)

Where,

$a \approx 3.75 \times 10^{-5}$

While it is established that $b \approx (1.3 \sim 1.7) \times 10^{-4}$, it is assumed that $b \approx 1.3 \times 10^{-4}$.



Appended Material Fig. 2
Definition of Notations

iii.　SJ (Subject Judgment) [2) 3)]

Let relative distance be R and rate of change of relative bearing be Ω. When using groups expressing three stages ("big," "medium," and "small"), and when relative distance belongs to the i group (i = 1,2,3) and rate of change of relative bearing belongs to the j group (j = 1,2,3), the subjective level of collision risk SJ_{ij} is expressed using expression (Appended Material 4). Additionally, SJ_{ij} is expressed in accordance with nine rules by combining relative distance and change of rate of relative bearing in each of the three-stage groups (Appended Material Table 1).

$$SJ_{ij} = a_{ij} + b_{ij} \times R' + c_{ij} \times \Omega$$ Equation (Appended Material 4)

Where,

Dimensionless relative distance: $R' = R/L_O$ (L_O: own ship's length)

Dimensionless rate of change of relative bearing: $\Omega = \dot{\theta} \times L_O/V_r$ (V_r: relative speed)

Factor: a_{ij}, b_{ij}, c_{ij}

When relative distance and rate of change of relative bearing are provided, the degree to which they belong to each group (μ) is obtained from the defined membership function (Appended Material Fig. 3). Next, the conformity of each expressed rule (weighting factor $\omega_{i,j}$) is obtained with the following equation. Finally, as is shown in equation (Appended Material 6), subjective level of collision risk is obtained from the weighting factor $\omega_{i,j}$ and the weighted average of the nine rules SJ_{ij}. Additionally, the membership function and rule table are defined for the give-way vessel and stand-on vessel, respectively, giving consideration to the meeting relationship.

$$\omega_{i,j} = \mu_i(\Omega) \times \mu_j(\mathrm{R}')$$ Equation (Appended Material 5)

$$SJ = \frac{\sum_{i,j=1}^{3} \omega_{i,j} \times SJ_{i,j}}{\sum_{i,j=1}^{3} \omega_{i,j}}$$ Equation (Appended Material 6)

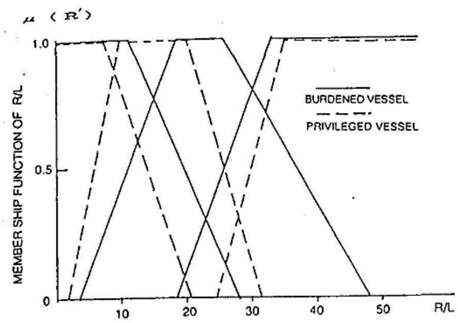


Fig.2.10 Membership function of relative distance to a target.

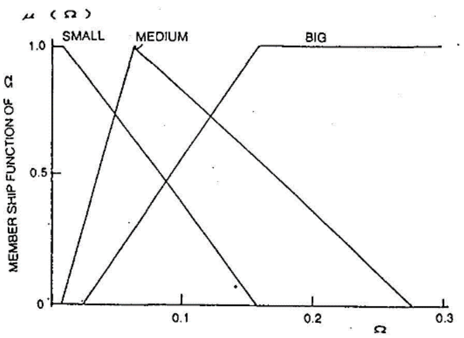


Fig.2.11 Membership function of relative change of bearing to a target.

Appended Material Fig 3 Membership factor (source: A. Hammer (1990))

Appended Material Table 1

Rule table when own ship is give-way vessel (source: Hammer (1990))

Table 3.1 Rule table of judgment on the risk of collision for a burdened vessel.

B	$SJ_{31}=8.46*\Omega+1.00$	$SJ_{23}=2.0$	$SJ_{33}=3.0$
M	$SJ_{21}=8.46*\Omega+1.00$	$SJ_{22}=37.98*\Omega+0.19*R'-5.72$	$SJ_{23}=2.0$
S	$SJ_{11}=-3.0$	$SJ_{12}=18.57*\Omega+0.06*R'-2.45$	$SJ_{13}=40.96*\Omega+0.12*R'-2.70$
Ω / R'	Small	Medium	Big

iv. CR (Collision Risk)

Let T refer to maneuverability index, which indicates the trackability of the own ship. *TCPA* and *DCPA* of the two vessels are corrected by equation (Appended Material 7) with consideration for the own ship's maneuverability and length.

