[MSI Report 2021-001]

Marine Safety Investigation Report on M/V *MILANO BRIDGE*

- Contact with gantry cranes -

Date of Accident: 6 April 2020

Date of Publication: 12 Jan 2021

Korea Maritime Safety Tribunal
Marine Safety Investigation Team

Note

This marine safety investigation report aims to identify the cause of the marine accident and prevent similar marine accidents or incidents in the future under Article 18.3 of the Act on the Investigation of and Inquiry into Marine Accidents. It is therefore advised that this report not be used for assigning blame or determining liability.

This report quotes the names of the relevant acts and agencies that were in place at the time of writing.

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1 Overview

1. Overview

1.1 *Milano Bridge* is a containership with a gross tonnage of 150,706 tons, a length of 365.94 meters, and a breadth of 51.20 meters, launched from the Imabari Shipbuilding Co., Ltd. shipyard in Japan on 18 July 2017 and operated by Ocean Network Express (ONE).

1.2 The vessel had been in drydock and completed repairs and inspections at PaxOcean Zhoushan yard, China. Then, with the master and his 22 crew members onboard, the vessel set sail for Busan New Port on 29 March 2020.

1.3 On 6 April 2020, the vessel arrived at the entrance of Gadeok Channel, the fairway into Busan New Port, and a pilot came on board at around 13:54. The pilot reported the port entry of *Milano Bridge* to the Vessel Traffic Service (VTS) center at Busan New Port while entering Gadeok Waterway at around 14:00 on the same day.

1.4 When entering the port, *Milano Bridge* had significantly low drafts, 4.5 meters forward and 6.9 meters aft, as she carried no cargo and loaded only 4,233 tons of ballast water. Therefore, the vessel was underway with 3.2 meters (32% of the diameter) of her propeller above the waterline.

1.5 Such propeller exposure hampered vessel maneuverability, with lower propulsion and turning ability. The master and the pilot, however, made the vessel proceed into the port as usual without having detailed discussions on how to safely maneuver the vessel despite her propeller exposure. And, the pilot replaced both tugs forward and aft with ones that had horsepower higher than was originally planned.

1.6 This vessel was scheduled to dock at Berth No.8 on Pier No.2 at the North Container Terminal in Busan New Port. However, other vessels were already berthed at both the front and back sides of the pier reserved for *Milano Bridge* as there were three containerships berthed alongside Pier No.3, west of Pier No.2, and one more vessel, M/V *Seaspan Ganges*, was at Berth No.7 on Pier No.2 as well.

1.7 Two tugs were made fast to *Milano Bridge* on her bow and stern. On the same day, the vessel passed the west breakwater of Busan New Port on a course of 000° at a speed of 9.5 knots at around 14:34. And, while passing To ("Earth") Islet, she began a 90° turn to starboard to berth at the pier at around 14:36.

1.8 When piloting previous vessels, the pilot reduced the speed to 6.5-8.0 knots as the vessels passed the waters in the vicinity of To Islet, where they started a large course change for berthing after passing the west breakwater, the gateway to Busan New Port.

1.9 While passing the islet and turning to starboard, the vessel turned slower than the pilot intended. Thus, the pilot ordered hard a starboard and continued to order the aft tug on the starboard quarter to push the vessel toward the port side at around 14:39 on the same day.

1.10 Still, the pilot judged that the low turning rate of *Milano Bridge* could bring a danger of collision with other vessel berthed at Pier No.3 and at around 14:41 ordered to put the main engine to full ahead to be farther away from the pier by increasing the turning rate. However, the vessel failed to increase it as intended, and drew closer to Pier No.3.

1.11 The vessel completed a 90-degree change of heading at around 14:43, and the pilot noticed danger of collision between *Milano Bridge* and the vessel berthed at the pier. So he gave up on berthing and attempted to turn the vessel to starboard. While doing so, he barely avoided collision with three vessels berthed at Pier No.3, but contacted three gantry cranes standing by for cargo operations at the berth for *Milano Bridge*. And, she also collided slightly with M/V *Seaspan Ganges*, a containership berthed at the next pier (Berth No.7).

1.12 In conclusion, *Milano Bridge* deviated from her planned routes and ended up in an accident when she made turning at excessive speed for berthing, as the master and the pilot of the vessel failed to fully consider navigation risks, such as maneuverability, which was hampered by an exceptionally low draft, and also insufficient communication and no proper maneuvering/pilotage plan agreed in advance between the master and the pilot for berthing.

1.13 At the time of the accident in Busan New Port, the wind was 5-9 m/sec south, wave height was less than 0.5 m, and tidal current was flowing southward at about 0.1 knots.

section

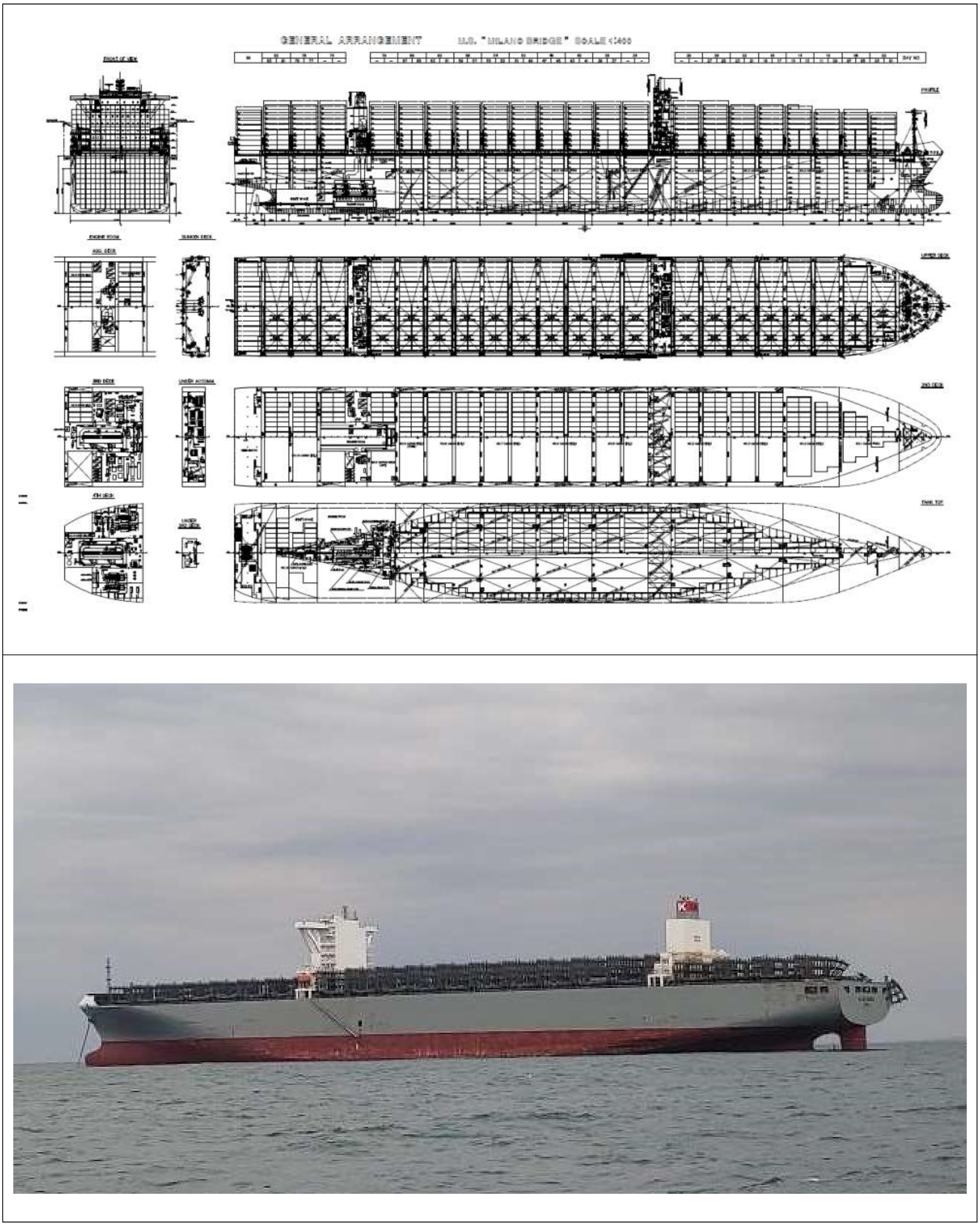
2 Factual Information

2. Factual Information

2.1 Vessel information

2.1.1 Specifications of *Milano Bridge*

Name	*Milano Bridge*
Flag State (Port of Registry)	Panama (Panama)
IMO No.	9757187
Call Sign	3FAY4
Ship Type	Full containership
Owner	Mi-das/Doun Kisen Co., Ltd.
Charterer	Ocean Network Express (ONE)
Manager	Fleet Ship Management Ltd.
Builder	Imabari Shipbuilding Co., Ltd.
Date of Keel Lay	30 July 2015
Date of Launch	18 July 2017
Date of Build	18 January 2018
Classification Society	Nippon Kaiji Kyokai (ClassNK)
Length (m)	365.94
Beam (m)	51.20
Depth (m)	29.90
Height (m)	71.33
Gross Tonnage (t)	150,706
Cargo Capacity (TEU)	13,900
Deadweight Tonnage (t)	146,931
Main Engine	MITSUI MAN B7W 11S90ME-C10.5
Max. Output	48,900kW×76.0rpm
Propeller	1(a solid screw-type 6-bladed propeller)
Rudder	1
Thruster	2,040 kW × 2 units (electric motor)
Design Speed (Kn)	21.85



<Figure 1> Layout (part) & view of *Milano Bridge*

2.2 Ownership and operation of *Milano Bridge*

2.2.1 *Milano Bridge* was launched at Imabari Shipbuilding Co., Ltd., in Hiroshima, Japan on 18 July 2017. As presented in the table of vessel information, she is a 13,900-TEU full containership with a gross tonnage of 150,706 tons, a length of 365.94 meters, a breadth of 51.20 meters, a depth of 29.90 meters, and a height of 71.33 meters.

2.2.2 After launching on 18 July 2017, the vessel was delivered to her registered owner, Mi-das Line S.A/Doun Kisen Co., Ltd., and registered in Panama on 18 January 2018.

2.2.3 On 18 January 2018, the shipowner of *Milano Bridge* signed a time charter contract with Kawasaki Kisen Kaisha Ltd. (K-line). On the very same day, a charter contract was also concluded with the Singapore-based Ocean Network Express (ONE), which had operated *Milano Bridge* for about two years and three months until the day of the accident.

2.2.4 *Milano Bridge* had completed 10 voyages since going into service from the Port of Busan on 23 January 2018. The vessel was deployed mainly on shipping routes between Asia and North America (East Coast 4, EC4) or between Europe and the Mediterranean (Mediterranean 1, MD1).

2.2.5 At the time of the accident, *Milano Bridge* was in service on MD1, which connects Asia and Europe, through the Chinese coast, Singapore, Suez Canal, and Mediterranean ports in Italy, Morocco, and Spain.

2.2.6 Before the accident, *Milano Bridge* had visited Busan New Port a total of four times[1)] and each time she had berthed at Pier No.2, the same one involved in this accident.

1) Dates of Arrival at Busan New Port: 22 Jan. 2018; 2 Apr. 2018; 6 Dec. 2019; and 10 Mar. 2020

2.3 Vessel surveys and safety management

2.3.1 *Milano Bridge* passed the first periodic survey, conducted by ClassNK on 18 January 2018, receiving a ship survey certificate[2)] valid until 17 January 2023. She underwent and passed annual surveys from the same classification society on 4 March 2019 and 21 February 2020.

2.3.2 In compliance with the International Safety Management (ISM) Code, outlined in Chapter IX of the International Convention for the Safety of Life at Sea (SOLAS)[3)], the company responsible for safety management of *Milano Bridge* is Fleet Ship Management Pte Ltd., based in Singapore. Apart from vessel safety management, the company was also taking care of crew management.

2.3.3 Fleet Ship Management Pte Ltd. passed an audit for certification renewal from ClassNK on 6 September 2018 and received a safety control compliance certificate (DOC) valid until 14 September 2024. *Milano Bridge* also passed an audit for initial certification on 30 January 2018, holding a vessel safety control certificate that expires on 29 June 2023.

2.3.4 Before the accident, the vessel underwent port state control (PSC) inspections in Singapore and in Shenzhen, China on 7 February and 18 December 2018, respectively. No deficiencies were discovered. However, two deficiencies were found during the PSC inspection that was carried out in Shanghai on 24 September 2019.

2.3.5 One of these deficiencies was related to General Service Pump 1, and was fixed before departure. The other deficiency was related to a Deck Logbook[4)], for managing and supervision of navigation, which did not require any structural or facility improvements.

2.3.6 Also, the Tokyo and Paris MOU, the regional Port State Control Agreements, evaluated this vessel as low-risk (the white list), based on her condition, deficiency record, and type.

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2) Certificates of Cargo Ship Safety Construction (SC), Cargo Ship Safety Equipment (SE), Cargo Ship Safety Radio (SR), International Load Line (ILL), and International Oil Pollution Prevention (IOPP).

3) SOLAS (International Convention for the Safety Of Life At Sea)

4) *Milano Bridge* deviated from the shipping routes set in the passage plan, and it was reported to the master but not recorded in the logbook.

2.4 Vessel structure

2.4.1 *Milano Bridge*, with a bridge 40 meters ahead of midship[5], consists of the compass deck for the antenna of the navigational devices; the navigation bridge deck, located right below; and the accommodation spaces just below that, from Deck G to Deck A, where the cabins and mess room for the ship's crew are located.

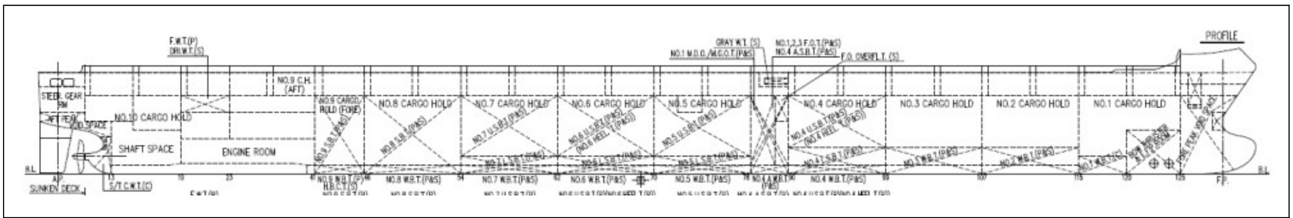
2.4.2 The ship's office, the fire station where firefighting equipment is stored, and the deck workshop are located in the upper deck, the first floor under the accommodation space.

2.4.3 And, the main engine, generators, and auxiliary propulsion system are in the engine room area (Decks 2-4) under the stern area of the upper deck, where the funnels are located.

2.4.4 *Milano Bridge* is a full containership, where containers can be stacked 7-9 tiers on the upper deck and as many as 11 tiers below.

2.4.5 The vessel has ten cargo holds in total, each accommodating two 40-feet containers placed lengthwise.

2.4.6 A fore peak void space and a bow thruster room are at the bow, where a ballast tank is located under each cargo hold, from 1 to 9. The engine room, shaft space, steering gear room, and an aft peak tank located in stern.



<Figure 2> The side of *Milano Bridge* (Capacity Table)

5) 142.2 meters from bow to bridge; 223.7 meters from bridge to stern

2.5 Navigation and radio communications equipment

2.5.1 The steering gear, automatic identification system (AIS), and global positioning system (GPS) are installed at the center of the ship's bridge, with the main engine telegraph on the left, and two radars and two electronic chart display & information systems (ECDIS) on the right.

2.5.2 The pair of radars on the right side of the bridge are S-band on the left and X-Band on the right. The two ECDIS include main and back-up units, which share the display screen.

2.5.3 At the front of the bridge are a gyro repeater, rudder (angle) indicator, clinometer, main engine rpm indicator, rate of turn indicator (ROTI) as well as the wind direction and speed gauges.

2.5.4 The rudder indicator, main engine rpm indicator, speed log (Do-log), and whistle are installed on the wing bridge as a remote system, for checking maneuvering conditions from the wing bridge when berthing.

2.5.5 *Milano Bridge*'s communication system includes VHF radio telephone, MF/HF radios, Navtex receiver, Inmarsat FBB service system, and VDR.[6]

<Figure 3> Navigation equipment of *Milano Bridge*

6) Manufacturer: Japan Radio Co., Ltd. (JRC), Model: JCY-1900

2.6 Crew composition & watchkeeping system

2.6.1 *Milano Bridge* may accommodate up to 30 persons onboard under the ship survey certificate issued by ClassNK and a minimum of 14 persons under the safe manning certificate issued by the government of Panama.

2.6.2 On the day of the accident, 23 crew were on board: 22 Indians, including the master, and one third engineer (3/E) from Bangladesh. They spoke mainly in English or the Indian languages when communicating on the vessel.

2.6.3 The ship's master, chief officer (C/O), second officer (2/O), and third officer (3/O) were on board for the deck department, while engine department personnel included the chief engineer (C/E), second engineer (2/E), third engineer (3/E), fourth engineer (4/E), and the electrical officer.

2.6.4 The officers' watch system was as follows: the C/O kept watch from 04:00 to 08:00 and from 16:00 to 20:00; the 2/O from 00:00 to 04:00 and from 12:00 to 16:00; and the 3/O from 08:00 to 12:00 and from 20:00 to 24:00. Each officer was assigned to watchkeeping duties with one helmsman.

2.6.5 When entering Busan New Port, all the crew members were standing by for berthing. The master, C/O, and helmsman were on the bridge[7)], and the 2/O and 3/O were stationed at the bow and stern, respectively.

2.6.6 The *Milano Bridge* master started his boarding career in 1997 and became master in February 2012. He has worked exclusively on containerships for about four years and three months after promotion to master, excluding vacation time. Also, he visited Busan New Port four or five times as master.

2.6.7 The C/O started his boarding career in 2009 and obtained his current position in January 2017. Since then, he has worked only on containerships, and his career as a C/O is about a

7) The arrangements of navigational officers were changeable depending on the conditions of each vessel and company, and the navigational officer, assigned to the bridge, is generally in charge of controlling the main engine telegraph.

year and eight months, excluding vacations. He has visited Busan New Port twice while aboard *Milano Bridge*.

2.6.8 The helmsman who was on watch during the accident started working onboard in February 2014 and has worked as a helmsman aboard containerships, bulk carriers, and reefers.

2.6.9 The master, C/O, and helmsman joined *Milano Bridge* in September 2019, November 2019, and February 2020, respectively. It was the first time for all of them to work on this vessel, but they all had experience on containerships of 100,000 tons or over.

