

Article

Reconsideration of IMO's Maneuvering Performance Standards for Large Fishing Vessels

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Abstract

This study evaluates the applicability and limitations of the International Maritime Organization (IMO)'s maneuvering standards (MSC.137(76)) for large fishing vessels under 100 m in length, which are not currently included in the regulation. Full-scale turning circle, zig-zag, and stopping tests were conducted on three representative vessels—a stern trawler, a purse seiner, and a squid-jigging boat—in accordance with ISO 15016:2015 and ITTC procedures. All the vessels satisfied the IMO criteria for their turning and stopping performance; however, the zig-zag tests revealed distinct differences in directional stability. The stern trawler and purse seiner showed excessive first-overshoot angles, indicating over-reactive yaw responses influenced by the hull form and propulsion–rudder interaction, whereas the squid-jigging boat exhibited very small overshoot angles, reflecting strong yaw damping. These patterns correspond with variations in the block coefficient (C_b), Froude number (F_n), and length-to-breadth ratio L_{BP}/B . Although all vessels met the IMO stopping requirements, their deceleration behavior differed due to their hull fullness and reverse-thrust efficiency. Overall, the findings clearly demonstrate a mismatch between merchant-vessel-based IMO standards and the maneuvering characteristics of fishing vessels, which require agility and frequent low-speed operations. The results provide a basis for refining maneuvering prediction methods and developing assessment criteria tailored to fishing vessel design and operational profiles.



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Keywords: fishing vessels; IMO maneuvering standards; turning circle test; zig-zag test; stopping test; hull form; maneuverability

1. Introduction

Ship collisions remain among the most common types of marine casualties and continue to cause substantial economic losses, human fatalities, and marine environmental damage, as reported by the European Maritime Safety Agency (EMSA) [1]. The steady growth of global maritime traffic has increased the vessel density, particularly in restricted waters and confined channels, thereby elevating the navigational risk. For example, data from the Yangtze River Basin—one of the world's busiest inland waterways—indicate that 59.18% of all marine accidents recorded between 2012 and 2021 were collisions [2]. These statistics demonstrate that collisions remain a major threat to maritime operational safety. Analyses by Zhou et al. [3] support this trend, reporting that collision-type accidents constitute a significant proportion of worldwide maritime casualties. Recent accident statistics from the IMO Global Integrated Shipping Information System (GISIS) Marine Casualties and Incidents (MCI) module reinforce these findings for fishing vessels. A total of 274 fishing vessel accidents were reported in international waters, of which 105 included

publicly accessible investigation reports [4]. Among these, 35 were collisions, 26 were sinkings, 6 were capsizings, and 27 involved work-related injuries, with the remainder categorized as flooding, steering failures, or other incidents. The global statistics illustrate that fishing vessels are consistently exposed to diverse types of casualties, underscoring the importance of establishing dedicated maneuvering assessment criteria tailored to their unique operational and design characteristics.

1.1. Exclusion of Fishing Vessels from IMO Maneuvering Criteria

The IMO adopted resolution MSC.137(76) in 2002 to ensure adequate ship maneuverability, establishing performance criteria for the turning ability (advance, tactical diameter), the yaw-checking and course-keeping ability (overshoot angle), and the stopping ability (track reach and time to stop) [5]. These criteria apply primarily to powered merchant vessels of 100 m or more in length (L_{BP} , length between perpendiculars)—such as cargo ships, tankers, and gas carriers—and compliance is verified through full-scale sea trials conducted during the commissioning of newly built ships. However, according to the Food and Agriculture Organization (FAO)'s global record of fishing vessels, the average L_{BP} of fishing vessels worldwide is approximately 35–45 m [6]. Consequently, most fishing vessels fall outside the scope of the IMO maneuvering standards, and no internationally recognized framework currently exists for assessing maneuvering safety at the design stage for this vessel category. Fishing vessels are also known to have the highest fatality rates among all maritime sectors. The International Labour Organization (ILO) reports that nearly 24,000 fishers lose their lives each year due to capsizing, collisions, falls overboard, and other incidents [7], and the fatality rate of commercial fishers has been estimated to be up to 28 times higher than the average across all industries [8]. Previous studies have further indicated that many of these accidents arise not only from human factors, but also from inherent limitations in the structural design and maneuvering characteristics of fishing vessels. For instance, Sviličić et al. [9] noted that “maneuverability is one of the key determinants influencing the likelihood of collision accidents,” while Míguez González et al. [10] emphasized that the structural and operational constraints of small fishing vessels significantly contribute to accident occurrence. Collectively, these findings underscore the critical need to quantitatively understand fishing vessel maneuvering characteristics and to incorporate them into design and operational guidelines to enhance maritime safety in the fishing sector.