$TCPA_c = TCPA - C_cT$ Equation (Appended Material 7)

$DCPA' = DCPA/max(L_O, L_T)$ Equation (Appended Material 8)

With the corrected TCPAC and DCPA' as elements, the level of collision risk CR is obtained based on fuzzy inference using the membership function and control law defined in Appended Material Fig. 4.

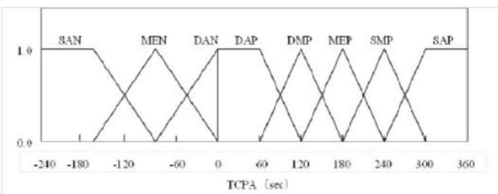


Fig. 1 Membership function for $TCPA_C$ or $TCPA_V$

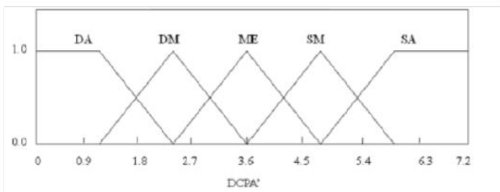


Fig. 2 Membership function for $DCPA'$

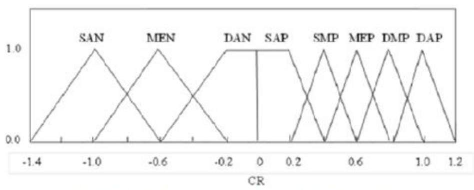


Fig. 3 Membership function for *CR*

Table 1 Fuzzy reasoning table for *CR*

		TCPA							
		SAN	MEN	DAN	DAP	DMP	MEP	SMP	SAP
DCPA'	DA	SAN	MEN	DAN	DAP	DMP	MEP	SMP	SAP
	DM	SAN	SAN	MEN	DMP	MEP	SMP	SAP	SAP
	ME	SAN	SAN	SAN	MEP	SMP	SAP	SAP	SAP
	SM	SAN	SAN	SAN	SMP	SAP	SAP	SAP	SAP
	SA	SAN	SAN	SAN	SAP	SAP	SAP	SAP	SAP

Appended Material Fig. 4 Membership and control law (source: K. Hasegawa (2012))

For example, when (TCPAC, DCPA') = (90, 2.7),

DM for DCPA' = 0.7 and ME for DCPA' = 0.25 based on membership function for DCPA.

Similarly, for TCPAc,

DAP for $TCPA_C$ = 0.5 and DMP for $TCPA_C$ = 0.5

Based on the control law of Appended Material Fig. 4,

DMP for CR = 0.5

MEP for CR = 0.5

SMP for CR = 0.25

CR is expressed using the following equation based on area center of gravity.

$$CR = \frac{\int yf(y)dy}{\int f(y)dy}$$ Equation (Appended Material 9)

v. BC (Blocking Coefficient)

Let the course that the own ship can take as a means of giving way be HDG_i, with five-degree increments up to 60 degrees port and starboard of the present course (total of 120 degrees). Let the speed that can be taken as a means of giving way be *SPDj*, with ten-percent increments from 0% to 120% of current speed. The level of collision risk $R(X_{i,j})$ for each course and speed is evaluated with equation (Appended Material 10) from the degree of encroachment into the avoidance area into which entry by other ships present around the vessel is undesired (Appended Material Fig. 5) (level of collision risk [Appended Material Fig. 6]) and time availability W_{tcpa}.

$$R(X_{i,j}) = Max(R_x, R_y) \times (1 - Tcpa/Wtcpa)$$ Equation (Appended Material 10)

$$a = \{3 - 2exp(-0.18R_v)\} \times L_g$$

$$b = 75V_O \geq 1.5L_g$$

$$c = 0.2a$$

$$d = 0.2b \qquad (0.02L_g \leq V_T)$$

$$= (10V_T \cdot b)/L_g \qquad (0.02L_g > V_T)$$

Where,

R_x: Level of danger from level of encroachment into avoidance area from abeam.

R_y: Level of danger from level of encroachment into avoidance area from the bow or stern.

W_{tcpa}: Time availability factor (assumed to be 15 minutes)

Because, for each course HDG_i and speed *SPDj*, a smaller change from the existing state results in less burden on the ship handlers and is thus desired, preference Pb is defined by equation (Appended Material 11) so as to be largest as weighting factors at the time of current course and speed.