<Table 1> Crew composition of *Milano Bridge* by rank

Dept.	Rank		No. of Crew (Nationality)	Min. No. of Manning
Deck	Officer	Master	1 (IND)	1
		Chief Officer	1 (IND)	1
		2nd Officer	1 (IND)	1
		3rd Officer	1 (IND)	
		Cadet Officer	1 (IND)	
	Rating	Bosun	1 (IND)	
		Able Seaman	4 (IND)	3
		Ordinary Seaman	2 (IND)	2
		Deck Boy	1 (IND)	
		Chief Steward	1 (IND)	
		Messman	1 (IND)	
Engine	Engineer	Chief Engineer	1 (IND)	1
		2nd Engineer	1 (IND)	1
		3rd Engineer	1 (BGD)	1
		Add 4th Engineer	1 (IND)	
		TR. ELC. Officer	1 (IND)	
	Rating	Oiler	3 (IND)	3
		Total	23	14

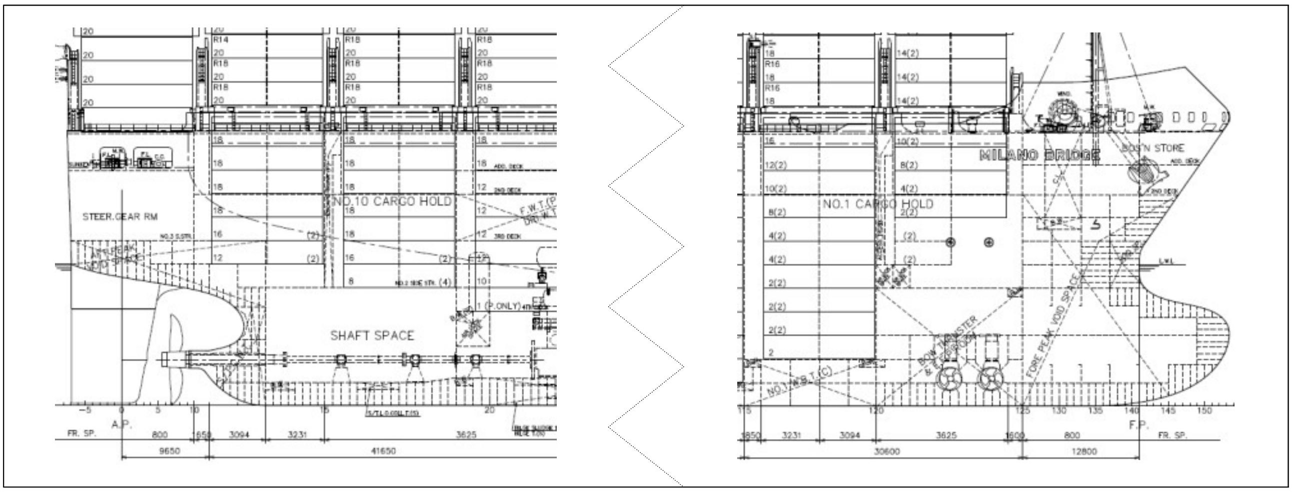
2.7 Main engine, propulsion system, and thruster

2.7.1 The main engine on *Milano Bridge* is a "Mitsui MAN B&W 11S90ME-C10.5," with a maximum continuous rating of 48,900kW×76.0rpm and normal continuous rating of 44,010kW×73.4rpm.

2.7.2 The vessel's six-bladed propeller is made of a nickel, aluminum and bronze alloy.[8] It is about 9.9m in diameter and has a mean effective pitch of about 10.32m, meaning the vessel proceeds forward about 10.32m per revolution. The propeller immersion draft is 10.1m.

2.7.3 *Milano Bridge* has a twisted leading edge full-spade rudder with a total rudder area of 85㎡. The rudder is trapezoid-shaped when seen from the side; the upper base is longer than the lower base, and the area ratio[9] of the rudder to the ship's underwater area is 1.74%.

2.7.4 Two thrusters are installed 25-30 meters from the bow, and each thruster is driven by a 2,040kW electric motor.

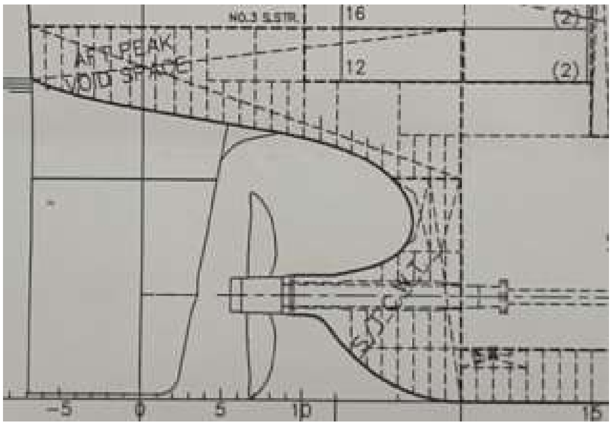


<Figure 4> Stern propeller & bow thruster

8) 6 solid blades (N-Al-Br) x 1, nominal dia-9900mm; pitch-10319.7mm (mean effective pitch)

9) The area ratio of the rudder is the calculated value of "A / (Lpp×ds)".
A: rudder area; Lpp: ship length between perpendiculars; and ds: average load line draught

2.7.5 When the accident occurred, her aft draft was 6.9m, and about 3.2m, or 32% of her propeller diameter was above the waterline. The upper part of the blades and even the upper part of the rudder were out of the water.



Propeller diameter, 9.9 meters

Propeller exposure[10]

<Figure 5> Propeller exposure at the time of the accident

2.8 Maneuverability of *Milano Bridge* during sea trials

2.8.1 Imabari Shipbuilding Co., Ltd., who built *Milano Bridge*, tested her maneuverability by conducting sea trials for the propeller and steering gear after her launch.

2.8.2 The maximum angle of the rudder is 35° on each side. According to the design, when the steering gear is tested for a hard-over rudder with two power units (pumps), the rudder can be put over within 27.8 seconds[11].

2.8.3 Table 2 illustrates stopping time and distance of *Milano Bridge* when her main engine is set to full astern from slow ahead, half ahead, full ahead, and full sea speed when in full loading and in ballast conditions.

10)This picture of the propeller conditions of *Milano Bridge* was taken right after the accident. The conditions are presumed to be the same as the ones at the time of the accident.

11)Under SOLAS Regulation II-1/29, the main steering gear must be capable of putting the rudder over from 35 degrees on one side to 30 degrees on the other side with the ship in no more than 28 seconds at maximum ahead service speed. It was proven that *Milano Bridge* took 26 seconds to put the rudder over during the steering test.

<Table 2> Stopping distance

TIME AND DISTANCE TO STOP

(NOTE: USING ENGINES FULL ASTERN AND WITH MINIMUM APPLICATION OF RUDDER)

		DESIGN LOADED CONDITION		BALLAST CONDITION	
		TIME	DISTANCE	TIME	DISTANCE
	FULL SEA SPEED	14' 11"	4785 m	8' 25"	3070 m
MANOEUVRING SPEEDS	FULL SPEED	8' 23"	1500 m	4' 22"	820 m
	HALF SPEED	7' 13"	1120 m	3' 49"	625 m
	SLOW SPEED	6' 22"	865 m	3' 16"	470 m

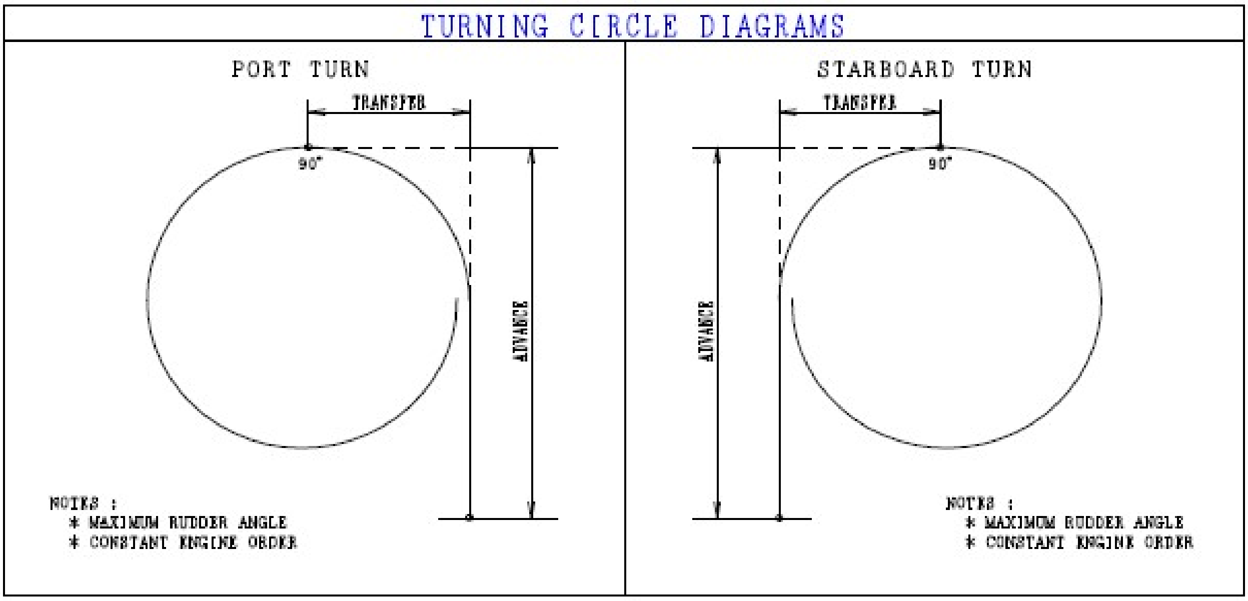
2.8.4 The rpm/speed table is shown in Table 3, when *Milano Bridge* proceed at the speed of dead slow ahead, slow ahead, half ahead, full ahead, and sea speed, in loading and in ballast conditions. The aft draft and forward draft, in loading conditions, are set at 14.02m even keel, and in ballast conditions, the aft draft and forward draft is 10.27m and 4.72m. Meanwhile, the steerageway is about 6.2 knots when stopped the engine.

<Table 3> Main engine rpm and speed

ENGINE ORDER / MIN^{-1} (~~PROPELLER PITCH~~) / SPEED TABLE

	ENGINE ORDER	MIN^{-1} (~~PROPELLER PITCH~~)	SPEED DESIGN LOADED CONDITION	SPEED BALLAST CONDITION
	FULL SEA AHEAD	73.4	21.85	23.7
MANOEUVRING SPEEDS	FULL AHEAD	35	11.6	12.2
	HALF AHEAD	30	10.1	10.6
	SLOW AHEAD	26	8.8	9.3
	DEAD SLOW AHEAD	22	7.5	8.1

2.8.5 Figure 6 shows the advance and transfer of *Milano Bridge* when put the rudder hard to starboard or hard to port while she proceed at the speed of dead slow ahead, slow ahead, half ahead, full ahead, and sea speed, in loading and in ballast conditions.



		DESIGN LOADED CONDITION			BALLAST CONDITION		
		TIME	ADVANCE	TRANSFER	TIME	ADVANCE	TRANSFER
FULL SEA SPEED	PORT	3' 09"	1430 m	785 m	3' 15"	1580 m	920 m
	STARBOARD	3' 10"	1435 m	795 m	3' 17"	1590 m	930 m
FULL SPEED	PORT	5' 07"	1235 m	675 m	5' 26"	1360 m	790 m
	STARBOARD	5' 10"	1245 m	685 m	5' 29"	1370 m	800 m
HALF SPEED	PORT	5' 43"	1195 m	655 m	6' 02"	1315 m	765 m
	STARBOARD	5' 46"	1205 m	665 m	6' 05"	1325 m	775 m

<Figure 6> Turning circle

2.8.6 The effectiveness of the bow thruster at different speeds is presented in Table 4, and when the speed is over 5 knots, the bow thruster shows almost zero effectiveness.

<Table 4> Maneuverability of the thruster

BOW THRUSTER	
VESSEL SPEED	EFFECTIVENESS
0 TO 1 KNOTS	100~73 %
1 TO 2 KNOTS	73~55 %
2 TO 3 KNOTS	55~43 %
3 TO 4 KNOTS	43~35 %
4 TO 5 KNOTS	35~28 %
ABOVE 5 KNOTS	0 %

2.9 Circumstances at Busan New Port

2.9.1 Conditions and Arrival/Departure traffic at Busan New Port

2.9.1.1 Busan New Port was completed in January 2006 to handle container cargo. There are two container terminals: one is the 4,200-meter North Container Terminal, where Piers No.1 (three berths), No.2 (six berths), and No.3 (four berths) of New Port are located; and the other is the 2,550-meter South Container Terminal on the opposite side, where Piers No.4 (four berths) and No.5 (four berths) of New Port are positioned. A multi-purpose pier with two berths for handling automobiles and general cargo is to the east.

2.9.1.2 Another facility, the West Container Terminal, is under construction to the west of Busan New Port. Three berths will be added with the completion of Construction Phase 2-5 by 2022, and two more will be ready after Construction Phase 2-6 is done in 2026.

<Figure 7> Berths at Busan New Port

2.9.1.3 A small land mass named "To Islet," lies between the North Container Terminal (New Port Piers No.1-3) and South Container Terminal (New Port Piers No.4-5). The waterway which *Milano Bridge* passed through between the North Container Terminal and the northern end of To Islet is narrow, about 0.42 miles (778m), which is about 2.1 times the LOA and 15.3 times the greatest breadth of the vessel.

2.9.1.4 The Busan Regional Office of Oceans and Fisheries conducted a To Islet removal project[12] between July 2017 and June 2020 to remove obstruction for arriving and departing vessels. At the time of the accident, the islet had already mostly been removed. Some work remained to be done, and therefore, 12 navigational aids were set around the islet for safety purposes.

Before removing To Islet
(Jul. 2017)

After removing To Islet
(Jun. 2020)

<Figure 8> Before and after removing To Islet

2.9.1.5 A total of 82,024 ships on an international voyage entered Busan Port over the past three years (2017-2019), and 20,718 of them entered Busan New Port. This breaks down to 6,906 ships on an international voyage coming to Busan New Port annually. Another 1,754 domestic vessels use the port per year, bringing the Busan New Port's annual traffic total to 8,660 vessels.

12) To ("Earth") Islet, with an elevation of 31 meters and an area of 22,400㎡, was deserted. In July 2017, the Busan Regional Office of Oceans and Fisheries initiated the islet removal operation with a budget of KRW 31.5 million to enhance navigation safety for super-large vessels, the traffic of which had increased since the opening of Busan New Port. At the time of the accident, the final work to secure the water level was left after about 2.24 million ㎥ of rock and sand had been removed. In May 2020, the construction was completed, and now the water depth of the area is 18 meters.

2.9.1.6 Especially, 3,845 ships on an international voyage that visited Busan Port over the past three years have gross tonnages in excess of 100,000 tons, as described in Table 5. Among those, 3,618 vessels entered Busan New Port, and all were containerships.

<Table 5> No. of vessels on international voyage entering Busan Port

	Less than 50K tons	50K to 100K tons	100K to 150K tons	150K to 200K tons	Over 200K tons	Total
2019	22,177 (2,692)	3,098 (2,626)	953 (862)	353 (348)	69 (69)	26,650 (6,597)
2018	22,841 (2,963)	3,242 (2,823)	910 (840)	348 (344)	36 (36)	27,377 (7,006)
2017	23,568 (3,222)	3,280 (2,774)	760 (709)	405 (399)	11 (11)	28,024 (7,115)
Sum	68,586 (8,877)	9,620 (8,223)	2,623 (2,411)	1,106 (1,091)	116 (116)	82,024 (20,718)

* Numbers in parenthesis mean the number of vessels on international voyages that entered Busan New Port

2.9.2 Rules of Navigation in Busan New Port

2.9.2.1 The Busan Regional Office of Oceans and Fisheries has publicly notified Rules of Navigation in Busan New Port, as fairway, navigational rules, and speed limits can be set within the harbor limits for safe traffic of vessels as prescribed in Paragraph 2 of Article 12 of the Act of the Arrival, Departure, Etc. of Ships.

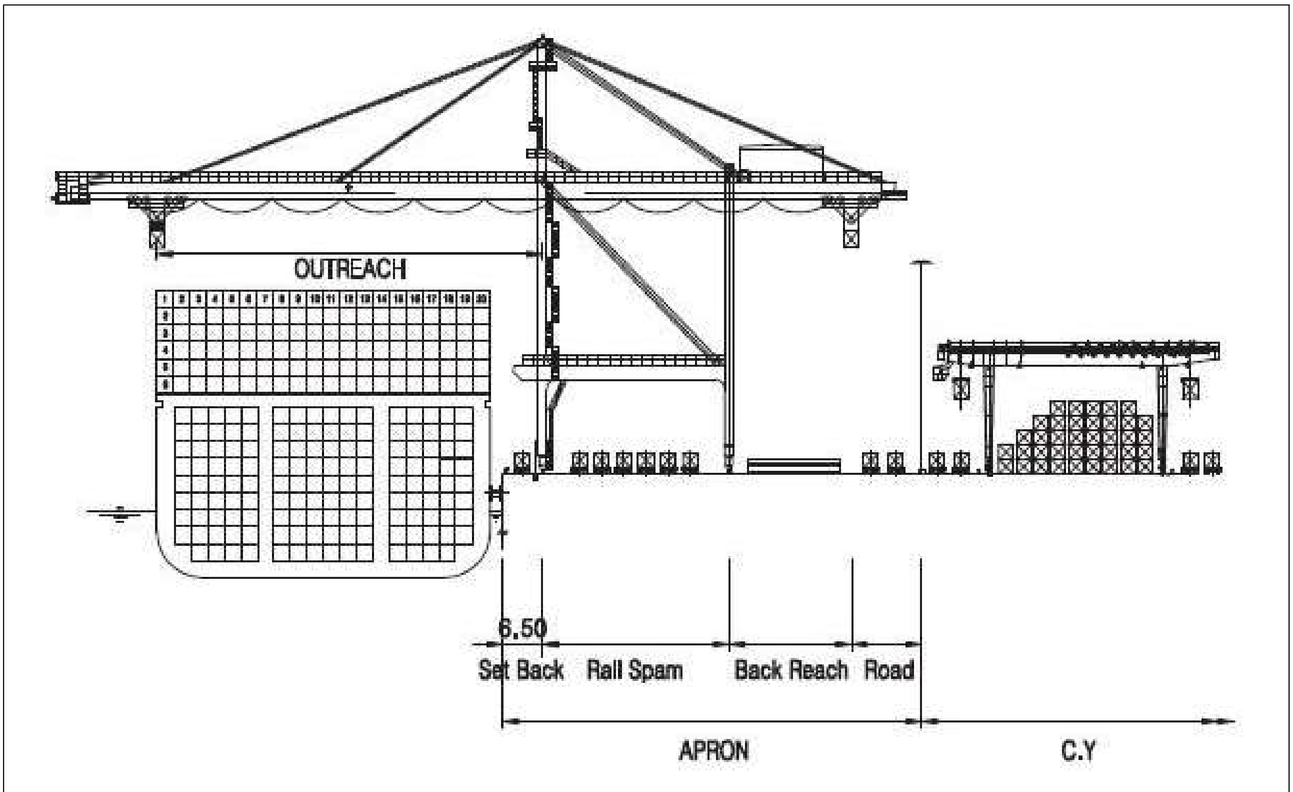
2.9.2.2 Under Article 12 (navigational rules in Busan New Port) of this rule, every ship using Passage No.5 or Gadeok Channel shall follow the instructions given by the VTS of Busan New Port. If a vessel enters the port along the Gadeok Channel of New Port, she shall navigate along the entry lanes, and along the departure lanes when leaving the port.