1.2. IMO Maneuvering Performance Criteria

According to the IMO [5], the evaluation of a ship's maneuvering performance is categorized into three principal criteria: the turning ability, the yaw-checking and course-keeping ability, and the stopping ability. First, the turning ability assesses a vessel's capability to change its heading when the rudder is set to its maximum angle, using non-dimensional parameters such as the advance and $Tac. Dia.$ (tactical diameter) normalized by the ship's length. Second, the yaw-checking and course-keeping ability is evaluated through the zig-zag test, with the overshoot angle indicating both the promptness of the response to rudder commands and the effectiveness of the turning motion control after counter-rudder input. Third, the stopping ability is determined from the crash-stop astern test, which measures the track reach (distance from full ahead to complete stop) and the time to stop following a full-astern command, thereby reflecting the vessel's emergency stopping capability and responsiveness.

The IMO further specifies that the maneuvering tests must satisfy certain validity requirements to ensure a reliable comparison with the MSC.137(76) criteria [5]. The tests should be conducted in deep and unrestricted waters, under calm environmental conditions,

and with the vessel at a full-load draft and an even-keel trim. The approach speed should be close to the designated test speed. The results are considered valid for comparison only when all the prescribed validity conditions are satisfied (see Table 1).

Table 1. Criteria of IMO standards.

Merchant Vessels	Criteria
Turning ability	Advance < 4.5 L, Tac. Dia. < 5.0 L
Yaw-checking ability and course-keeping ability	(1) 10°/10° zig-zag test ☐ 1st overshoot angle • 10°, if L/V is less than 10 s • 20°, if L/V is 30 s or more • $(5 + 1/2(L/V))^\circ$, if L/V is 10 s or more, but less than 30 s ☐ 2nd overshoot angle • 25°, if L/V is less than 10 s • 40°, if L/V is 30 s or more • $(17.5 + 0.75(L/V))^\circ$, if L/V is 10 s or more, but less than 30 s
Stopping ability	(2) 20°/20° zig-zag test 1st overshoot angle < 25° Track reach < 15 L; this value may be modified by the administration, but should in no case exceed 20 L

1.3. Research Trends and Limitations in IMO Maneuverability Studies

Recent studies related to the IMO maneuverability standards have mainly focused on merchant vessels. For instance, Sutulo and Guedes Soares [11] reviewed the IMO maneuverability criteria by considering environmental influences and evaluating the adequacy of the calm-water assumptions. Sarigul et al. [12] investigated the maneuvering performance of naval ships under non-calm-water conditions, while Shigunov et al. [13] examined the limitations of the existing IMO maneuverability standards for merchant vessels. Furthermore, Maljković et al. [14] analyzed the applicability of the IMO maneuverability standards to merchant vessels operating in shallow-water and confined-channel environments. Despite these efforts, most research has concentrated on merchant or naval vessels, and the research specifically addressing fishing vessels remains limited. Significant gaps persist in understanding how the IMO maneuverability standards apply to vessels with fundamentally different hull forms, propulsion characteristics, and operational profiles. Therefore, the present study sought to analyze the full-scale maneuvering test results of large fishing vessels in relation to the IMO criteria and to identify potential improvements for developing assessment standards tailored to the unique characteristics of fishing vessels.

2. Applicability and Limitations of IMO Maneuverability Standards for Fishing Vessels

2.1. Comparison of Maneuvering Characteristics Between Merchant and Fishing Vessels

The IMO maneuverability standards [5] were primarily established for merchant vessels to ensure a sufficient level of maneuvering response and stability in course-keeping, which must be verified during the design stage. However, merchant vessels and fishing vessels exhibit fundamental structural and hydrodynamic differences. Consequently, applying the same criteria to both vessel types may result in substantial variations in the maneuvering performance due to differences in the hull form, mass properties (such as the displacement of inertia), propulsion arrangements, and operational requirements.

Representative merchant vessel types—namely bulk carriers, very large crude carriers (VLCCs), and container ships—were selected and are summarized in Table 2. The merchant vessel group included in Table 2 falls within the scope of the IMO maneuverability stan-

dards and exhibits hull-form characteristics optimized for cargo-carrying efficiency and service speed. As shown in Table 2, merchant vessels typically have a high C_b (0.65–0.83), a large L_{BP}/B (5.52–7.14), and an extremely large Δ (4.5×10^4 – 3.1×10^5 tons). Such hull-form parameters substantially increase the inertia and added mass of large hulls, thereby reducing their responsiveness during turning and stopping maneuvers.

Table 2. Dimensions of merchant vessels.