Preference for course change:	$Pb(X_{i,0}) = exp(-a_C \cdot \Delta C_O)$	
Preference for speed change:	$Pb(X_{0,j}) = exp(-a_V \cdot \Delta V)$	Equation (Appended Material 11)
Preference for course change and speed change:	$Pb(X_{i,j}) = Pb(X_{i,0}) \times Pb(X_{0,j})$	

Where,

ΔC_O: Course change angle (deg)

ΔV: Rate of speed increase/decrease (%)

Turning to starboard: $a_C = 0.019$

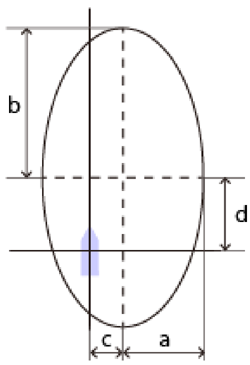
Turning to port: $a_C = 0.026$

Decreasing speed: $a_V = 0.0114$

Increasing speed: $a_V = 0.0456$

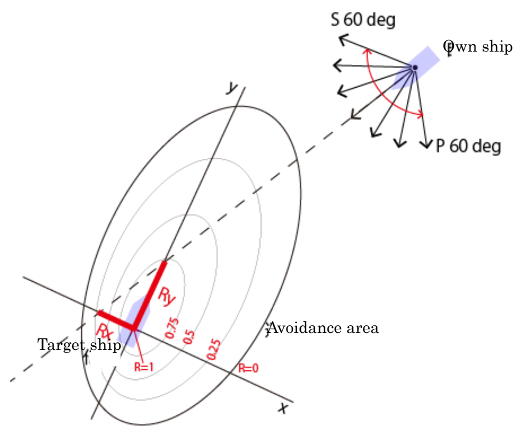
Finally, as seen in equation (Appended Material 12), BC is calculated from level of collision risk vis-à-vis each course HDG_i and speed $SPDj$ and the weighted average of preference P_b. It should be noted that when p vessel(s) are present around the own ship, the value of the kth vessel with the highest level of collision risk $R(X_{i,j})$ defined with equation (Appended Material 10) is used. Additionally, although the range of course change angle and rate of speed increase/decrease are established in Nagasawa (1993) as described above, in this investigation, they were evaluated using BC value that was set within the scope noted in the main body of this report (page 9) with consideration for navigational status, etc.

$$BC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} Max_{k=1,p}\{R(X_{i,j}) \times P_b(X_{i,j})\}}{\sum_{i=1}^{m}\sum_{j=1}^{n} P_b(X_{i,j})}$$ Equation (Appended Material 12)



Appended Material Fig. 5

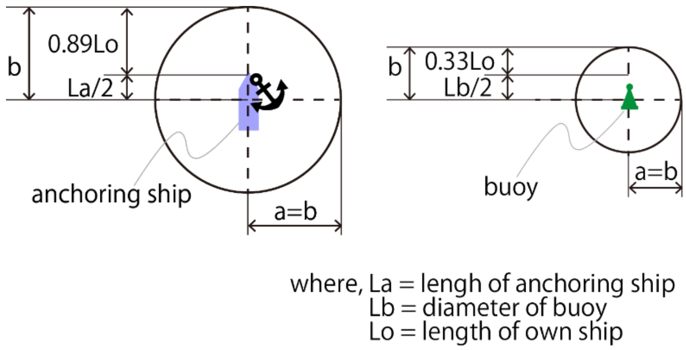
Definition of avoidance area around hull



Appended Material 6

Concept of level of collision risk

Furthermore, anchored vessels and light buoys are not considered in Nagasawa (1993). However, given the idea that the level of collision risk can be calculated from the degree of encroachment into an avoidance area, which is an exclusive area, it was believed that, if the size of the exclusive area around anchored vessels and light buoys can be defined, it is possible to calculate BC to include those obstacles using the same method. Therefore, evaluation was conducted with BC values that assume circular exclusive zones like those shown in Appendix Material Fig. 7, using the separation distances from obstacles presented in Inoue (1994).



Appended Material Fig. 7　Exclusive area around anchored vessel and light buoy

Appended References

1) Hayama IMAZU: Computation of OZT by using Collision Course, Navigation, No. 188, pp. 78-81, 2014.

2) A. HAMMER, K. HARA: Knowledge Acquisition For Collision Avoidance Manoeuvre By Ship Handling Simulator, Proc. of MARSIM & ICSM'90, Tokyo, 1990.

3) Japan Highway Public Corporation: (Provisional title) Investigation on Ships Navigation Safety Accompanying Construction of Tokyo Bay Highway (Supplementary Volume), 1991.