2.9.2.3 In addition, every vessel shall navigate at a speed not exceeding the speed limits as specified in attached Table 4 under Paragraph 1 of Article 17 (Speed Limits) of this rule. Accordingly, the Port Authority set the maximum navigation speed at 12 knots (speed through the water) in dangerous zone of Gadeok Channel which is a fairway into Busan New Port.

2.9.3 Quay wall height and pier setbacks[13)]

2.9.3.1 The quay wall of Pier No.2 at Busan New Port is 21 meters high in total, 4 meters above and 17 meters below the waterline. Given that the water was 17.4 to 17.8 meters deep at Busan New Port when the accident occurred, the quay height above the waterline would have been about 3.5 meters.

2.9.3.2 As prescribed in Article 4.3.2 Container Terminal Design Code of the Design Standard for Ports and Fishery Harbors (KDS 64 60 10), aprons shall be designed so that containers can be temporarily laid, or that loading equipment such as cranes and vehicles can be easily operated. In general, setbacks are designed to be 3.5 to 6.5 meters, depending on the characteristics of the bollards, gantry crane cable trays, and terminals. In the case of Pier No.2 at Busan New Port, the setback was about 6.5 meters.

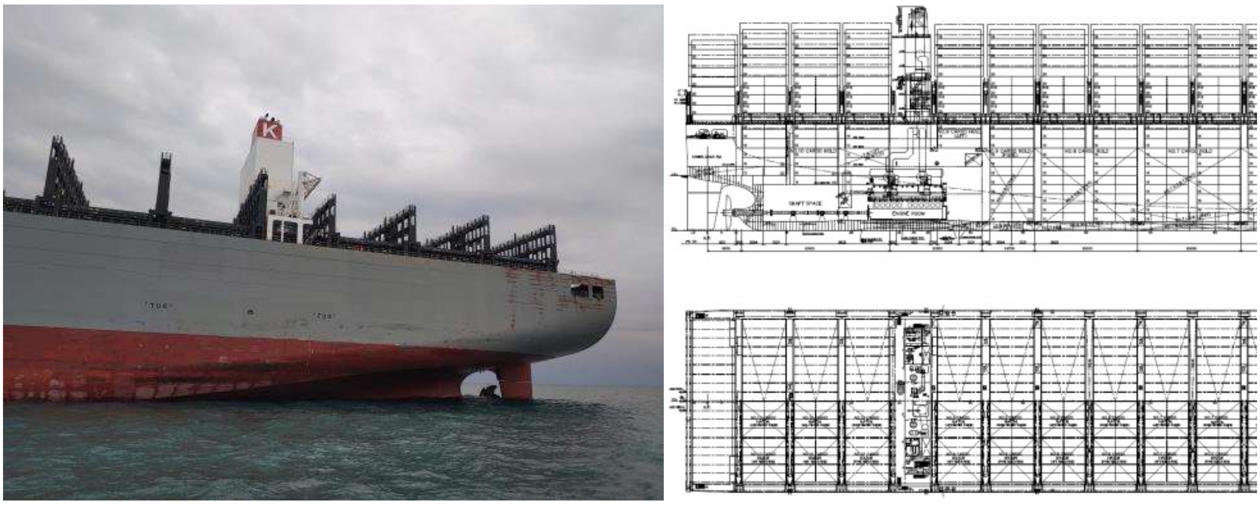


<Figure 9> Apron of Pier No.2

13) It means the distance from the quay line to the rail track near the sea, as prescribed in Article 1.4 Definition of the Design Standard for Ports and Fishery Harbors (KDS 64 60 10).

2.9.3.3 The depth of *Milano Bridge* is 29.9 meters. When the accident occurred, her aft draft was 6.9 meters, meaning that the part of the vessel above the waterline to the upper deck was about 23 meters high. Moreover, the quay wall was about 3.5 meters above the waterline at the time the ship was berthing at the pier. At Pier No.2, therefore, the height from the top side of the quay wall where the gantry crane was located to the upper deck of the vessel was about 19.5 meters.

2.9.3.4 Containerships have a flared bow and stern. As *Milano Bridge* also has a flared stern, the deck areas of cargo hold Nos.8 to 10 at the stern are like those midships. But, the area narrows sharply at the lower part near the propeller and rudder.

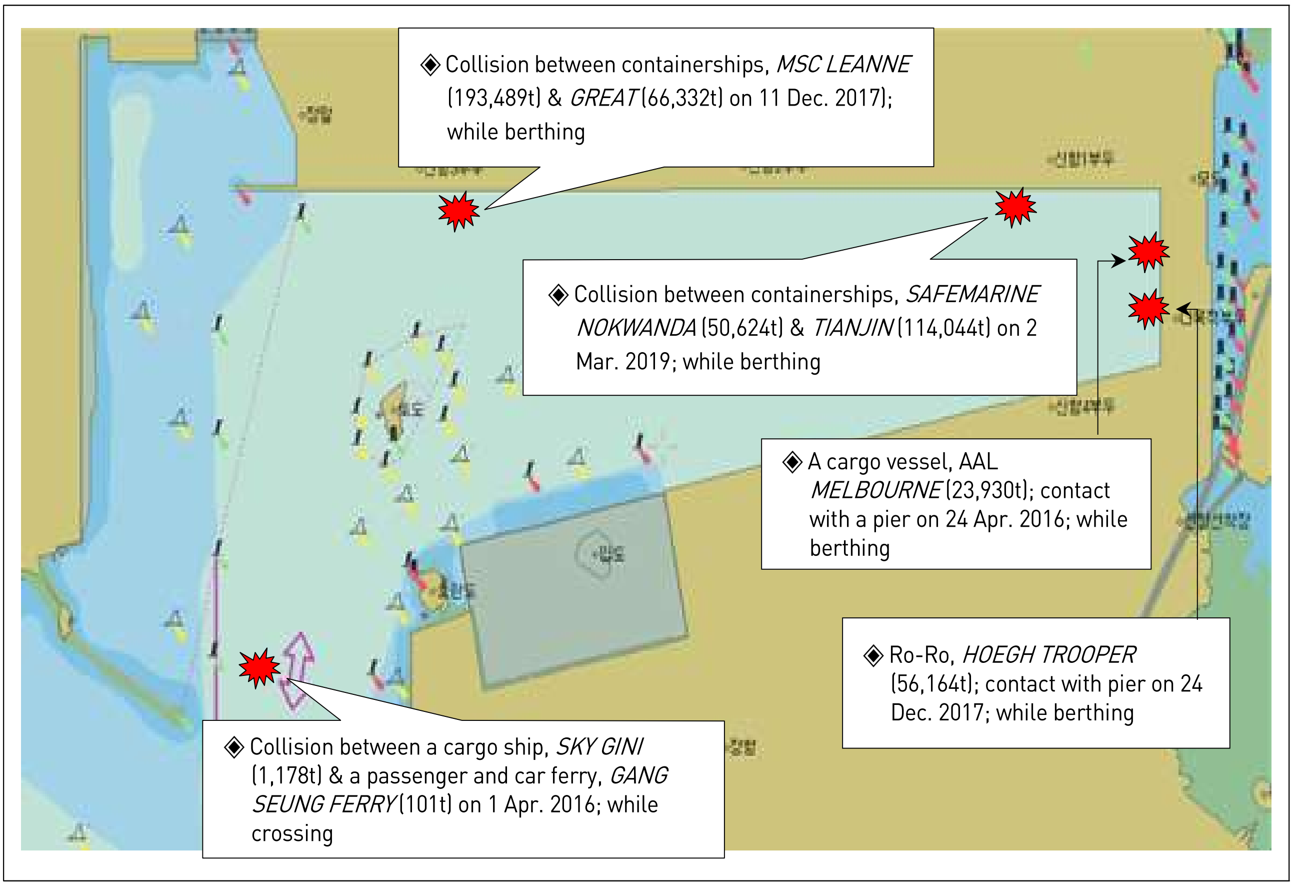


<Figure 10> Aft body of *Milano Bridge*

2.9.3.5 If a containership approaches the quay wall at a large angle with her upper part significantly exposed above the waterline due to a low draft, the upper part is likely to cross over the quay line. *Milano Bridge*, too, given both the aft draft and water depth of the quay wall at the time of the accident, was likely to have had the upper part of the side shell of her stern enter further into the quay without contacting the wall, depending on the berthing angle. And, in that case, avoiding contact with a gantry crane would have been particularly difficult while turning to starboard just ahead of the pier.

2.9.4 Marine accidents at Busan New Port

2.9.4.1 According to the Busan Regional Maritime Safety Tribunal, five marine accidents took place at Busan New Port from 2016 to 2019: three were collisions between vessels; and the other two were contacts with piers. All of these occurred while the pilots were onboard and maneuvering the vessels for berthing.



<Figure 11> Marine accidents at Busan New Port (2016 to 2019)

2.9.4.2 Each accident, which occurred with a pilot onboard at Busan New Port, has a different primary cause, and none of which were considered to have a specific relation with physical geography or structural features of the port. In four of the five cases, however, the KMST decided that one of the causes was attributed to the pilot's failure to control the vessel speed in time while berthing like the *Milano Bridge* accident.

2.10 Tugs at Busan Port

2.10.1 A total of 47 tugboats are registered in Busan Port for berthing and unberthing. Among the tugs, nine of them are for Busan New Port. They are operated on a rotational basis by Korea Tug Business Co. (Busan Branch).[14)]

2.10.2 Under the provisions of Article 6 of the Regulations on the use of Tugboats in Busan Port[15)], vessels with 150,000 gross tonnages or over that are not equipped with assistive devices for berthing/unberthing are required to use a 4,000hp tug and two 5,000hp tugs. When the vessels are equipped with assistive devices for berthing/unberthing, the master and the pilot of the vessels should discuss and decide whether to use tugs.

2.10.3 The Rules of Pilotage set by Busan Marine Pilot's Association require vessels with a gross tonnage of over 80,000 tons but less than 160,000 tons, which are equipped with assistive devices for berthing/unberthing, to use one 4,000hp tug and one 5,000hp tug.

2.10.4 *Milano Bridge* was assigned with one 4,000hp tug and one 5,000hp tug for entering Busan New Port. However, the pilot checked vessel information before boarding and upgraded them to a 6,500hp tug (M/V *Seonjin 100*) for aft and 5,400hp tug (M/V *Hankook 51*) for forward out of concern that the extraordinarily low draft of the vessel might impair her maneuverability.

2.11 Pilot A of *Milano Bridge*

2.11.1 In accordance with the internal regulations of the Busan Marine Pilot's Association, pilots working at the Port of Busan are assigned to one of three shifts: duty, standby, and off-duty. When a pilot is on duty, he or she works for 16 days in total, alternating among two day shifts, one night shift, and one day off. Then, he or she is rotated to a standby and provides pilotage service when demand increases. After finishing a standby rotation, pilots take a two-week leave before going back on duty. Those on duty work in turn at Busan North Port, Gamcheon Port, and Busan New Port.

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14) If necessary, other tugs for ports of Busan (Busan North Port, etc.) are sent to Busan New Port.

15) Regulations on the use of Tugboats in Busan Port (Notified by the Busan Regional Office of Oceans and Fisheries, No. 2019-241, 30 Sep. 2019)

2.11.2 A shipowner or a ship's agent should submit information, including vessel particulars, and apply for pilotage service on the website of the Busan Marine Pilot's Association before vessel's arrival. The Association assigns pilots to the applied vessels according to the preset duty rotation.

2.11.3 Pilot A, who piloted *Milano Bridge*, has worked as a ship's officer and master for 25 years since 1982. In February 2009, he obtained his pilot license and had piloted vessels for 11 years until the day of the accident. Although he had never piloted *Milano Bridge* before, he had much experience[16] in piloting similar-sized vessels.

2.11.4 Pilot A had been off or on standby between 10 March and 24 March 2020. And then, he was put on duty at Busan New Port, piloting on average of 2.7 vessels a day, totaling 32 vessels from 25 March to 5 April.

2.11.5 On 5 April 2020, one day before the accident, Pilot A piloted four vessels from 00:00 to 06:00 and took a break at Busan New Port. On the very day of the accident, he piloted M/V *Proteus*, a 6,000-ton containership and berthed her at Busan New Port from 09:00 to 10:00.

2.11.6 After piloting M/V *Proteus*, Pilot A took a rest from 10:00 to 13:00 and embarked on a pilot boat, M/V *Eulsookdo*, to pilot the next vessel, *Milano Bridge*, scheduled to enter the port at around 13:10.

2.11.7 After finishing the pilotage, he was supposed to pilot one more vessel, scheduled to depart from the South Container Terminal of Busan New Port at around 17:00. However, he could not go on the next vessel because of this accident.

2.12 Weather conditions

2.12.1 The Korea Meteorological Administration (KMA) was observing the ocean weather through marine weather observation buoy and wave height buoys, and among them, a marine weather observation buoy off Geoje Island, about 30 kilometers south of Busan

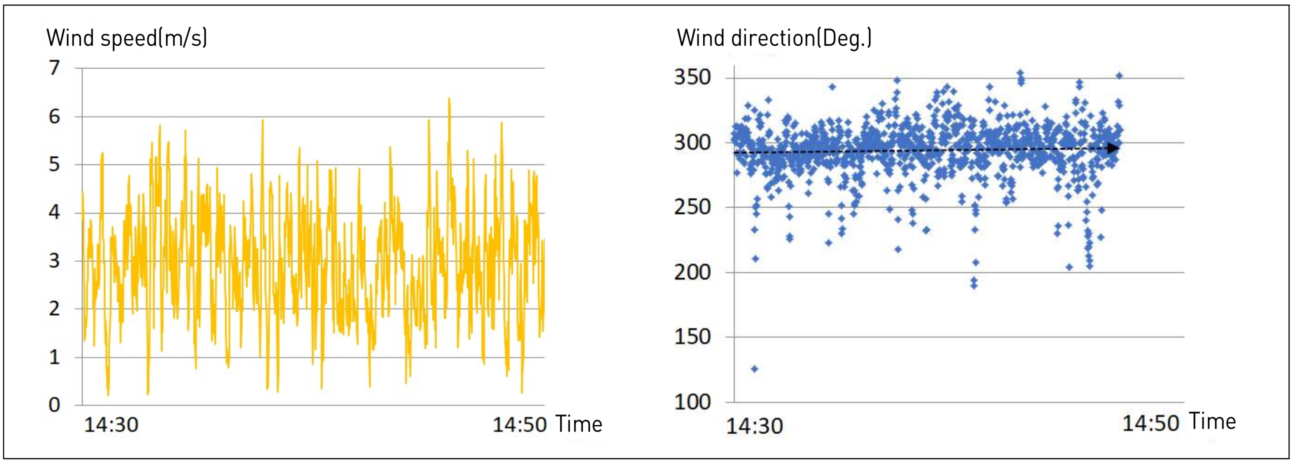
16) No. of times piloting vessels with a gross tonnage of 150,000 tons or over: 21 in 2017, 29 in 2018, 21 in 2019, and 6 till Apr. 2020

New Port, measures wind direction and speed, while a wave height buoy off Jam Island, about 10 kilometers west of the port, measures wave height and water temperatures. Also, the on-shore automatic weather station (AWS), located at the southern end of Gadeok Island, observes wind direction and speed. The weather data of the KMA at the time of the accident are described in Table 6.

<Table 6> Wind direction and speed, and wave height (KMA)

Date and Time	AWS (Gadeok Island)			Ocean buoy (Geoje Island)			Wave buoy (Jam Island)	
	Direction (Deg)		Speed (m/s)	Direction (Deg)		Speed (m/s)	Avg. wave height (m)	Sig. wave height (m)
6 Apr. 2020 12:00	282	W	1.4	241	WSW	1.0	0.1	0.1
6 Apr. 2020 13:00	159.1	SSE	1.8	160	SSE	1.4	0.1	0.2
6 Apr. 2020 14:00	150.4	SSE	2.4	177	S	2.6	0.1	0.1
6 Apr. 2020 15:00	153.2	SSE	3.8	194	SSW	6.3	0.1	0.1

2.12.2 Pusan Newport Company (PNC), an operator on Pier No.2 at Busan New Port, set up an observation station for wind speed and direction, about 100 meters from Berth No.2 of Pier No.2 at Busan New Port. According to the data stored at the observation station, the wind direction was consistent at 250 to 350°, wind speed was mostly at around 2-4 m/sec, and no wind was recorded over 10 m/sec between 14:30 and 14:50 on 6 April 2020.



<Figure 12> Wind direction and speed (PNC)

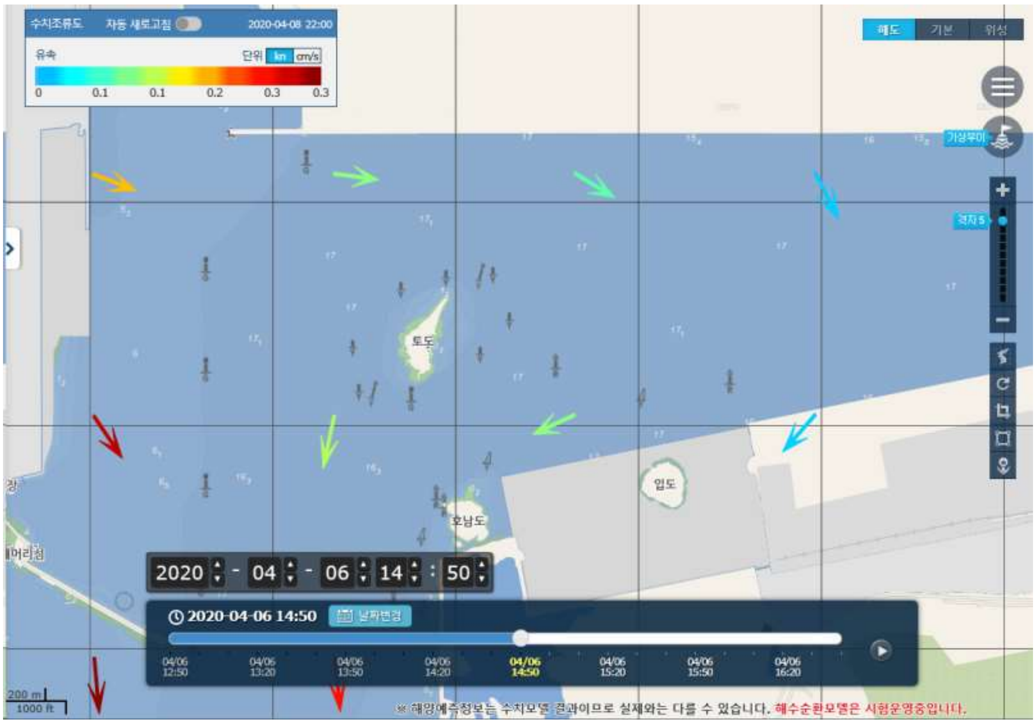
2.12.3 The relative wind direction (RWD) and the relative wind speed (RWS) were stored in the VDR on *Milano Bridge*. Table 7 shows the true wind direction (TWD) and the true wind speed (TWS) converted from the RWD and RWS at the time. Given the statement by Pilot A that a southerly wind blew from the starboard beam after the vessel turned starboard, the TWD was similar to the wind at the time of the accident. The wind speed was momentarily higher[17] for several minutes right before the accident than it had been when the vessel turned to starboard. However, mostly it was recorded less than 10 m/s.