Merchant Vessels	A	B	C
Type	Bulk Carrier	VLCC	Container
L_{BP} (m)	280.0	320.0	230.0
B (m)	45.0	58.0	32.2
d (m)	18.0	20.8	10.8
Δ (ton)	44,900	312,600	52,030
C_b (-)	0.83	0.80	0.65
L_{BP}/B (-)	6.22	5.52	7.14
$1 - C_b$ (-)	0.20	0.19	0.35
$(1 - C_b)(L_{BP}/B)$ (-)	-4.51	-3.47	-3.64
$B(1 - C_b)L_{BP}$ (-)	0.03	0.03	0.05
$d(1 - C_b)/B$ (-)	0.07	0.07	0.12

Notes: L_{BP} = length between perpendiculars; B = breadth; d = draft; Δ = displacement; C_b = block coefficient; L/B = ratio of length between perpendiculars to breadth; $1 - C_b$ = hull fineness parameter; $(1 - C_b)(L_{BP}/B)$ = combined slenderness–fineness index; $B(1 - C_b)L_{BP}$ = breadth-normalized fineness parameter; and $d(1 - C_b)/B$ = draft–breadth fineness ratio.

To quantitatively illustrate how these hull-form differences influence the maneuvering hydrodynamics, four non-dimensional maneuverability indices ($1 - C_b$, $1 - C_b(L_{BP}/B)$, $B(1 - C_b)/L_{BP}$, and $d(1 - C_b)/B$) are also presented in Table 2. For merchant vessels, these indices consistently showed low values, indicating that hulls with a high C_b and large mass moments of inertia are generally oriented toward achieving a superior course-keeping stability rather than a rapid maneuvering response.

In contrast, the three large fishing vessels presented in Table 3 (F1: stern trawler, F2: purse seiner, and F3: squid-jigging boat) exhibit structurally distinct hull forms, reflecting the operational demands for frequent turns and rapid deceleration. The hull-form proportions of the fishing vessel group are consistent with international fishing vessel design studies, such as those reported by the JICA [15]. These vessels typically have a low C_b (0.42–0.48), a short L_{BP}/B (4.67–5.82), and a relatively small Δ (1280–3374 tons). Moreover, their high power-to-displacement ratios ($P/\Delta = 1.00$ – 1.44 kw/ton) contribute to an enhanced maneuvering responsiveness.

Table 3. Dimensions of fishing vessels.

Fishing Vessels	F1	F2	F3
Type	Stern trawler	Purse seiner	Squid-jigging boat
L_{BP} (m)	64.5	72.5	64.0
B (m)	13.8	14.5	11.0
d (m)	4.9	6.7	4.3
Δ (ton)	2082.5	3374.0	1280.3
C_b (-)	0.48	0.48	0.42
L_{BP}/B (-)	4.67	5.0	5.82
$1 - C_b$ (-)	0.52	0.52	0.58
$1 - C_b(L_{BP}/B)$ (-)	-1.23	-1.39	-1.46
$B(1 - C_b)/L_{BP}$ (-)	0.11	0.10	0.10
$d(1 - C_b)/B$ (-)	0.19	0.24	0.23
P (kw)	3000	3269	1323.9
P/Δ (kw/ton)	1.440	0.969	1.030
Propeller type	FPP	FPP	FPP
Propeller No. of blades	4	5	4

Notes: P = engine power (kw); P/Δ = power-to-displacement ratio (kw/ton).

The four non-dimensional maneuverability indices introduced in this study exhibit substantially higher values for fishing vessels, indicating a superior initial turning response, but a reduced directional stability, rendering these vessels more sensitive to external disturbances. Yoshimura and Ma [16] attributed these characteristics to the inherently short L_{BP} , low L_{BP}/B , and pronounced stern trim—features that increase the nonlinearity of the maneuvering hydrodynamic forces and lead to maneuvering behaviors that are distinct from those of merchant vessels.

Figure 1 visually compares the relationship between C_b and L_{BP}/B for merchant vessels (Table 2) and fishing vessels (Table 3), clearly illustrating that the two vessel types form distinctly separated clusters. Merchant vessels are concentrated in the region of a high C_b and a large L_{BP}/B , whereas fishing vessels are distributed in the region of a low C_b and a low L_{BP}/B , resulting in clearly distinguishable clustering patterns.