<Table 7> Wind direction and speed at the time of the accident stored in the VDR of *Milano Bridge*

Time (LT)	RWD (deg. from bow)	RWS (m/s)	Heading (deg)	SOG (knots)	TWD (deg. from N)	TWS (m/s)	Beaufort Wind Force Scale
14:29:58	125.0	0.9	353.5	9.2	165.5	5.6	3
14:37:24	119.0	2.4	3.8	9.4	164.5	6.7	4
14:38:20	143.0	2.6	10.1	9.1	177.1	7.3	4
14:39:40	123.0	3.0	25.8	8.1	182.4	6.6	4
14:41:00	111.0	4.5	47.1	6.6	187.1	6.9	4
14:42:43	77.0	7.3	78.3	5.0	175.7	7.5	4
14:43:41	71.0	8.0	87.0	5.2	177.5	7.9	4
14:44:33	74.0	7.0	93.2	5.5	190.8	7.1	4
14:45:30	66.0	8.0	94.4	5.8	182.3	7.7	4
14:46:20	73.0	6.6	89.3	6.2	190.6	6.7	4
14:47:10	80.0	9.0	88.1	6.2	188.5	9.4	5
14:48:00	85.0	7.5	91.2	6.0	199.2	8.3	4
14:48:50	53.0	8.1	94.5	5.7	167.8	7.1	4
14:49:36	45.0	9.0	101.1	5.4	161.7	7.7	4

2.12.4 According to the tidal current diagram of the Korea Hydrographic and Oceanographic Agency (KHOA), the tidal current near the accident site was flowing south at about 0.1 knots at the time of the accident.

17)Even if adding up all the time that the RWS exceeded 10 m/sec after *Milano Bridge* passed the west breakwater of Busan New Port, it would not have been longer than 10 seconds.



<Figure 13> Tidal current diagram (KHOA)

2.12.5 According to the KHOA nautical chart and tidal table, the water depth between the gateway east of To Islet and the front area of Pier No.2 ranges between 17.1 and 17.5 meters, and the tidal water level was minus 2 centimeters at 13:31 and 165 centimeters at 20:00 on 6 April, the day of the accident. Therefore, the water was 17.4-17.8 meters deep at around 14:50 when the accident occurred.

2.13 Damage

2.13.1 After colliding with *Milano Bridge*, one gantry crane at Pier No.2 crashed and fell onto the vessel, causing damage to the port stern shell plate, aft lashing bridges and hatch coaming (Frames 10 and 11), and causing dent on part of the port side wing bridge as well. Later, *Milano Bridge* collided with the containership, M/V *Seaspan Ganges*, berthed at Pier No.7, on her way out from the pier, leaving dents[18] on the

18)The information on the damaged conditions of *Milano Bridge* is based on the survey report by ClassNK, submitted by the shipowner.

part of the port shell plate of *Milano Bridge*.

<Figure 14> Damage to the stern of *Milano Bridge*

<Figure 15> Dented port shell plate of *Milano Bridge*

2.13.2 *Milano Bridge* contacted Gantry Cranes Nos.85, 84, 83, and 81, which were standing by for cargo operations at the pier. Nos.85 and 81 were a total loss,[19] while Nos.84 and 83 sustained damage that required 9-months of repair at Jinhui Shipping Repairing & Building Factory Co., Ltd., in China. Apart from that, a rail track of

19)Gantry Crane No.85 collapsed and was destroyed after colliding with *Milano Bridge*. Nos.84 and 83 sustained partial damage. When investigating No.82, no damage was found. As for No.81, the boom of the crane collided with the wing bridge of *Milano Bridge*, and its legs collapsed, causing a total loss.

the gantry crane at Pier No.2 and asphalt sustained damage[20].

<Figure 16> Collapsed and damaged cranes

2.13.3 Also, M/V *Seaspan Ganges*, a containership docking at Berth No.7 of Pier No.2, east of the berthing place of *Milano Bridge*, sustained damage[21] to the port bow shell plate (bulwark plating, etc.) and empty forepeak tank (upper bracket, etc.).

<Figure 17> Dents & damaged areas of M/V *Seaspan Ganges*

20) The information on the damage to the gantry cranes and Pier No.2 is based on the detailed statement of damage submitted by PNC.

21) The information on the damage to M/V *Seaspan Ganges* is based on the survey report submitted by the shipowner.

section

3

Development of Accident

3. Development of Accident

3.1 Operations before entering Busan New Port

3.1.1 *Milano Bridge* had been in service on the regular shipping lanes of MD1 and EC4, which encompass Asia, Europe and America, since 23 January 2018. At the time of the accident, she was en route to MD1, sailing to Italy and Morocco after passing along the Chinese coast, stopping in Singapore, and passing through the Suez Canal.

3.1.2 On 14 March 2020, all the containers on *Milano Bridge* were unloaded at Yangshan Port in Shanghai and stayed in drydock at the shipyard of PaxOcean Engineering Zhoushan Co., Ltd., in Zhejiang province for repairing unidentified damage[22] from 15 to 29 March 2020.

3.1.3 During the stay, the repair work was completed, and 2,993 tons of ballast water was put into Water Ballast Tanks No.2 and No.4 on both sides of the ship. The water was pumped in through hoses onshore (at the drydock) on two occasions.

3.1.4 On 29 March 2020, *Milano Bridge* left the drydock around 07:18. After the pilot disembarked around 09:18 on the same day, the vessel set the main engine at 39 rpm[23] and started sailing toward Busan New Port, her next destination, at a speed of 10 knots.

3.1.5 When leaving the shipyard in China, the vessel was loaded with 2,993 tons of ballast water, 2,270.34 tons of fuel oil (LSFO and MDO), and 188 tons of fresh water. At the time, the draft aft and forward were 6.8 and 4.4 meters, respectively, exposing part of the

22)The operator of *Milano Bridge* explained that the purpose was to repair the bottom part of Water Ballast Tank No.4. However, it refused to submit objective data, such as a detailed statement of repair or the survey report of the classification society after repair.

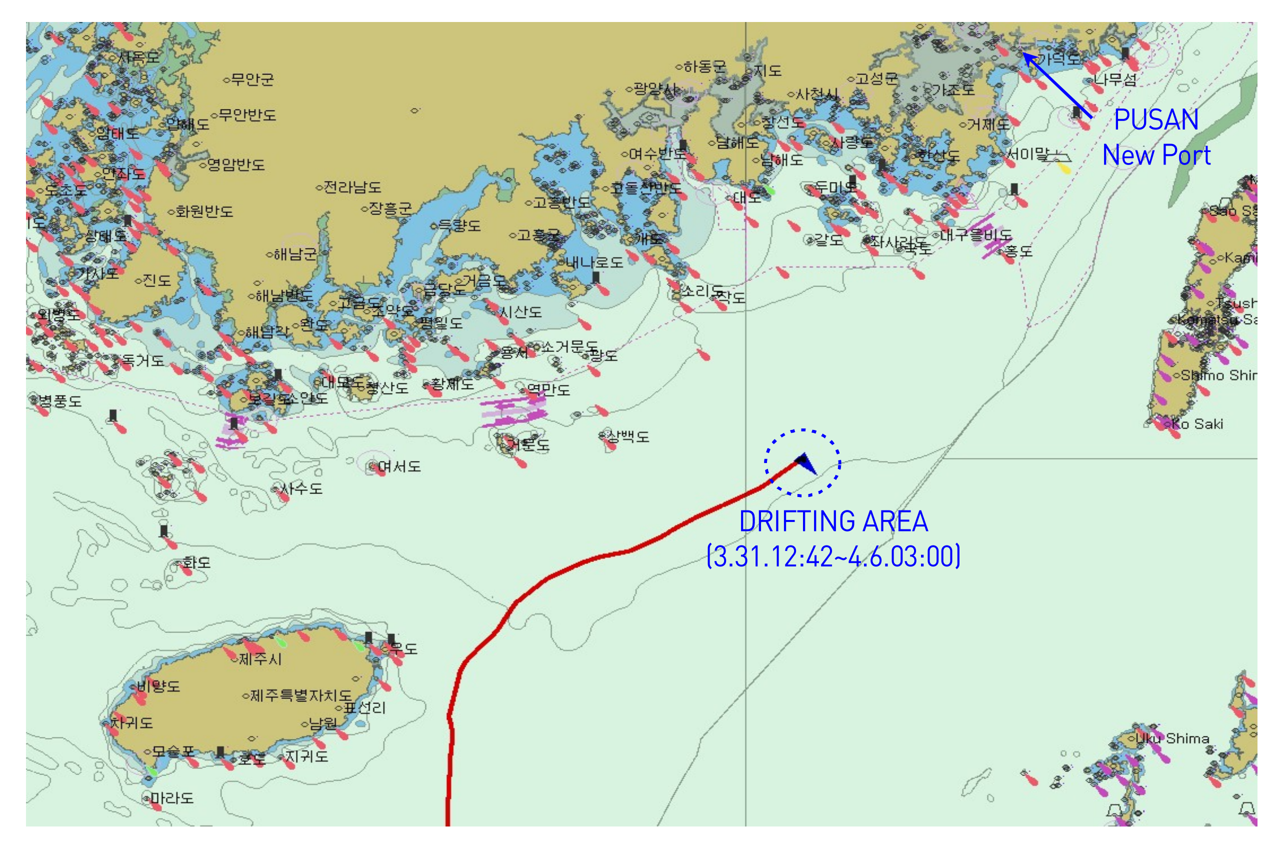
23)The main engine of *Milano Bridge* runs harbor full ahead at 35 rpm. And, the speed was calculated into 12.2 knots during the sea trials in ballast. (See Paragraph 2.8.4) propeller above the waterline. However, no clear statement was given by the master on why he did not add more ballast to fully immerse the propeller.

3.1.6 On 31 March 2020, the vessel arrived in the waters off the south coast of Korea at around 12:42, stopped the main engine, and drifted in order to arrive at Busan New Port on schedule. At the time, the wind speed was 5 to 10 m/s, and the wave height was 1 to 2 meters.

3.1.7 On 3 April 2020, the vessel again drifted from 17:30 to 18:30. While drifting, the ballast pump was used to put about 1,230 more tons of water into Water Ballast Tanks No.6 on both sides.

<Table 8> Ballast water taken before arriving at Busan New Port

Time of Ballasting	Tank Location	Amount of Ballast Water
From 17:00 to 21:30 on 21 March	W.B.Tank No.2 P+S	1,763 tons
From 22:00 on 21 March to 01:30 on 22 March	W.B.Tank No.4 P+S	1,230 tons
From 17:30 to 18:30 on 3 April	W.B.Tank No.6 P+S	1,230 tons
Amount of ballast water in total		4,223 tons



<Figure 18> Drifting area before arriving at Busan New Port (AIS track)

3.1.8 Therefore, the vessel took on total 4,223 tons of ballast water in W.B.Tanks No.2, No.4, and No.6 on both sides, which made the draft aft and forward to 6.9 and 4.5 meters, respectively.

3.1.9 Later, *Milano Bridge* restarted her engine to enter Busan New Port at around 03:00 and passed through the traffic separation zone near Hong Island at around 10:25 on 6 April. On the same day, she arrived at the waters 7 miles southeast from Gadeok Island and tested the main engine for entering and berthing at Busan New Port at around 13:12.

3.2 Pilot A on board *Milano Bridge*

3.2.1 The agency of *Milano Bridge* gave vessel information, such as gross tonnage, length, and draft, to Pilot A in advance when applying for pilotage service on the website of the Busan Marine Pilot's Association.

3.2.2 Before boarding *Milano Bridge*, Pilot A checked the given information and worried that the maneuverability of the vessel might be impaired by her excessively low drafts aft and forward, which were 6.9 and 4.5 meters, respectively. Therefore, he changed his original plan of using 4,000hp and 5,000hp tugs to 6,500hp and 5,400hp models.

3.2.3 On 6 April, Pilot A boarded the pilot boat, M/V *Eulsookdo,* in the vicinity of the Hanjin Container Terminal of Busan New Port to pilot *Milano Bridge* at around 13:10. And, on the same day, he boarded *Milano Bridge* near the pilot station, the buoy named Racon B, at around 13:54.

3.2.4 And then, at around 13:55, Pilot A went up to the bridge, shared a short greeting with the master, ordered the main engine to half ahead, and briefly explained his plan of port-side berthing at Pier No.2 of Busan New Port.

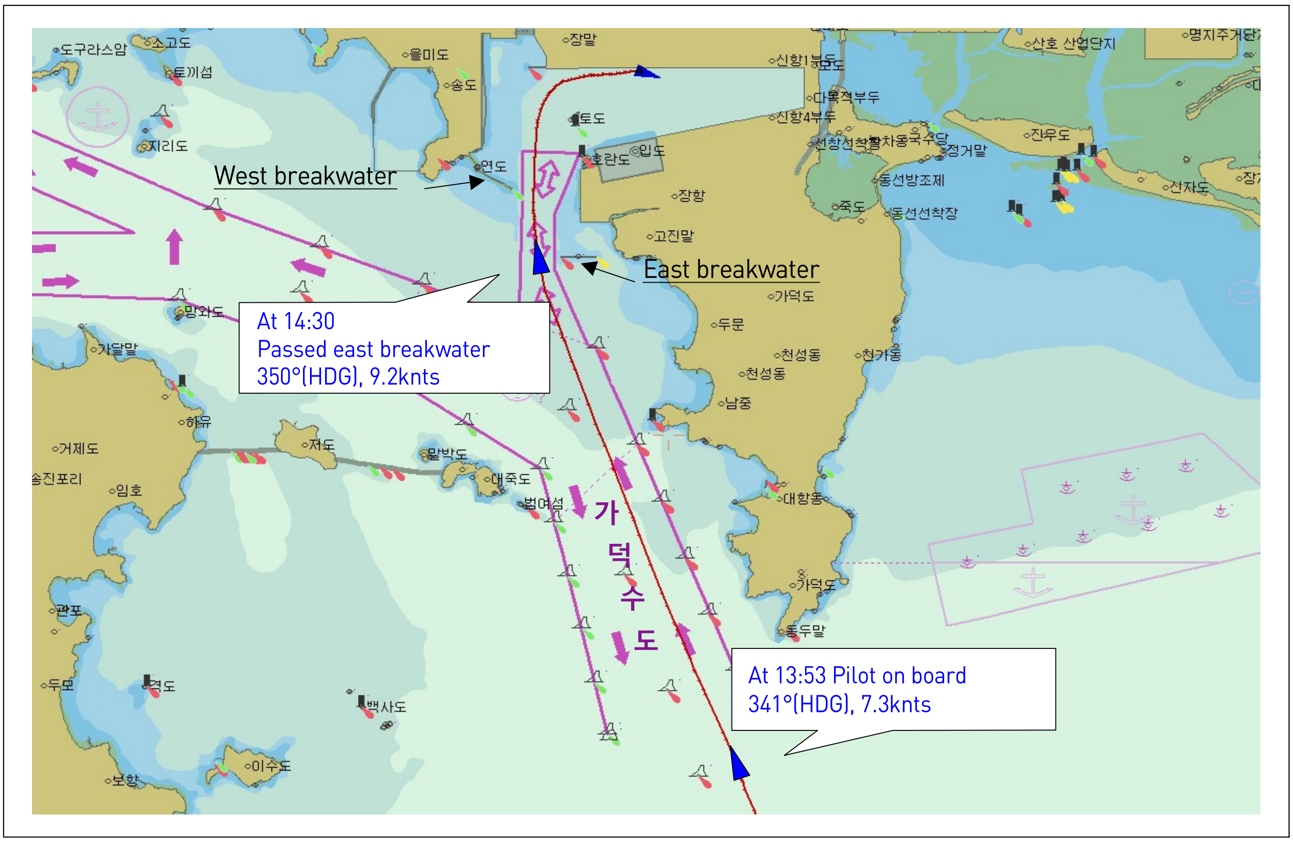
3.2.5 On the same day, the master and Pilot A both signed the Master/Pilot Information Exchange Checklist and shared information about *Milano Bridge*, including drafts and the immersion state of the propeller, at around 13:57, and Pilot A maneuvered the vessel thereafter.

3.3 Entry into Busan New Port

3.3.1 On 6 April 2020, *Milano Bridge* approached the right side of Gadeok Channel at around 14:00. While reporting the port entry of the vessel to the VTS of Busan New Port, Pilot A said that the vessel would "enter the waterway between the Hanjin Terminal (Pier No.3) and To Islet," and the VTS responded by saying, "understood."

3.3.2 After entering Gadeok Channel, the vessel proceeded about 4.5 miles on a course of 338° with the main engine running half ahead at 30 rpm and at a speed of 9 knots (referring to SOG, hereinafter the same applies), to the east breakwater of Busan New Port.

3.3.3 As *Milano Bridge* sailed along the channel, no other vessels were on her route except a general cargo ship (M/V *Qing Ping*), which departed from the multi-purpose pier of Busan New Port. On the same day, *Milano Bridge* met with M/V *Qing Ping* in the waters about 0.9 miles south of the east breakwater at around 14:23, and they passed port-to-port.



<Figure 19> Port entry track at Busan New Port (AIS track)

3.3.4 On the same day, the vessel arrived at the waters 0.5 miles south from the westernmost side of the east breakwater of Busan New Port at around 14:27. Then, Pilot A ordered the course be altered to 355° while keeping the main engine running half ahead. As the vessel passed the east breakwater on her starboard beam at about 9.2 knots around 14:30, he asked the master to take the tow lines of the aft tug on the starboard quarter.

3.3.5 When *Milano Bridge* was about to pass the east breakwater around 14:31, Pilot A ordered the course altered to 000° while keeping the main engine revolutions and speed the same. On the same day, the tow line of the aft tug, M/V *Seonjin 100*, was secured on the starboard quarter of *Milano Bridge* at around 14:33 while that of the forward tug, M/V *Hankook 51*, on the starboard bow was not.

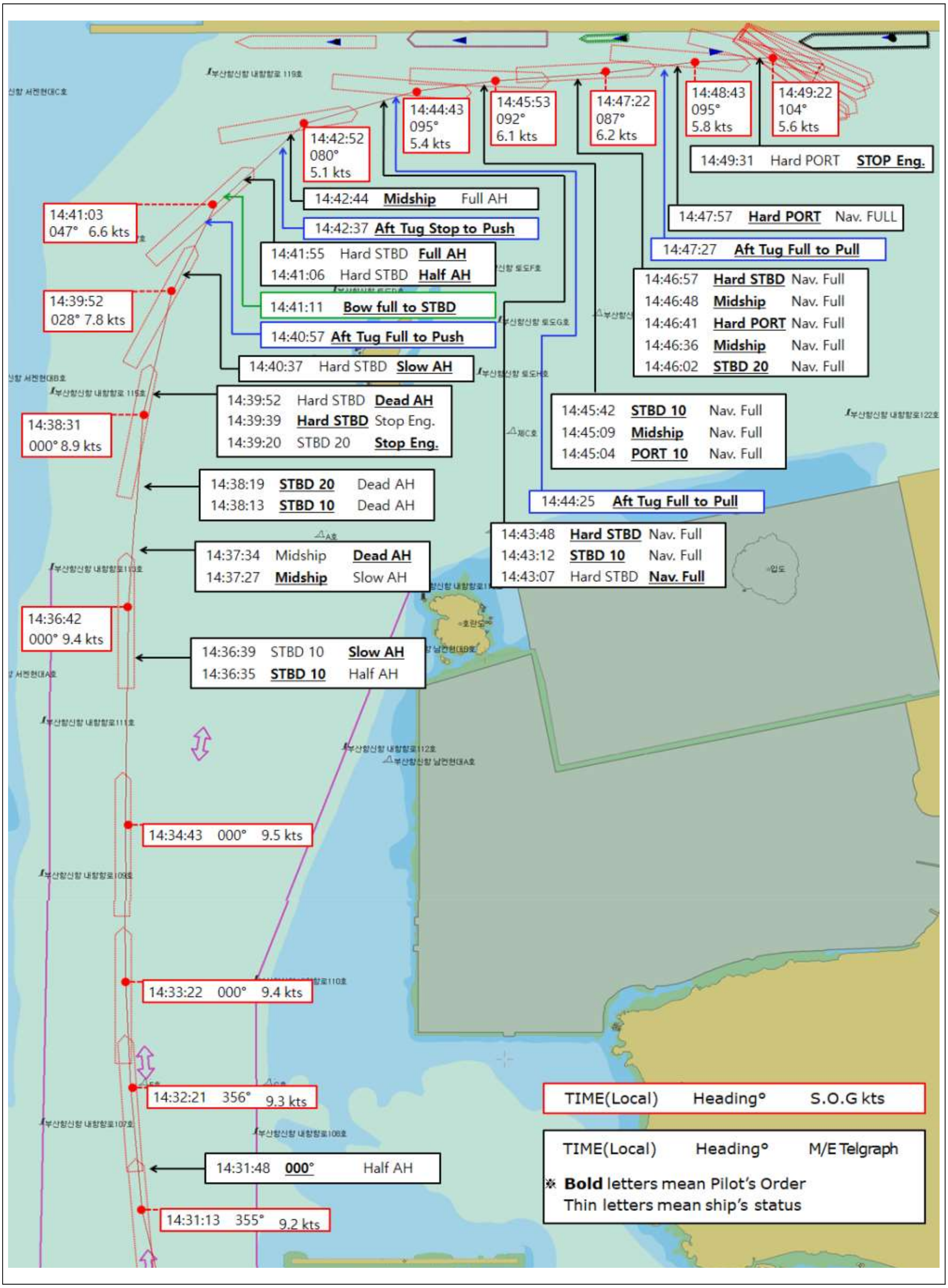
3.4 Attempt to berth at Pier No.2

3.4.1 *Milano Bridge* passed the west breakwater on a heading of about 000° at a speed of about 9.5 knots at around 14:34 on the same day. And around 14:36, Pilot A ordered starboard 10° and slow ahead to approach the waters off Pier No.2, making a course change of up to 90°. At the time, he asked the master about the speed and confirmed that it was 9.5 knots.

3.4.2 On the same day, Pilot A maintained rudder amidships and ordered the main engine to dead slow ahead at around 14:37. At around 14:38 when the heading was changing to 010°, the bow of *Milano Bridge* was passing abeam of To Islet 0.26 miles away and the pilot ordered starboard 20°.

3.4.3 At around 14:39 on that day, Pilot A ordered the main engine stopped and turned the rudder hard to starboard to increase the turning rate. About 20 seconds later, however, he thought the rate of turn was still lower than it should be and therefore ordered the main engine to dead slow ahead.

3.4.4 At around 14:40, the master informed Pilot A that the vessel's speed was 7.4 knots. And, the pilot ordered the aft tug on the starboard quarter to push the vessel with maximum power, while putting the main engine to slow ahead to increase the rate of turn.



<Figure 20> Pilot's instructions right before the accident (Bold letters: pilot's order)

3.4.5 At around 14:41, Pilot A ordered the main engine to half ahead and the bow thruster full to starboard. Later when he again ordered half ahead, the master said it was already half ahead, and then, the pilot ordered full ahead.[24] At that time, *Milano Bridge* was slowing down from about six to five knots on a course of about 047° at 30 rpm with her bow about 250 to 300 meters away from the quay of Pier No.3.

3.4.6 At around 14:42, Pilot A continuously asked the master whether the main engine was running full ahead and warned him of an urgent situation that the vessel might collide with the berthed vessels or pier facilities, shouting out "Collision, Collision, Emergency, Emergency." At the same time, he ordered the aft tug to stop pushing *Milano Bridge* and get ready to pull her so that she would not proceed toward the pier.

3.4.7 At around 14:43, *Milano Bridge* came parallel with the quay after a 90-degree change in heading. Also, the vessel proceeded closer to the containership, M/V *MSC Eva*, berthed at Pier No.3 less than 100 meters away. Therefore, Pilot A ordered the master to continuously increase main engine rpm, yelling, "Full, Full, Sea-speed." While putting the rudder to starboard 10°, the pilot repeated the order to increase engine rpm, and then, he ordered the rudder hard to starboard.[25]

3.4.8 At around 14:44, Pilot A again ordered the bow thruster full to starboard,[26] shouting at the master to continue increasing the speed. To prevent the Kick effect, which pushes the stern to port, the pilot ordered the aft tug to pull the vessel with maximum power while ordering rudder amidships. At the time, the main engine rpm was 44 to 45, the speed was about 5.4 to 5.6 knots, and the heading was turned up to 095°.

3.4.9 At around 14:45, Pilot A continued to order port 10°, then rudder amidships, and then

24) After the accident, Pilot A stated that the vessel deviated from the expected routes and proceeded towards the pier because of slow turning to starboard. Therefore, in order to avoid dangerous situations by enhancing the turning ability, he said he increased vessel's speed.

25) After the accident, Pilot A stated that the vessel was so close to the pier that he did not berth right away. Rather, he steered the vessel out to a much broader area on the starboard side and turned the vessel to starboard to try berthing again.

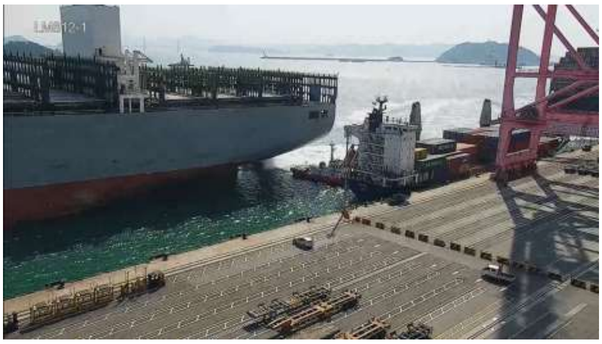
26) According to the VDR, since then, Pilot A continued to set the bow thruster full to starboard until after the time of the accident. However, vessel speed remained at five knots or higher, so her bow barely turned to starboard.

starboard 10°.

3.5 Contact with Pier No.2

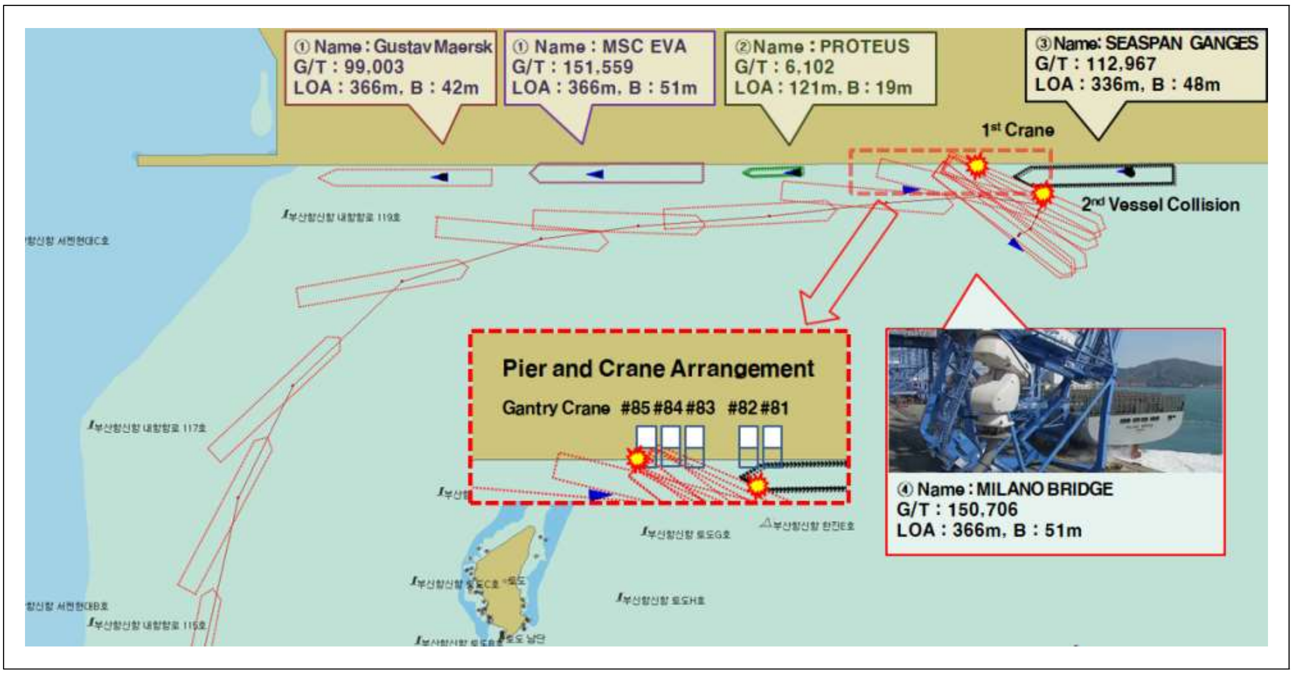
3.5.1 At around 14:46, Pilot A repeatedly ordered the aft tug to pull with maximum power while ordering the rudder to starboard 20° to avoid collision with vessels berthed at Pier No.3. After ordering rudder amidships, he continued to order hard port, rudder amidships, and hard starboard. In this way, the pilot managed to prevent the stern of *Milano Bridge* from being pushed to port and controlled the bow from turning to starboard at the same time. However, the vessel was moving closer to the pier almost in parallel.

3.5.2 At around 14:47, Pilot A ordered the aft tug to stop pulling and the rudder hard to starboard as the heading became about 087°. He then issued a series of urgent steering orders, including hard to port and hard to starboard to turn the vessel to starboard while preventing the stern from drifting toward the pier. At that time, the speed of *Milano Bridge* was about 6.2 knots, and her stern moved to within ten meters of M/V *Proteus,* a containership standing by for departure at Berth No.1 of Pier No.3.



<Figure 21> Space between *Milano Bridge* and M/V *Proteus* (CCTV)

3.5.3 At around 14:38, with the bow turning to starboard, *Milano Bridge* barely passed M/V *Proteus*. However, at around 14:49, when *Milano Bridge* was on a heading of 104° at about 5.6 knots, the port bow of the vessel contacted Gantry Cranes No.84 and No.83 in succession, after a crash into a Gantry Crane No.85 at Berth No.8 of Pier No.2. As for Gantry Crane No.81, its boom, a horizontally lowered beam, made a hard contact with the port wing bridge of *Milano Bridge*, cutting the support frame of the crane and collapsing its lower part.



<Figure 22> Berthing arrangement and collision when the accident occurred

<Figure 23> Collision between *Milano Bridge* and the gantry crane (CCTV)

3.5.4 After the series of contacts with those gantry cranes, Pilot A set the main engine to crash astern in addition to dead slow astern and full astern. However, the vessel was turned to starboard and moving away from the pier at around 14:50. While doing so, the port shell plate of *Milano Bridge* brushed against the port bow of the containership, M/V

Seaspan Ganges, berthed on the starboard side at Berth No.7 of Pier No.2, causing dents and scratches.

<Figure 24> Collision between *Milano Bridge* and M/V *Seaspan Ganges* (CCTV)

3.5.5 The vessel was checked for damage while waiting in front of the berthing pier at a 400-meter distance. The next day she berthed at Berth No.8 of Pier No.2 as planned at around 15:00 and moved to the repair yard of Samkang S&C Co., Ltd., in Koseong, South Gyeongsang Province to repair the damaged part on 14 April 2020.

section

4

Analysis

4. Analysis

4.1 Time and location of the accident

4.1.1 *Milano Bridge* made hard contact on her stern with a gantry crane installed at Berth No.8 while approaching the berth at Pier No.2 at Busan New Port. Then, she cleared the berth and again made hard contact on her port beam with the port bow of the moored vessel, M/V *Seaspan Ganges*, at Berth No.7, east of Berth No.8.

4.1.2 The voyage data recorder on *Milano Bridge* recorded the conversation on the bridge, communications by VHF radio telephone, and navigation record during the accident. Also, a closed-circuit TV at Pier No.2 covered the accident.

4.1.3 At that time of the accident, three gantry cranes (Nos.85, 84, and 83) were standing by in a row for loading and unloading operations of *Milano Bridge* and two more (Nos.82 and 81) were waiting for in a row for a vessel moored at the next berth.

4.1.4 The VDR's audio recording includes the crashing sounds of metal parts and urgent conversations on the bridge about the accident. The CCTV on the pier has footage of the series of collisions between the port quarter of *Milano Bridge* and (1) Gantry Crane No.85, (2) Gantry Cranes No.84 and No.83, (3) the vessel (M/V *Seaspan Ganges*) moored next to the berth, and (4) Gantry Crane No.81.

4.1.5 Thus, this accident is considered to have begun at Berth No.8 of Pier No.2 in Busan New Port (34°04'39" N, 128°47'56"E) at around 14:49 on 6 April 2020 when *Milano Bridge* contacted Gantry Crane No.85 on her stern.

4.2 Weather and sea conditions at the time of the accident

4.2.1 According to the tidal current diagram provided by KHOA, the tidal current within Busan New Port was heading south at about 0.1 knots at the time. Waves were no higher than about 0.5 meters, given the fact that the accident occurred inside the west and east breakwaters of Busan New Port.

4.2.2 The weather data, such as wind direction and speed during the accident, were based on weather observations obtained from three locations. The first data were given by the KMA meteorological station at the southern end of Gadeok Island, which is 10 kilometers from the accident site. Based on these data, wind direction and speed were recorded as 150° and 2.4 m/s at 14:00 and 153° and 3.8 m/s at 15:00 on 6 April.

4.2.3 Secondly, according to the data from both anemoscope and anemometer installed by PNC at the North Container Terminal of Busan New Port, the recorded wind direction and speed fell into the 250°-350° range and the 2-4 m/s range between 14:30 and 14:50 on 6 April.

4.2.4 The third data source on relative wind direction (RWD) and relative wind speed (RWS) was digitally converted through analogue anemoscope and anemometer on the bridge and stored in the VDR of *Milano Bridge*. When reflecting the vessel's course and speed into RWD and RWS in the VDR to calculate the true wind direction (TWD) and true wind speed (TWS), the figures ranged from 164° to 169° and from 5 to 9 m/s between 14:30 and 14:50 on April 6.

4.2.5 KMA's observation instruments for wind speed and direction are located significantly away from the accident site, while the internal data of PNC's terminals included temperature gaps from the data observed at sea and disturbance by facilities. For these reasons, it was difficult to establish whether the data given by the KMA and PNC terminals accurately presented wind direction and speed at the time and location of the accident. It is, therefore, considered that the data originating from the VDR of *Milano Bridge* are the most suitable[27] for describing the situation at the time.

27)After the accident, KMST investigators boarded *Milano Bridge*. After comparing the wind speed and direction, read in the anemoscope and the anemometer on the bridge, with the ones, stored in real time in the VDR, investigators confirmed that they were equal. Also, the anemoscope and the anemometer on the

4.2.6 In conclusion, the wind blew towards 164° to 199° at about 5 to 9 m/s (Beaufort wind scale 4 to 5), tidal current flowed south at about 0.1 knots, and waves were no higher than about 0.5 meters in Busan New Port at the time of the accident.

4.2.7 As for wind, an average speed threshold for both high seas watch[28)] and strong-wind warning[29)] released by the KMA is 14 m/s. At the time, however, the figure was no higher than 10 m/s, meaning that such wind speed was at an ordinary level and hardly considered a wind force requiring special attention from the port.

4.3 Maneuverability at the time of the accident

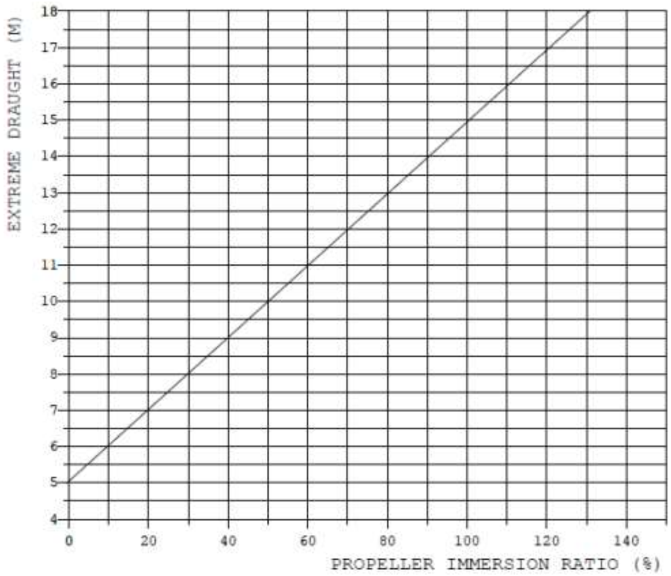
4.3.1 *Milano Bridge* was verified to be in ballast and with drafts of 4.5 meters forward and 6.9 meters aft when entering Busan New Port on April 6, 2020.

4.3.2 According to the general arrangement (G/A) of *Milano Bridge*, the propeller immersion draft is 10.1 meters. If subtracting the draft aft from the propeller immersion draft, it is clear that 3.2 meters of her propeller was exposed above the waterline.

bridge were in normal operation with no history of failures.

28) When wind blows at 14 m/s or over for more than three hours, or a significant wave height is expected to be 3 meters or above at sea.