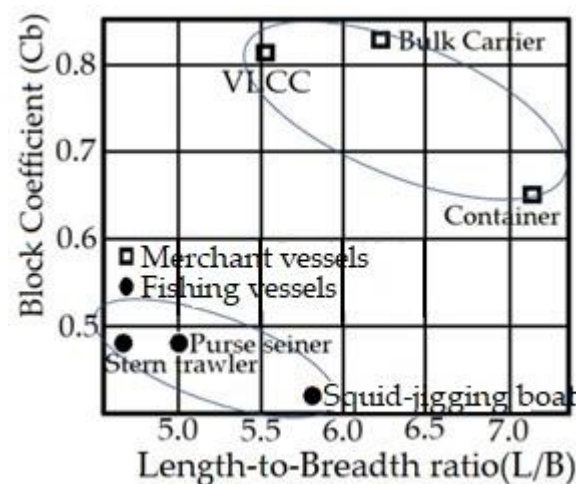


Figure 1. Relationship between the C_b and L/B of the model ships. Notes: Blue ellipses are used to visually group the representative parameter regions of merchant ships and fishing vessels for comparison.

Due to these structural and hydrodynamic differences, applying the same IMO maneuverability standards to both vessel types inevitably leads to markedly different test outcomes. For instance, the overshoot angle and track reach specified in the IMO criteria are based on the inertial characteristics of large merchant vessels [5]. Applying these criteria to fishing vessels—which typically have a short L_{BP} , low inertia, and a high P/Δ —may result in excessively rapid turning responses or unstable deceleration behavior [17]. In other words, the IMO criteria may lead to evaluations of over-responsiveness or an unstable stopping performance for fishing vessels. Thus, maneuvering standards that were formulated primarily around the characteristics of merchant vessels do not adequately reflect the geometric proportions, propulsion configurations, or operational environments of fishing vessels. This highlights the necessity for a dedicated maneuvering performance assessment framework tailored specifically to fishing vessels.

2.2. Environmental and Loading Conditions of Maneuvering Trials

Although each maneuvering trial for the three vessels was conducted only once for each test type, each trial fully satisfied the environmental and operational conditions specified in ISO 15016:2015 and the ITTC's recommended procedures for maneuvering trials [18]. According to these guidelines, external disturbances such as wind, waves, and current must remain within limits that do not significantly influence the ship motion. During the present trials, the wind speed remained below 12 m/s, corresponding to a Beaufort Sea state of 1–2, and no noticeable swell or cross-sea effects were observed. The environmental conditions recorded during the trials fell within the acceptable range for

an IMO maneuvering performance evaluation, ensuring that the measured responses predominantly reflected the inherent hydrodynamic characteristics of the vessels rather than environmental interference.

All experiments were conducted in sufficiently deep water ($h/T > 4$), effectively eliminating shallow-water effects on the turning, zig-zag, and stopping maneuvers. Each vessel was tested in a stable loading condition close to its typical operating configuration, with an appropriate trim and draft confirmed before the trials. Therefore, the maneuvering data obtained from the trials represent valid and reliable measurements that conform to the IMO MSC.137(76) standards and provide a robust basis for evaluating the maneuvering performance of the three vessels.

2.3. Research Objective and Target Vessels

Fishing vessels exhibit fundamentally different operational characteristics from merchant vessels due to their fishing methods, gear arrangements, propulsion configurations, and hull-form designs. Nevertheless, most countries lack an international standard for systematically evaluating the maneuvering performance of fishing vessels. In particular, fishing vessels under 100 m in length (L_{BP}) are excluded from the IMO MSC.137(76) standards, resulting in many vessels being constructed without clear guidance during the design stage. This absence of a fishing-vessel-specific regulatory framework, combined with the structural and operational features unique to fishing vessels, has been identified as a contributing factor to maneuvering-related safety issues and the disproportionately high incidence of marine accidents. The IMO MSC.137(76) standards were originally developed for merchant vessels exceeding 100 m (L_{BP}), and the criteria for the turning ability, course-keeping ability, and stopping ability were established based on the inertial and hydrodynamic characteristics of large merchant vessels [5].

However, fishing vessels differ significantly from merchant vessels in terms of their hull geometry and propulsion configuration. They typically have a short L_{BP} , a high P/Δ , a low C_b , and a single-screw arrangement, all of which generate maneuvering characteristics that are not fully compatible with the merchant-vessel-based IMO MSC.137(76) standards. The mismatch between fishing vessel hydrodynamic properties and the merchant-vessel-oriented IMO criteria is even more pronounced for small and medium-sized fishing vessels, whose low displacement, shallow draft, and high sensitivity to waves, wind, and currents result in maneuvering responses dominated by nonlinear hydrodynamic and environmental effects. Consequently, directly applying the IMO criteria to small and medium-sized fishing vessels may lead to inaccurate or unreliable evaluations.