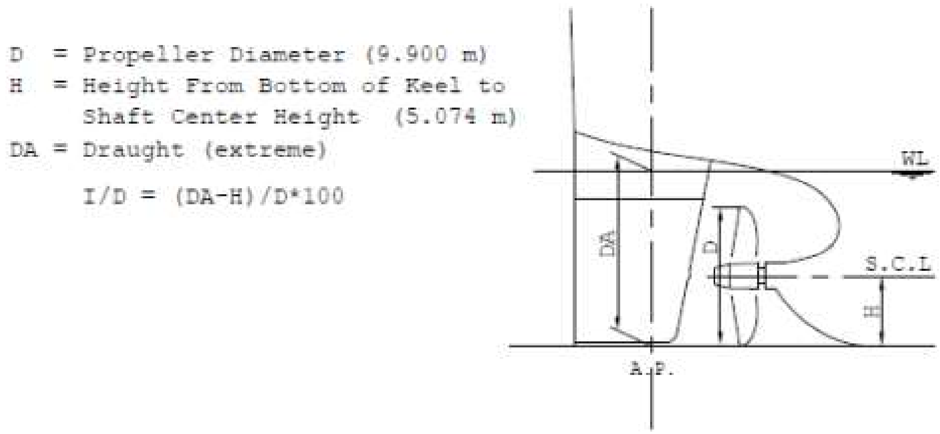
29) When wind speed is 14 m/s or over, or the instantaneous wind speed is expected to be 20 m/s or above on land.



<Figure 25> Propeller Immersion Ratio Curve of *Milano Bridge*

4.3.3 Figure 25 shows the propeller immersion ratio of *Milano Bridge*, as presented in the Stability Booklet with Loading Guidance, approved by the Classification Society when building the vessel.

4.3.4 A more specific calculation of the immersion ratio is illustrated in Figure 26, based on which the I/D value is calculated to be 18.4.[30)] It means the immersion ratio of *Milano Bridge* is estimated only at 68.4% (50+18.4) at the time of the accident.



<Figure 26> Calculation for the propeller immersion ratio of *Milano Bridge*

30)If putting the values into the equation, I/D = (DA-H) / D × 100, the calculation is as follows: I/D = (6.9-5.074) / 9.9 × 100 = 18.4. The sea trials were conducted in ballast with I/D of 55.1% (draft aft: 10.53m, draft forward: 4.67m) after *Milano Bridge* had been built.

4.3.5 If a vessel does not use tugs or bow thrusters, she can make a turn with a moment created by rudder force. The size of this rudder force, which creates a moment to push her stern to either side, is proportional to the rudder area, the square of the velocity of the water past the rudder, and the sine of the rudder angle.[31)] Therefore, a vessel generally increases her rudder angle and ramps up the main engine rpm to increase the flow velocity to improve rudder effectiveness by steering when altering course.

4.3.6 During the accident, however, *Milano Bridge* had only 68.4% of the propeller immersion ratio with a 6.9-meter draft aft. Thus, despite a higher rpm, the flow velocity was not as fast as it should have been. There is no widely recognized calculation to figure out how much the vessel's propulsive efficiency is reduced at the same rpm if her propeller is partly immersed. However, it is undeniable that a vessel with a 68.4% propeller immersion ratio, just as in this case, has a significantly lower propulsive efficiency than the one with the ratio over 100%.

4.3.7 If the propeller is excessively exposed, a higher rpm would introduce a rapid surge in aeration where air bubbles flow in through the propeller blades, and such effect would rather lower propulsive efficiency.

4.3.8 Analysis on a six-minute track of *Milano Bridge*, recorded in the VDR right before the accident, showed that despite consistent efforts to increase rpm (35 to 44)[32)] the vessel had advanced about 0.6 miles in 6 minutes, equal to about 6 knots (over 12.2 knots according to the vessel information). Given that, such analysis is considered to demonstrate deterioration of propulsive efficiency when the propeller rpm was increased, as described in Paragraph 4.3.7.

4.3.9 Such a low propulsive efficiency would only decrease the velocity of the water past the rudder, and thereby, rudder effectiveness would be lowered as well in proportion to the

31) Fn, the size of the normal force on the rudder area, is calculated as follows: Fn = K·A·v2·sinΘ (A: rudder area, V: velocity of water inflow to rudder, and Θ: rudder angle). When the vessel speed is zero, the rudder moment is the calculated value of Fn·CosΘ·0.5L (L: ship length between perpendiculars). (Prof. Yoon Jeomdong. "Theory and Practice of Vessel Maneuvering". 2015.)

32) At the time, the bow thruster continued to be set to full starboard, and the aft tug was ordered to pull the stern to starboard for about three minutes. However, the vessel speed was 6 knots or over, so these orders are presumed to not have affected speed much.

square of the decreased velocity. In other words, excessive exposure of the propeller was one of the major reasons behind a decrease in propulsive efficiency as well as in rudder effectiveness.

4.3.10 As for *Milano Bridge*, the upper part of her rudder exposed above the waterline was also at least 3.2 meters, just as that of the propeller. Given that, the submerged area of the rudder at the time was calculated at about 64% of the rudder area of 85 ㎡ (54㎡),[33] presented in the vessel information. Such a reduced area of the rudder was also another factor of proportionately worsening rudder effectiveness.

4.3.11 The maneuverability of *Milano Bridge* was calculated on sea trials at the time of shipbuilding when her propeller and rudder were fully immersed (See Paragraph 2.8). As mentioned above, however, the maneuverability would be affected by a low propulsive efficiency and rudder effectiveness if the exposed parts of the propeller and the rudder were 3 meters or more, as in this accident. Therefore, at the time of the accident, *Milano Bridge* is presumed to have had lower maneuverability than she had during her trial performance as posted on the bridge.

4.3.12 Meanwhile, the vessel master gave a statement that no maneuverability issues occurred from the departure from China to entry into Busan New Port. However, he increased the vessel's draft by about 0.1 meters by loading about 1,230 tons of ballast water when the vessel was drifting in open water off the southern coast of Korea ahead of her entry. Given that, it is presumed that the master had been aware of a certain degree of impaired maneuverability.

4.3.13 Pilot A also recognized an exceptionally low draft of *Milano Bridge* and changed the scheduled tugs to ones with higher horsepower so that they can assist in maneuvering. However, since there was no way point for a large course change, he did not directly order rudder angles, rather ordered a specific heading to make a small course alteration until the vessel passed To Islet at around 14:41, 46 minutes after he boarded. It seems that the pilot did not pay careful attention into the hull's

33) When briefly calculating the immersed area of the rudder with a draft aft of 6.9 meters based on the general arrangement (G/A) of *Milano Bridge*, it is presumed to be 54㎡, or about 64% of 85㎡, the total rudder area.

steering responsiveness.

4.3.14 In this regard, neither the master nor the pilot, who were in command of *Milano Bridge*, had an accurate knowledge on how much her maneuverability was affected by a low draft until making a large course change of 90° near the islet. They are, thus, considered to have failed to sufficiently consider such conditions when preparing for voyage plan and emergency response plan.

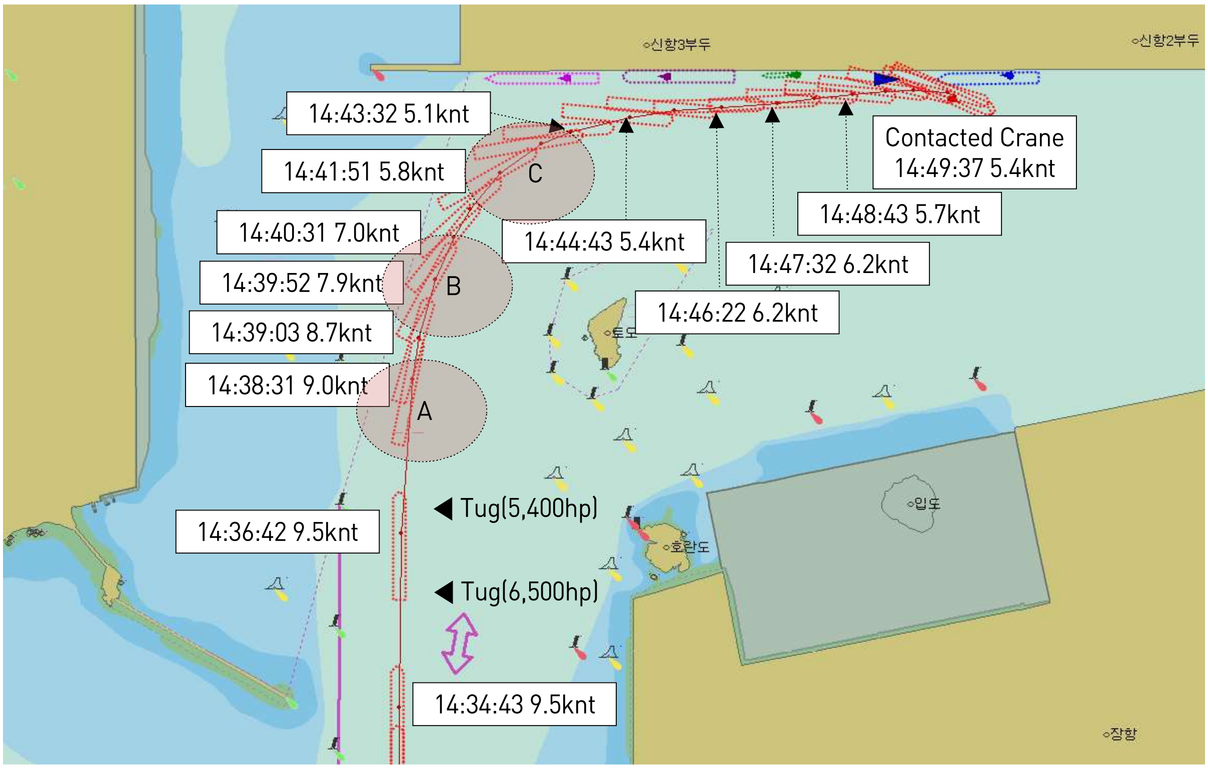
4.4 Analysis on a navigational track when entering port

4.4.1 Maneuvering and navigational track of *Milano Bridge* when entering port

4.4.1.1 Pilot A boarded *Milano Bridge* in the vicinity of Racon B, a buoy located off the southernmost tip of Gadeok Island, at around 13:54 on 6 April 2020. At around 14:34, he piloted the vessel past the west breakwater of Busan New Port on a course of about 000° at about 9.5 knots, as illustrated in Figure 27.

4.4.1.2 Around 14:36, Pilot A first ordered starboard 10° to turn the vessel to make a 90° change in heading to starboard and proceeded to the waters off Pier No.2 at the position with a straight-line distance of 0.84 miles (1,556 meters) from the quay of the North Container Terminal before arriving Point A, marked in Figure 27.

4.4.1.3 At around 14:39, Pilot A ordered the main engine stopped to lower the speed when passing Point B. He, however, feeling that the vessel turned much slower than expected due to a low rate of turn, sought to increase the rate of turn further by ordering hard to starboard and setting the main engine to dead slow ahead. Also, at around 14:40, the pilot ordered the aft tug on the starboard quarter to push the stern and the bow thruster full to starboard to increase her turning rate to starboard.



<Figure 27> Track of *Milano Bridge* at the time of the accident

4.4.1.4 Despite this, the starboard turn was further delayed while the vessel proceeded even closer to the pier. Thus, Pilot A, who was worried that the vessel might collide with the other vessels berthed at Pier 3, at around 14:41 ordered to increase the turning rate at Point C so that the speed can increase and he can avoid collision.

4.4.1.5 At around 14:43, *Milano Bridge* passed Point C and made a large course change of 90°, approaching within 100 meters from the vessel berthed at Pier No.3 (150 meters from the quay). She proceeded further, reached dangerously close to the vessel, almost hitting her, and then turned to starboard. The recorded track shows that while being turned, her port stern struck a gantry crane at the berthing pier and then collided with the berthed ship, M/V *Seaspan Ganges*.

4.4.1.6 Figure 28 illustrates rpm, vessel speeds, headings, and change of rudder angle, recorded in the VDR from around 14:30 right before *Milano Bridge* approached the west breakwater of Busan New Port to around 14:50 when the collisions took place.

<Figure 28> VDR Record

4.4.1.7 The vessel put To Islet on the starboard side and made a large course change of 90° to turn starboard from 14:36 to 14:43 (approximately 7 minutes and 45 seconds on a per second basis). In the following table, such a track (from Point A to C) was compared with the track of *Milano Bridge* during the sea trials,[34] when she was in ballast at half ahead (10.6 knots), like the conditions at the time of the accident.

<Table 9> Track comparison of *Milano Bridge*

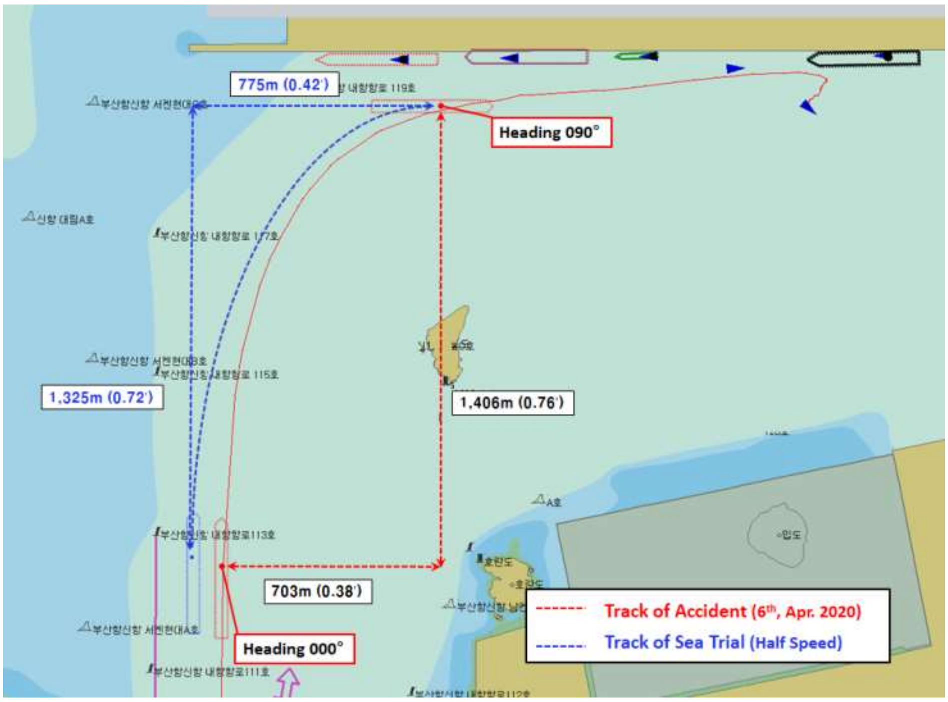
Track	Navigation conditions	Time consumed	Advance	Transfer	Remark
A 90° course change during the accident (A)	Draft aft: 4.5m Draft forward: 6.9m Speed: 9.4kn	7m 45s	1,406m	703m	Use main engine, rudder, tugs, and bow thrusters to speed up her turning.
Maneuverability performance during the sea trials (B)	Draft aft: 4.72m Draft forward: 10.27m Speed: 10.6kn	6m 5s	1,325m	775m	Keep starboard 35°
Difference (B-A)		+1m 40s	+81m	-72m	

- Compared with the performance during the sea trials in ballast at half ahead, it took 1 minute and 40 seconds longer to make a 90° change of heading from its initial path of heading by turning to starboard. The advance was 81 meters longer while the transfer was 72 meters shorter than that of the sea trials. (See Table 9)

- In the initial turning, as the vessel turned slowly, her advance was increased due to forward momentum. However, in the latter half of her turning, the vessel veered starboard relatively fast as she used tugs, presumed to reduce the transfer.

- It turned out that the reduction in rudder force (lower turning moment) from the low propulsive efficiency of the propeller was significant in delaying the initial turning of the vessel.

34)It is not appropriate to simply compare the actual track of *Milano Bridge* during the accident, where she turned while adjusting main engine speed variously, to the track during the sea trials, where she turned with the engine half ahead and rudder angles of starboard 35°. Still, the latter was used as a comparing value in order to give a simple explanation on the vessel track during the accident.



<Figure 29> Track comparison
(Red: Track on the date of the accident, Blue: Overlapping track during the sea trials)

4.4.1.8 Meanwhile, if the location the vessel arrived to prepare for safe berthing after passing Point C and turning by 90° is the mid-point[35] between the quay of the North Container Terminal and To Islet, it might locate about 0.21 miles (389 meters) from the pier.

4.4.1.9 In this case. *Milano Bridge*'s rate of turn had not increased as much as expected after the vessel started turning starboard during the accident. Even though the pilot tried increasing main engine rpm, putting the rudder hard to starboard, and even using an aft tug and bow thrusters, the 90° turning was still too late. At that moment, the vessel passed the mid-point and then proceeded 239 meters ahead and arrived the position, only 150 meters from the pier.

4.4.1.10 Consequently, if the pilot had been able to predict that maneuverability, such as turning ability, would be impaired and increase the tactical diameter, it would have

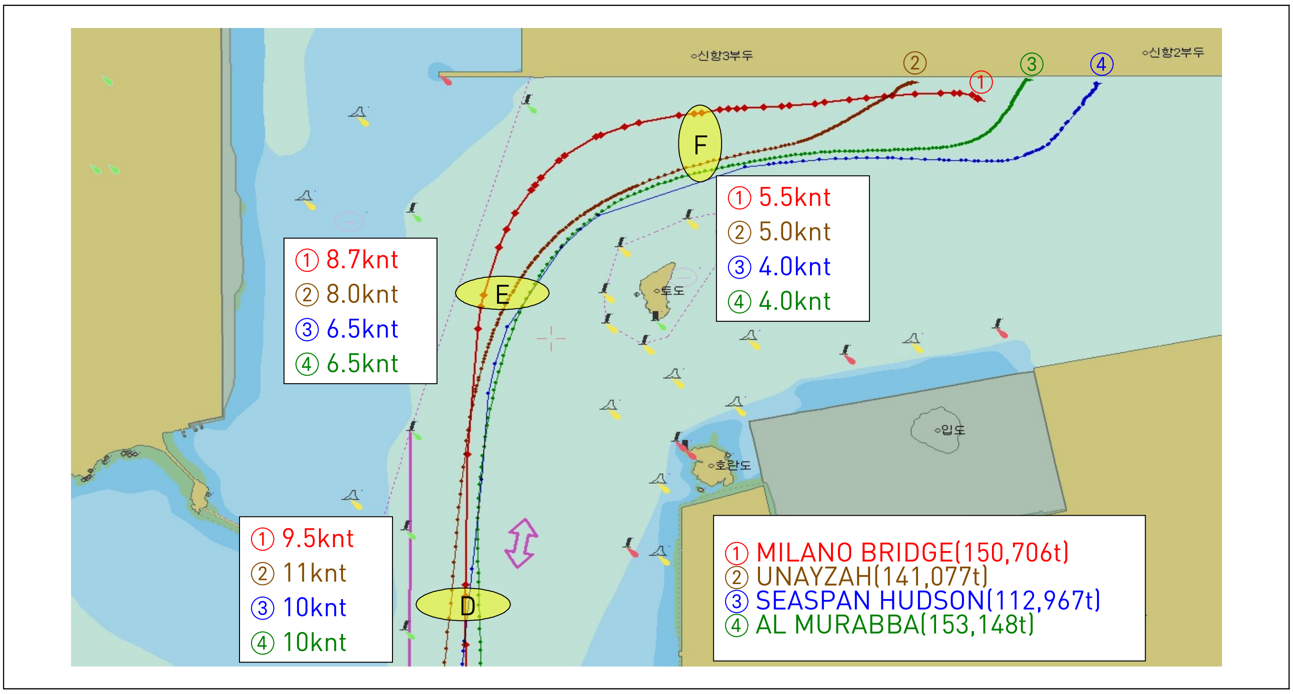
35) Even when the vessel was turned 90° to berth at the North Container Pier, she could be pushed in the heading direction, meaning it is necessary to consider whether the vessel can secure enough space from the quay. Also, most of the tracks of similar vessels in Paragraph 4.4.3 showed that they were well positioned to berth by turning 90° at the mid-point between the quay of the North Container Terminal and To Islet.

been desirable to reduce speed before turning and alter the course earlier, or to reduce the vessel speed to no more than 5 or 6 knots in the beginning and seek an emergency response by tugs or bow thrusters to support her turning ability.