Nevertheless, the IMO MSC.137(76) standards remain a useful reference framework for comparing and interpreting the maneuvering performance. The IMO criteria allow structural differences between fishing vessels and merchant vessels to be quantitatively assessed and provide a baseline for evaluating the extent to which the current criteria capture the maneuvering characteristics of fishing vessels. In particular, large fishing vessels (approximately 60–100 m in L_{BP}) offer a practical representative group for examining the applicability of the IMO standards because, unlike smaller vessels, their larger displacement, greater inertia, and reduced sensitivity to environmental disturbances enable more stable and repeatable maneuvering trials under the calm, deep-water conditions required by IMO testing procedures. Therefore, the present study focused on large fishing vessels to investigate the applicability and limitations of the IMO criteria and to provide foundational insight for developing maneuvering performance standards tailored to fishing vessels, differentiated by vessel size and fishing operation type.

Accordingly, three representative types of large fishing vessels were selected as the research subjects: F1, F2, and F3. The classification of these vessel types is consistent with

the FAO's international definitions of fishing vessel categories [19]. The three selected vessels (F1, F2, and F3) were selected because they exhibit distinctly different operational characteristics—towing operations, high-speed purse seine operations, and rapid turning during short-range navigation, respectively—making them suitable for conducting a comparative analysis of maneuvering behavior. The stern trawler employs a large-diameter, low-pitch propeller to provide towing power, resulting in superior deceleration and astern thrust performance [16]. The large purse seiner features hull proportions and block coefficients optimized for high-speed navigation, providing an excellent forward propulsion performance, but a potentially reduced deceleration capability during sudden stop maneuvers, consistent with the operational characteristics described in the *MCS Practitioner Guide* [20]. The squid-jigging boat generally adopts a slender hull form and a large rudder area ratio, enabling rapid turning and fast heading-change responses.

In this study, turning circle tests (turning ability), zig-zag tests (course-keeping ability), and stopping tests (stopping ability) were conducted for the three vessels, and the resulting maneuvering performance metrics were compared against the IMO MSC.137(76) standards to evaluate compliance and identify limitations. Furthermore, differences between fishing vessels and merchant-vessel-oriented criteria were analyzed to inform the development of dedicated maneuverability standards for fishing vessels. The findings not only provide an assessment of the IMO standards' applicability to large fishing vessels, but they also supply foundational data for developing prediction and verification models at the design stage and for establishing size- and operation-type-specific maneuvering criteria for fishing vessels.

3. Maneuvering Performance of Target Vessels

3.1. Turning Circle Tests

Turning circle tests were carried out on the three fishing vessels (F1–F3) at a rudder angle of $\pm 35^\circ$, and the results are summarized in Table 4. All the vessels satisfied the IMO maneuverability standards [5]. The results indicate that the advance values of F1–F3 ranged from 54% to 78% of the IMO criterion (4.5 L), while the tactical diameter ranged from 58% to 68% of the IMO criterion (5.0 L). The turning performance measurements obtained from the tests demonstrated that all the test vessels exhibited a turning performance well within 80% of the standard limits, confirming their excellent maneuverability characteristics (see Tables 5 and 6 and Figures 2 and 3).

Table 4. Environmental and loading conditions during maneuvering trials.

Target Vessels	Weather	Wind Direction	Wind Speed (m/s)
F1 (stern trawler)	Cloudy	NNE	8~12
F2 (purse seiner)	Fine	NE	2~6
F3 (squid-jigging boat)	Fine	NW	2~3

Table 5. Value of turning circle tests of target vessels.

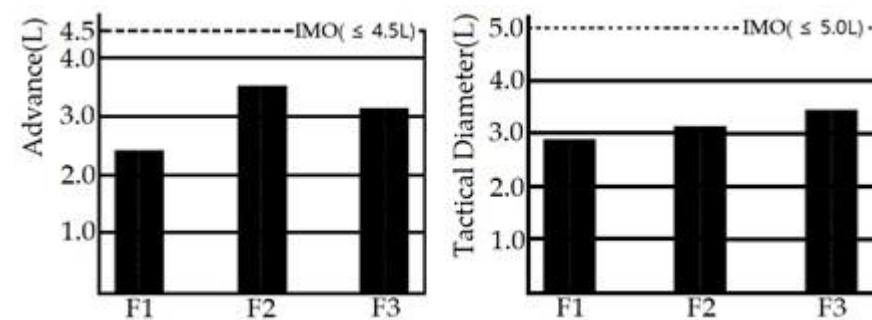
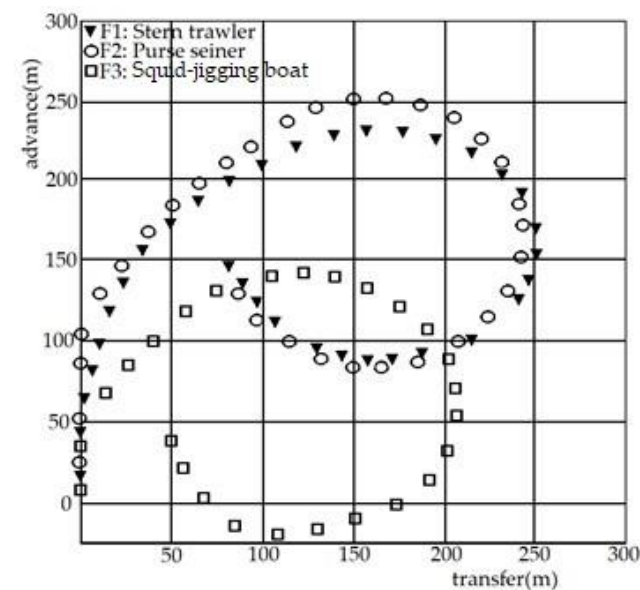
Target Vessels	Starboard Turn			
	Advance (L)	IMO Criteria (L)	Tac. Dia. (L)	IMO Criteria (L)
F1 (stern trawler)	2.43	4.5	2.91	5.0
F2 (purse seiner)	3.55	4.5	3.16	5.0
F3 (squid-jigging boat)	3.15	4.5	3.44	5.0

Notes: *Advance* = distance traveled in original heading direction until the ship reaches a 90° change in heading. *Tac. Dia.* = tactical diameter; defined as the maximum transverse distance traveled by the ship when the heading changes by 180° during a turning maneuver.

Table 6. Initial trial speed and corresponding Froude number for the turning circle tests.

Target Vessels	Starboard Turn			
	C_b (-)	L_{BP} (m)	Trial Speed (m/s)	F_n (-)
F1 (stern trawler)	0.48	64.5	7.9	0.317
F2 (purse seiner)	0.48	72.5	8.6	0.326
F3 (squid-jigging boat)	0.42	64.0	5.9	0.238

Notes: Trial speed = the steady approach speed immediately before initiating the starboard turning maneuver. F_n = the Froude number; calculated as $F_n = U / \sqrt{gL_{bp}}$.

**Figure 2.** Comparison of advance and tactical diameter of target vessels.**Figure 3.** Comparison of turning circle tests of target vessels.

The turning circle test results were further examined with respect to the hull-form parameters and the F_n of each vessel. According to Kijima and Nakiri [21], the non-dimensional Tac. Dia. can be approximated by a linear function of the C_b and the F_n , expressed as follows:

$$\text{Tac. Dia.}/L_{BP} = a + bC_b + cF_n, \quad (1)$$

indicating that increases in C_b and F_n generally lead to a larger Tac. Dia. The full-scale results obtained in this study closely follow this empirical trend. The stern trawler, F1, with a C_b of 0.48 and a moderate F_n (0.317), exhibited the smallest Tac. Dia. (2.91 L). F2, which had the same C_b (0.48), but the highest F_n among the three vessels ($F_n = 0.326$), showed a larger tactical diameter (3.16 L). The squid-jigging boat, F3, with the lowest C_b (0.42) and the lowest F_n (0.238), exhibited the largest Tac. Dia. (3.44 L).

The ordering of the turning performance was $F1 < F2 < F3$ in terms of the Tac. Dia. This confirms the dependence on C_b – F_n proposed by Kijima and Nakiri [21]. The individual turning characteristics also reflect each vessel's operational design objectives. F1, designed for towing, uses a wide stern and a large-diameter, low-pitch propeller, resulting in a high rudder effectiveness and a rapid rotational response at low speeds. F2, optimized for high-speed transit, features a slender hull and exhibits a smooth, but slower, turning behavior due to the increased added mass and yaw moment of inertia. F3, designed for frequent rapid heading changes, has the lowest C_b , a large rudder area ratio, and a small propeller diameter, enabling an excellent yaw responsiveness. Although all vessels satisfied the IMO criteria, the differences in the turning behavior clearly reflect their design intent and hydrodynamic characteristics. The turning performance trends identified in this study are consistent with both the empirical relationship found by Kijima and Nakiri [21] and the full-scale observations reported by Lee et al. [22], demonstrating that a lower C_b promotes a faster turning response, whereas a higher F_n tends to increase the turning stability.

3.2. Zig-Zag Tests

Full-scale zig-zag tests were conducted for the three fishing vessels (F1–F3), and the results are summarized in Table 7. The L/V values of the vessels ranged from 5.9 s to 8.4 s, all of which were below 10 s. Therefore, the category of the IMO MSC.137(76) standards that applies to vessels with an L/V of less than 10 s was used for the evaluation. Under the IMO zig-zag criteria for this category, the first overshoot angle in the 10°/10° zig-zag test must not exceed 10°, and the second overshoot angle must not exceed 25°. For the 20°/20° zig-zag test, the first overshoot angle must be 25° or less to satisfy the IMO requirements (see Table 8).