4.4.1.11 Factors such as maneuvering orders given by Pilot A or distances to other vessels were put together in order to analyze the track of *Milano Bridge* from passing Point C to colliding with the gantry cranes. The pilot gave up on berthing *Milano Bridge*, and then he tried to minimize the vessel's movement towards the port side to avoid a collision with the pier or the other berthed vessels while accelerating her heading to turn starboard. However, it presumed that the pilot failed to effectively control the vessel as he intended.

4.4.2 Track of the other vessels Pilot A worked

4.4.2.1 Pilot A had piloted four vessels in total (including *Milano Bridge*) into berthing at Pier No.2, putting To Islet on starboard side, among vessels over 100,000 tons that had entered Busan New Port since 2019 until the day of the accident. Figure 30 illustrates their tracks.



<Figure 30> Tracks of vessels at the time of the accident

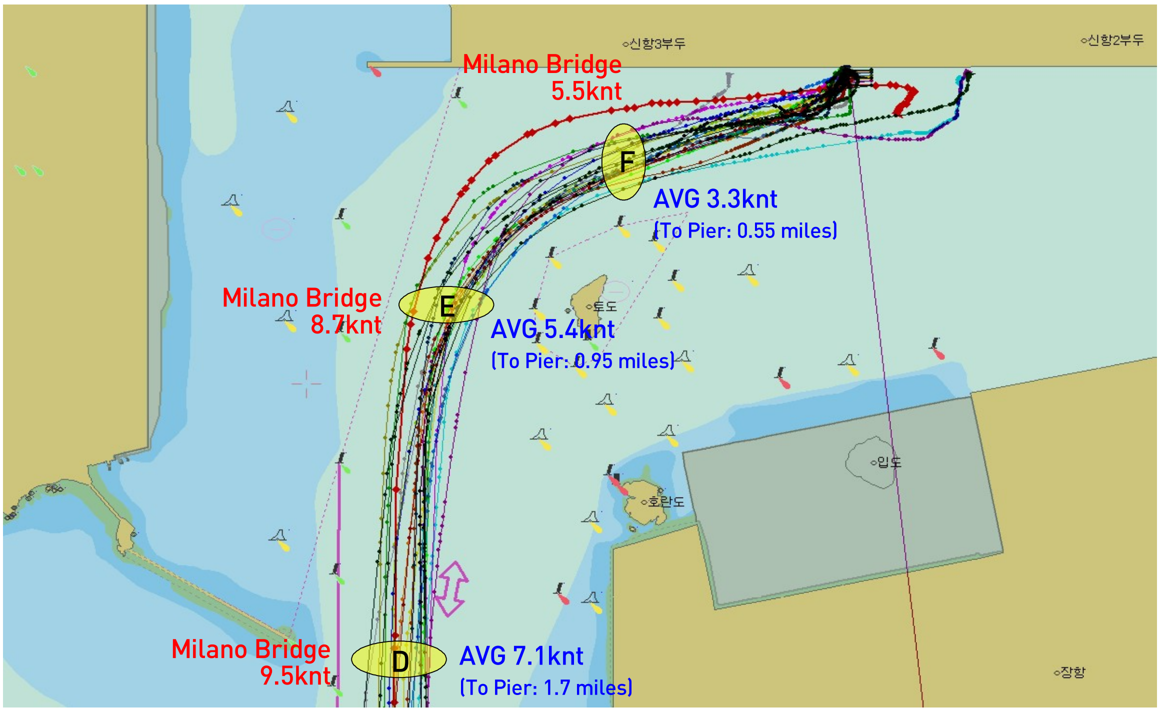
4.4.2.2 *Milano Bridge* proceeded into the port 0.8 knots slower than the other three vessels' average speed of 10.3 knots at Point D, passing the west breakwater of Busan New Port. At Point E, passing To Islet, however, Pilot A started to turn *Milano Bridge* at speed 0.7 to 2.2 knots faster than the other vessels he had piloted. Her speed at Point F in front of Pier No.3 remained 0.5 to 1.5 knots faster than that of the other vessels as the speed of *Milano Bridge* was slowly reduced.

4.4.2.3 In other words, unlike the other vessels whose speeds were slowed 27.3-35%, *Milano Bridge* lowered speed just 8.4%, from 9.5 to 8.7 knots until passing Point D, west of the west breakwater, and reaching to Point E abeam To Islet. Also, in the section where vessels turn from Point E to F, *Milano Bridge* decreased her speed 42.1%, from 8.7 to 5.5 knots while the others slowed by 54.5 to 60%, meaning that the speed of *Milano Bridg*e was reduced less than that of the other vessels, and her tactical diameter was increased significantly.

4.4.2.4 Meanwhile, the other three vessels turned relatively gradually by making small angle turns several times in advance when proceeding from Point D to E and passing through the waters west of To Islet. On the other hand, *Milano Bridge* kept a course of 000° for some time, and when reaching close to Point E, she started veering starboard in order to make a large course alteration, which is considered to have *Milano Bridge* adversely affected more by her already impaired maneuverability.

4.4.3 Track comparison between *Milano Bridge* and the other similar vessels

4.4.3.1 Among the large vessels (over 140,000 tons) that had entered Busan New Port from January to April 2020, a total of 23 had berthed at Piers No.2 or 3, putting To Islet on the starboard. Figure 31 compares the tracks of these vessels with that of *Milano Bridge* during the accident.



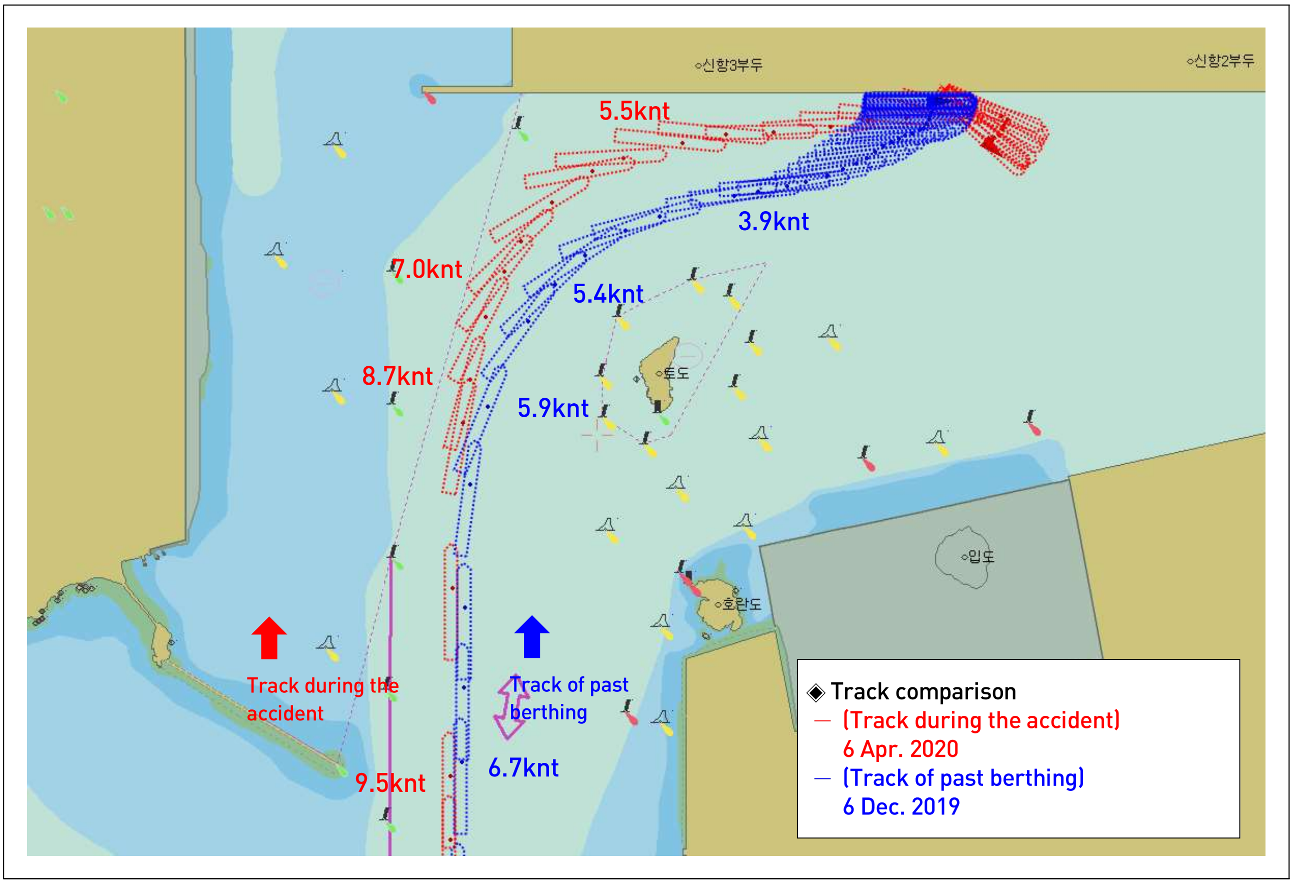
<Figure 31> Berthing tracks of 23 vessels

4.4.3.2 Figure 31 shows that *Milano Bridge* was at 9.5 knots, 2.4 knots faster than the other vessels, whose average speed was 7.1 knots at Point D, passing the west breakwater. Even at Point E, passing To Islet, *Milano Bridge* was at 8.7 knots, 3.3 knots faster than the other vessels' average speed of 5.4 knots.

4.4.3.3 At Point F in front of Pier No.3, about 0.45 miles to Pier No.2, the other vessels reduced their speed to 3.3 knots on average, but not *Milano Bridge*, which proceeded at 5.5 knots, 2.2 knots faster than other vessels of similar size. However, when she was about to pass Point F, she tried to increase the rate of turn by speeding up. And, after passing the berthing pier, *Milano Bridge* again tried berthing. Therefore, the track of avoiding collision after passing Point F was excluded from this comparative analysis.

4.4.3.4 A simple comparison would be difficult as operation conditions at the time, such as weather, vessel drafts, or maneuverability, varied. However, when comparing the process of *Milano Bridge* passing the islet and making a large course change, with those of the other 23 vessels, it turns out that *Milano Bridge* approached at a relatively fast speed, made a late turn, and increased the tactical diameter.

4.4.3.5 Figure 32 compares the track of *Milano Bridge* being normally berthed at Pier No.2 of Busan New Port by a different pilot on 6 December 2019 with the track of this accident on 6 April 2020.



<Figure 32> Comparison between the past track of *Milano Bridge* and the track during the accident

4.4.3.6 The track of *Milano Bridge* on 6 December 2019 when berthing at Busan New Port was like the average track of the other large vessels illustrated in Figure 32. Operating conditions, such as maneuverability or weather, in addition to the draft of 12.7 meters at the time, meaning that her propeller was fully immersed, were different from the conditions during the accident. Still, speeds at the points passing the west breakwater and To Islet at the time were relatively faster than those in the past track and reduced slowly, which increased the tactical diameter according to the analysis.

4.4.4 Conclusion

4.4.4.1 When berthing a vessel after entering the port, a pilot should maneuver her with a sufficient distance by considering the possibility of effects by external forces such as wind and current. When a vessel approaches her berthing pier, a pilot should be able to use auxiliary measures such as tugs or bow thrusters as well as emergency anchoring when necessary. To do that, minimizing speed is desirable so that the pilot has the time and room to take emergency action.

4.4.4.2 However, a comparison and analysis of *Milano Bridge*'s track when entering the port at the time of the accident show that the speed when entering the port in the vicinity of To Islet, an area impossible to make a large course change, was 2.2 to 2.8 knots faster than other vessels of similar size. Most other large vessels slowed their speed to about 3 knots, preparing for auxiliary measures such as tugs until passing the islet, turning starboard, and proceeding to the waters off Pier No.3. *Milano Bridge*, however, increased main engine rpm to accelerate her turn starboard, maintaining a speed of 5-6 knots.

4.4.4.3 The *Milano Bridge* pilot expected that he would have rudder effectiveness earlier and a higher rate of turn if he increased speed when making a large course change. Thus, he chose to increase main engine rpm to accelerate her turning. According to the theory of ship maneuvering, acceleration of speed when stopped will significantly increase turning moment due to the rudder force before creating forward speed, making it possible for a vessel to turn even in a small tactical diameter. However, when a vessel accelerates her speed from a certain level, even if turning moment is increased by the rudder force, her advance caused by forward speed would further increase, ultimately increasing the tactical diameter. In the *Milano Bridge* case, as the vessel turned to starboard at a speed of 9 knots, she started her initial turn late and her advance was increased by forward momentum. Moreover, her maneuverability characteristics, including propulsion and turning ability, were significantly impaired by the propeller exposure at that time (see Paragraph 4.3). Consequently, she left a track with a large tactical diameter.

4.4.4.4 Importantly, the distance from the waters off Pier No.3, where a large course change of 90° ends, to the berthing pier, was only 0.45 miles, which means that in general berthing situations a vessel should reduce the speed enough to use tugs and bow thrusters. However, *Milano Bridge* did not slow down when passing this area. Rather, she again tried to increase main engine rpm to accelerate the turn starboard so that she could avoid a collision with the berthed vessel. In the end, such decision to increase the rpm made it more difficult to take advantage of auxiliary measures, such as tugs or bow thrusters, and even emergency response, such as emergency anchoring.

4.4.4.5 Meanwhile, *Milano Bridge* was close enough to Pier No.3, causing a risk of collision with the berthed vessel. Then, the pilot tried repeatedly to increase the rpm and turn to starboard with her main engine and rudder and to move out into more open space while avoiding a collision. This process was excluded from analysis as it constitutes emergency avoidance actions inevitable to avoid an urgent risk of collision.

4.5 Ship maneuvering simulation

4.5.1 Various vessel maneuvering simulations, including reproducing accident scenes and other possible conditions to avoid collisions,[36] was conducted by using the navigation records stored in the VDR of *Milano Bridge*.

4.5.2 First, the three-dimensional modeling of all of Busan New Port including the accident area was carried out for the simulations. Also, a 3D modeling of *Milano Bridge* was carried out based on her major information, G/A, and draft levels at the time of the accident.

4.5.3 In general, the modeling of the ship maneuverability in simulations applies empirical methods to calculate the forces of the hull, rudder, propeller, and external factors (wind, current, etc.) on the vessel in the equation of motion. For *Milano Bridge*, however, 3.2 meters of her propeller had already been exposed above the waterline.

36) The simulations were conducted by SafeTechResearch Co., Ltd., which the Korea Research Institute of Ships and Ocean Engineering (KRISO), affiliated with the Korea Institute of Ocean Science and Technology (KIOST), established by investing in technology.

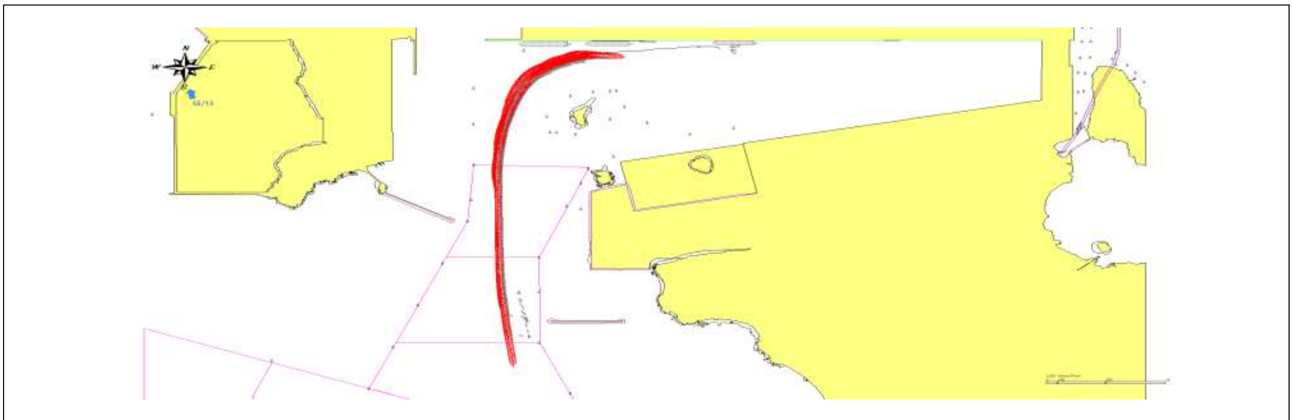
4.5.4 First, the maneuvering performance of the vessel was fine-tuned by applying the recorded data in the VDR to general dynamic models for modelling the propulsion forces of the propeller and the rudder force of the vessel affected by the exposure of the propeller. Next, the engine orders were applied with use of the rudder in order to compare the result of model ship with that of the actual vessel. As a result, the simulation produced a similar result to the recorded data in the VDR.

4.5.5 In the simulations, wind and wave factors were considered sea conditions. Based on the data stored in the VDR at the time of the accident, the wind direction and speed were set at 170° and 13 knots (7 m/s), respectively. As for waves, since the target aea were inside the east and west breakwaters of the port, a significant wave height of 0.5 meters in the same direction as the wind was applied.

4.5.6 The ship maneuvering simulations were carried out in compliance with the steering and engine orders recorded in the VDR. The same number of tugs with the same horsepower as the tugs actually used were assigned to the simulations at the exact time of use as recorded in the VDR.

4.5.7 The simulations were conducted based on the following scenarios: a simulation to represent the accident situation recorded in the VDR; a simulation with no wind; and a simulation with changed draft levels for propeller immersion.