Table 7. Value of zig-zag tests of target vessels.

Target Vessels	L/V (sec)	10°/10° Zig-Zag Test		20°/20° Zig-Zag Test
		1st Overshoot Angle (°) /IMO Criteria (°)	2nd Overshoot Angle (°) /IMO Criteria (°)	1st Overshoot Angle (°) /IMO Criteria (°)
F1 (stern trawler)	8.3	11.8/10.0	24.4/25.0	25.1/25.0
F2 (purse seiner)	8.4	13.4/10.0	15.8/25.0	22.7/25.0
F3 (squid-jigging boat)	5.9	3.5/10.0	5.0/25.0	11.0/25.0

Notes: L/V = length-to-speed ratio, representing the time required for the ship to travel a distance equal to its own length; overshoot angle = the excessive heading deviation occurring after the counter-rudder is applied, representing the ship's yaw-checking and course-keeping ability in a zig-zag test.

Table 8. Initial trial speed and corresponding F_n for the zig-zag tests.

Target Vessels	Zig-Zag Test			
	C_b (-)	L_{BP} (m)	Trial Speed (m/s)	F_n (-)
F1 (stern trawler)	0.48	64.5	7.72	0.307
F2 (purse seiner)	0.48	72.5	8.44	0.316
F3 (squid-jigging boat)	0.42	64.0	5.92	0.236

All three vessels demonstrated an excellent turning performance, with the turning circle parameters remaining below 80% of the IMO limits. However, the zig-zag test results revealed distinct maneuvering characteristics among the vessel types. As shown in Figures 4 and 5 and Table 7, F1 and F2 exceeded the IMO first-overshoot angle criterion in the 10°/10° zig-zag test, indicating that vessels with a high turning agility tend to exhibit excessively rapid initial yaw responses—a reflection of the inherent trade-off between agility and directional stability. In contrast, F3 showed overshoot angles far below the IMO

criteria (3.5° , 5.0° , and 11.0°), resulting in maneuvering behavior that was significantly more stable than required. The performance pattern observed for F3 indicates that, although F3 formally satisfies the IMO criteria, the standard may not adequately represent the typical maneuvering characteristics of vessels with exceptionally high yaw damping and low inertial effects.

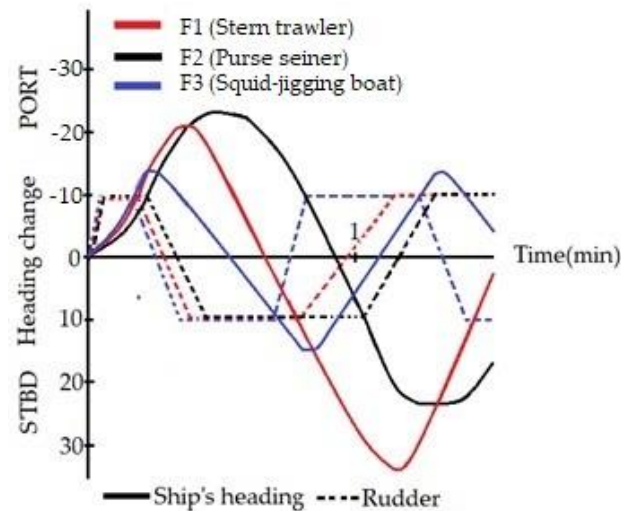


Figure 4. 10°/10° zig-zag test results of target vessels.

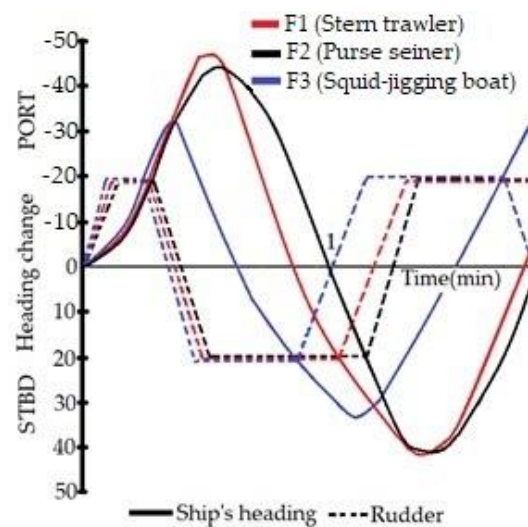


Figure 5. 20°/20° zig-zag test results of target vessels.