CASE 1. Simulation to represent the accident situation

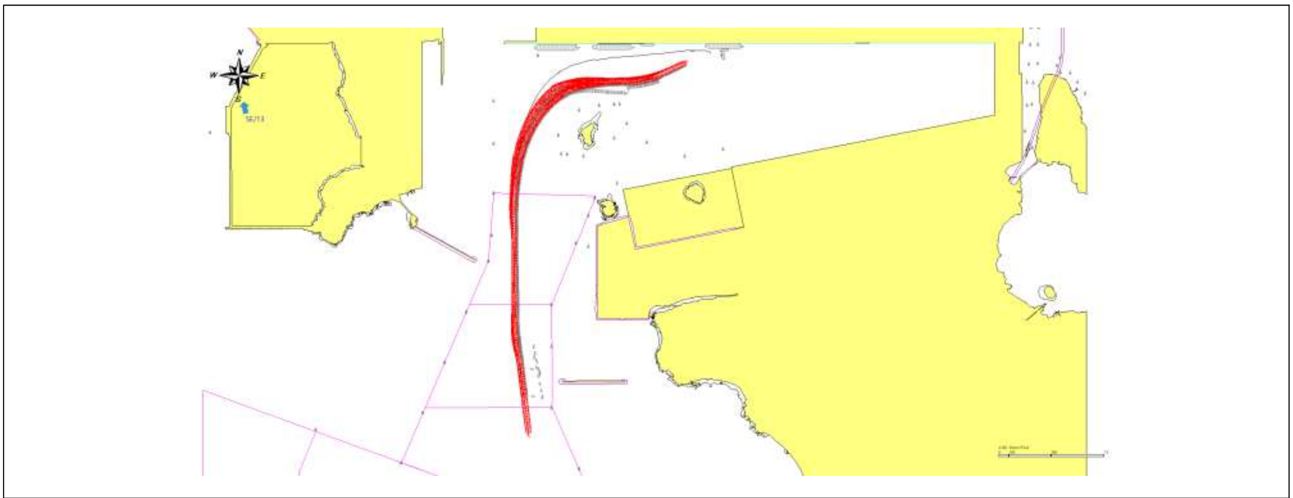


<Figure 33> Track of the simulation

○ This simulation was applied with the same rudder and engine orders, as recorded in the VDR, under the same weather conditions (wind and waves) and draft levels as during the accident. Also, the causal factors, which weakened the propulsion forces and rudder effectiveness of *Milano Bridge* due to her propeller exposure, were reflected in the simulation. The result represented a vessel track almost identical to the one during the accident[37] (a solid line marked in the figure above).

○ While reproducing the trial performance in ballast and the actual track during the accident, ship maneuverability was proven to have been significantly degraded compared with the trial performance after shipbuilding, as the propeller's propulsive efficiency had been weakened due to its excessive exposure.

CASE 2. Simulation with changed draft levels

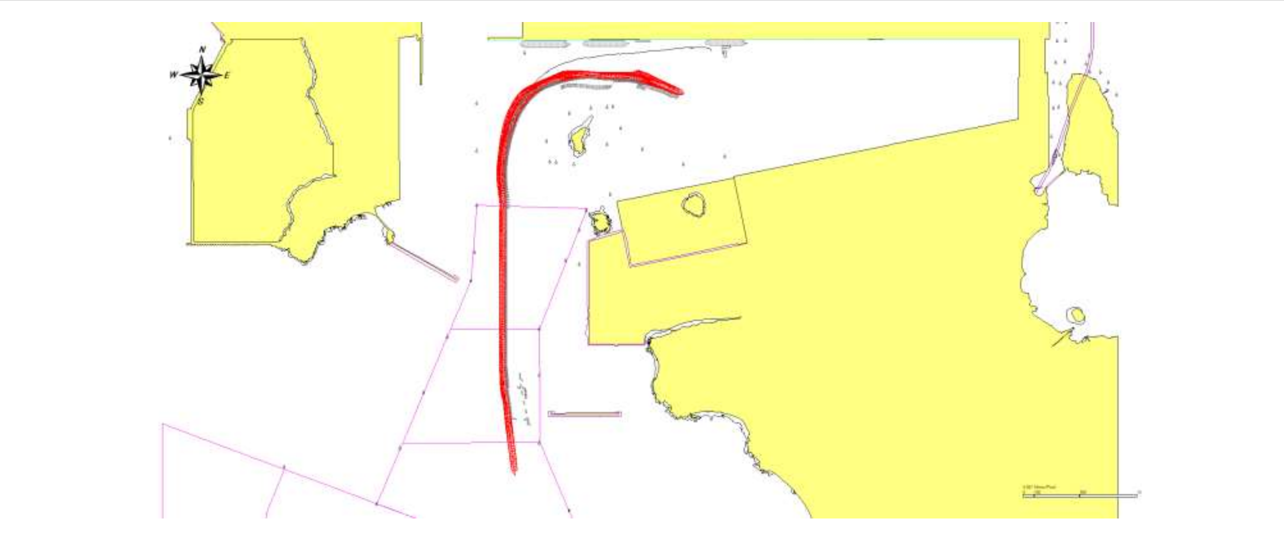


<Figure 34> Track of the simulation

○ Under the same conditions as in Case 1, only the draft was changed, setting the vessel in full ballast where the propeller was 100% immersed. The same rudder and engine orders were used just as recorded in the VDR, while no decrease was made in propulsion forces and rudder effectiveness. As a result, the vessel turned out to be able to secure a safe distance from the pier as her tactical diameter was smaller than that it had been during the accident.

37) In this simulation, it was not possible to exactly reproduce situations from the time when the vessel was close to Pier No.3 to the time when the pilot urgently maneuvered the vessel. However, it is considered that the causal factors of this accident and even the situation where the vessel could not avoid the accident were represented well.

CASE 3. Simulation with no wind



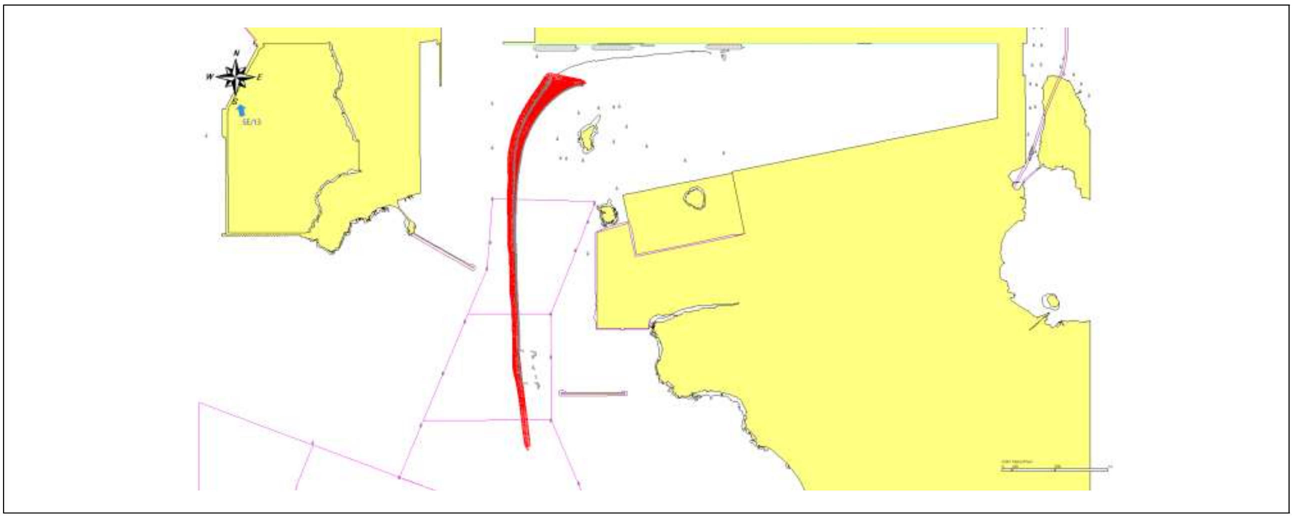
<Figure 35> Track of the simulation

○ In this simulation, the wind factor was removed under the same conditions as in Case 1 (wind speed, reduced from 13 knots to 0). As a result, the track in this simulation presented the vessel getting farther away from Pier No.3, at a distance of 100-150m, two or three times the beam, compared with the track during the accident. In general, a vessel is more affected by external forces, such as wind or current, if she reduces her speed so that she can maintain her maneuverability to the minimum level required for berthing. The result from this simulation was not much different from the facts above.

○ That means the wind *Milano Bridge* faced at her stern before passing To Islet, further affected the ship's movement as the vessel speed reduced to 5 or 6 knots when making a large course alteration to starboard. In addition, the wind blew towards the starboard beam of the hull, proven to add forces to push the vessel towards the pier. However, no significant increase in the windage area[38] occurred, as the vessel had no containers stacked on her deck at the time of the accident. Therefore, the hull is presumed to be pushed as far as 100-150 meters toward the pier by the wind.

38) The gap in the lateral area (LOA×draft) between the average draft (5.7 meters) at the time and the average draft (7.495 meters) during the sea trials in ballast is estimated at about 6.0% of the total lateral area below the upper deck (10,942㎡).

CASE 4. Simulation of port entry at low speed



<Figure 36> Track of the simulation

○ In this simulation, when passing To Islet, the vessel reduced her speed to about 5 knots and made a turn to starboard as recorded in the VDR under the same weather and draft conditions as in Case 1. As a result, the vessel made a 90° change in heading at the mid-point between the quay and the islet.

○ That means if *Milano Bridge* had reduced her speed to about 5 knots while passing the islet, she is presumed to have secured a safe distance from the quay as the vessel would make a 90° change in heading at the mid-point between the quay and the islet, just as the track of the other similar vessels described in Paragraph 4.4.3.

4.5.8 The comprehensive outcome from the ship maneuvering simulations of *Milano Bridge* shows that her maneuverability was significantly improved when the propeller was fully immersed, increasing the possibility of avoiding this accident.[39] It means that maneuverability impaired by propeller exposure was a significant factor in the accident. Even when the vessel reduced her speed when entering the port, it was possible to reduce the risk of an accident as the vessel made a 90° change in heading at

39) These simulations were conducted for qualitative analysis on the causes of the accident. For quantitative analysis, it is necessary to perform a careful modeling of the maneuverability and review the results based on various actual operating results of the vessel conditions during the accident. However, access to the actual data is limited.

the mid-point between the quay and To Islet. Therefore, the fact that *Milano Bridge* maintained a higher speed than she normally does when approaching the islet to make a turn to starboard at the time was determined to increase the accident risk in tandem with the impaired maneuverability.

4.5.9 The risk of a collision was also confirmed to have been increased as the vessel was pushed toward the pier by a southerly wind at the time of the accident. Still, such wind effect was insignificant, and the wind speed did not change much while the vessel was being piloted, making it difficult to point to the wind as a major cause of this accident.

4.6 The master's passage plan and information exchange during piloting

4.6.1 The master is required to appraise all information related to the vessel's navigation or routes (appraisal). A detailed passage plan must be made, executed, and monitored (planning, execution, and monitoring). Such planning must cover the entire voyage from berth to berth, including the pilotage area where the pilot comes onboard.[40].

4.6.2 When a vessel arrive or depart from the port with assistance of a pilot at the pilotage area, the master and the pilot must share information on ship's conditions, maneuverability, and pilotage plans of the vessel and maintain effective communication system so that the vessel can be safely piloted based on the passage plans and the shared information[41].

4.6.3 When it comes to *Milano Bridge*, the master knew the vessel had a draft so low that part of the propeller was above the water since the vessel left the drydock in Zhoushan, China. However, he did not take the exposure of the propeller into account when establishing the passage plan for entering Busan New Port. Also, he did not share with Pilot A his passage plan for berthing or information on the vessel's condition and maneuverability, even after the pilot offered the Master/Pilot

40) IMO Resolution A.893(21) Guidelines for voyage planning

41) IMO Resolution A.960(23) Recommendations on trainings and certification and on operational procedures for maritime pilots other than deep-sea pilots

information exchange checklist.

4.6.4 Before piloting, Pilot A also knew the fact that *Milano Bridge* had a low draft and her propeller was exposed above the waterline. Thus, he upgraded the tugs' horsepower out of concern that the exposed propeller might have impaired maneuverability. Then, he signed the checklist onboard. However, he did not share with the master specific pilotage plans, such as the entry routes and berthing plans in consideration of the vessel's condition and maneuverability.

4.6.5 Pilot A approached the vicinity of To Islet at a 9 knots after taking over the handling of the vessel from the master. Later, the vessel made a large course alteration that took longer than expected. While doing so, the vessel was pushed toward Pier No.3, leading to a dangerous situation where she could collide with the pier or a berthed vessel. In this process, the master did not actively engage in pilotage or offer sufficient feedback, and the pilot also did not ask him for advice. There was no communication between the master and the pilot.

4.6.6 In conclusion, no communication or information was exchanged on the master's passage plan or the pilot's pilotage plan. Without knowing the exact maneuverability of *Milano Bridge*, Pilot A decided to approach the way point, To Islet, at excessive speed and such misjudgment was not corrected. Later, he failed to slow down and took time to turn, which did not allow the pilot enough time and space to use the tugs, bow thrusters, and emergency measures, such as emergency anchoring, right before the accident.

section

5 Conclusions

5. Conclusions

5.1 Inappropriate maneuvering for a vessel entering port with impaired maneuverability due to propeller exposure

5.1.1 The narrow channel between the North Container Terminal and the northern end of To Islet, where *Milano Bridge* was supposed to pass, is 0.42 miles (778 meters) wide, which is very narrow, 2.1 times of her LOA. At the time of the accident, buoys were installed around the islet, as a project was underway to remove it. Containers were being unloaded from a large containership at the pier, which would have made the pilot feel the narrow channel even more narrow. Therefore, high maneuverability and sophisticated pilotage skill were required for the vessel to make a large course change of 90° and safely enter from the west side of the islet.

5.1.2 Meanwhile, *Milano Bridge* was in ballast and maintained her draft forward and aft at 4.5 and 6.9 meters, respectively. She loaded only 4,223 tons of ballast water, 10% of her capacity, exposing 3.2 meters of the propeller above the waterline when entering the port. This low propeller immersion ratio of 68.4% weakened her propulsive efficiency significantly, making maneuverability far lower than during the sea trials in ballast after shipbuilding.

5.1.3 Wind was blowing from the south at 5-9 m/s (Beaufort Wind Scale 4 to 5) at the area where the accident occurred. It was a following wind when *Milano Bridge* proceeded north and approached To Islet. When the vessel turned to starboard and became parallel with the quay, the wind direction then was from the starboard beam, pushing the vessel to port, or in other words, to the pier. Given that, the vessel was required to approach at a distance farther away from the pier.

5.1.4 Despite such circumstances, which required significant attention, the vessel started turning starboard at a higher speed than other vessels do when approaching the islet.

The initial turning was carried out slowly in spite of her high speed, and therefore, the pilot again ordered increase in main engine rpm and used tugs and bow thrusters to increase the rate of turn. When the vessel completed the turn, it was dangerously close to the pier, only 150 meters away.

5.1.5 This means the vessel entered Busan New Port at excessive speed with impaired maneuverability at the time of the accident. While passing To Islet and making a large course alteration toward the berthing pier, her speed remained high to increase the rate of turn, which further increased her advance. These factors are considered among the major causes of this accident.[42]

5.1.6 In fact, after making the turn, the pilot tried to increase vessel speed to increase the rate of turn, which, in turn, maintained her speed at around 6 knots for minutes right before the accident. Such a high speed did not allow the pilot to take auxiliary measures, such as using tugs or bow thrusters, or urgent measures such as emergency anchoring. In this case, it is regrettable in that pilotage within the port requires a pilot to seek and take various emergency measures in advance.

5.2 Insufficient passage plans and emergency response of the master

5.2.1 The *Milano Bridge* master, an expert seaman who had served 23 years as a seafarer and 4 years and 3 months as a master until the day of the accident, had enough expertise and experience to anticipate and respond to the vessel's impaired maneuverability from incomplete propeller immersion. He was capable of setting up the proper passage plan based on the vessel's condition, as he had already been to Busan New Port 4 or 5 times.

5.2.2 The master was already aware that the vessel's propeller was excessively exposed, impairing her maneuverability. Still, he neither prepared passage plans appropriate to

42) It is common for ships to use the 'kick ahead (a technique of instantly increase the main engine power with the hard-over rudder, which will maximize the rudder effectiveness before the vessel makes headway) for a while in order to enhance her turning ability while moving forward at a slow speed within the port. However, if a vessel repeatedly or constantly increases speed with the main engine, she has much headway, increasing the tactical diameter.

enter Busan New Port nor emergency measures to respond to the impaired maneuverability. After Pilot A boarded the vessel, the master appeared to fully depend on him for entering Busan New Port, not offering relevant information to him or sharing opinions with the pilot on the vessel's condition.

5.2.3 Pilots are required to board and maneuver vessels that enter Busan New Port as the port constitutes the compulsory pilotage area under the provisions of Paragraph 1 of Article 20 of the Pilotage Act. However, when the pilotage is considered inappropriate, the master has the authority and responsibility to intervene in the act of pilotage. In addition, if the master is inattentive to the pilotage, he/she shall not be exempt from his/her responsibility for the results due to negligence.

5.2.4 In this regard, the following actions are considered major factors that caused a failure to prevent this accident: the master did not prepare an appropriate passage plan considering the condition and maneuverability of *Milano Bridge*; he depended excessively on Pilot A in the whole process of pilotage to enter and berth at Busan New Port; by doing so, he did not actively engage in pilotage or respond to emergencies; and therefore, he failed to fulfill his authority and responsibilities as a master.

5.3 Pilot's overconfidence and insufficient communication with the master

5.3.1 Pilot A is a highly skilled expert who worked as an officer and master for 25 years and piloted vessels for 11 years at the Port of Busan. Also, he was equipped with enough knowledge and experience to anticipate and respond to the fact that vessel maneuverability would be impaired somewhat when the propeller is exposed above the waterline.

5.3.2 The pilot, noticing in advance that the maneuverability of *Milano Bridge* had been already weakened due to an excessive exposure of her propeller, replaced the tugs with ones that have higher horsepower. However, the pilot did not pay careful attention but simply depended on his experience: he neither observed nor assessed safety measures to figure out whether simply upgrading the tugs' horsepower would be enough to maneuver the vessel effectively. He was also negligent in sharing detailed pilotage plans with the master and did not put sufficient effort in risk assessment.

5.3.3 Without knowing that his preliminary risk assessment was insufficient as mentioned above, Pilot A tried to make a large course alteration starboard while passing To Islet just as usual, which increased the tactical diameter and put the vessel in danger of a collision.

5.3.4 In principle, Pilot A should prepare an appropriate pilotage plan based on the preliminary risk assessment properly conducted on the vessel's condition and maneuverability and support the vessel's safe navigation by maintaining effective communication with the master. However, he failed to fulfill the above-mentioned duties and piloted the vessel just as usual, which is considered to be one of the major reasons this accident was not avoided.

6. Recommendations

6.1 Restrict the port entry of vessel in light condition with propeller exposed

6.1.1 It is recommended that the port authorities set out safety measures, such as using additional tugs or increasing power, or restrict port entry and departure for vessels in light condition having impaired maneuverability due to the propellers exposed above the waterline.

6.2 Set procedures and manuals for safe pilotage

6.2.1 It is recommended that the port authorities and the Korea Maritime Pilots Association should prepare safe pilotage procedures or manuals, including methods of approaching the pier or berthing/unberthing, considering navigational circumstances at port.

6.3 Enhance communication while piloting

6.3.1 Both the master and the pilot should maintain and fully utilize from effective communication to prevent possible accidents while piloting and respond well in emergencies.

6.4 Enhance maneuvering practice by training pilots and masters on a regular basis

6.4.1 It is recommended that the port authorities, the Korea Maritime Pilots Association, and shipping companies regularly provide masters and pilots with vessel maneuvering simulations on various vessel conditions for safe port entry and departure.

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