The overshoot exceedance of F1 and F2 can be explained by their hull-form and hydrodynamic properties—a strong rudder–propeller interaction in F1 due to its wide stern form and increased initial yaw acceleration in F2 caused by its highest F_n (0.326) and larger yaw moment of inertia. Conversely, F3's exceptionally low overshoot angles are attributed to its lowest block coefficient ($C_b = 0.42$), small mass moment of inertia, large rudder area ratio, and strong yaw damping. The contrasting overshoot responses observed among the three vessels are consistent with the hydrodynamic tendencies described by Kijima and Nakiri [21], and further highlight that the IMO overshoot criteria do not fully represent the behavior of highly maneuverable fishing vessels such as F3. In summary, F1 and F2 exceeded the overshoot limits due to hull-induced agility, whereas F3's values were so low that its response characteristics demonstrate the limited applicability of the IMO standards to this vessel category.

3.3. Stopping Tests

Full-scale stopping tests were conducted for the three fishing vessels (F1–F3), and the results are summarized in Table 9. Each test was performed from the vessel's full-ahead condition, measuring the elapsed time and track reach from the moment the “full astern” order was given until the ship's speed reduced to zero. According to the IMO maneuverability standard (IMO MSC.137(76)), the minimum stopping distance (track reach) should not exceed 15 L.

Table 9. Value of stopping tests of target vessels.

Target Vessels	L_{BP} (m)	Initial Speed (kt)	Time When Speed = 0 (s)	Track Reach (m)	Track Reach (L)
F1 (stern trawler)	64.5	16.1	60.0	300.3	4.6
F2 (purse seiner)	72.5	17.1	195.0	1006.8	13.8
F3 (squid-jigging boat)	64.0	11.8	113.0	402.0	6.2

The full-scale stopping tests for the three vessels are summarized in Figure 6 and Table 9. All the vessels satisfied the IMO stopping criterion (track reach ≤ 15 L), demonstrating an acceptable braking capability under standardized conditions. However, substantial differences were observed in the stopping distance and time among the three vessel types, reflecting their distinct propulsion configurations and hull-form characteristics. F1 recorded the shortest stopping distance (4.6 L) and the fastest stopping time of 60 s at an initial speed of 16.1 kt. In contrast, F2 exhibited the longest stopping track reach (13.8 L) with a stopping time of 195 s, while still satisfying the IMO limit. F3 demonstrated intermediate behavior, with a track reach of 6.2 L and a stopping time of 113 s, corresponding to approximately 41% of the allowable IMO limit. The stopping performance measurements obtained from the trials indicate that, although all the vessels met the IMO criteria, their deceleration characteristics varied significantly depending on their hull-form parameters, inertia, and astern thrust performance.

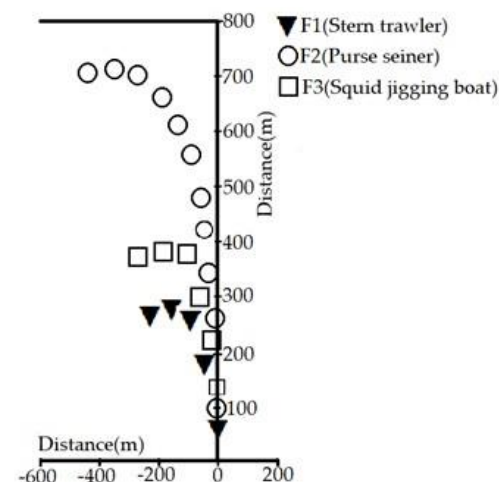


Figure 6. Stopping test results of target vessels.

The superior braking performance of F1 can be attributed to its maneuver-oriented propulsion system and stern wake characteristics. Its large-diameter, low-pitch propeller generates a strong astern thrust and rapid wake-flow reversal, while its moderate C_b (0.48) increases the hydrodynamic resistance during astern operation, thereby accelerating deceleration. The braking pattern observed for F1 is also consistent with the flow-field characteristics around modern commercial ship hulls reported by Kim et al. [23], which highlight the role of stern wake behavior in determining the deceleration response and

thrust-reversal efficiency. As a result, its stopping distance corresponds to only 31% of the IMO limit. In contrast, F2 recorded the longest stopping distance due to its propulsion-efficiency-oriented hull form. Its higher L_{BP}/B (5.0), larger added-mass effects, and slender mid-body geometry delay flow reversal and reduce the effectiveness of rudder-induced braking. Moreover, its high-pitch propeller and single-screw arrangement limit the reverse-thrust efficiency, resulting in a prolonged stopping time. F3, with the lowest C_b (0.42) and a smaller mass moment of inertia, exhibited moderate, but effective, braking behavior. Its slender hull promotes rapid wake-flow reversal, and its large rudder area ratio contributes to enhanced hydrodynamic braking. However, as in the zig-zag test, the stopping performance of F3 was substantially better (much shorter) than the IMO threshold, suggesting that the merchant-vessel-based IMO stopping criterion may not fully represent the maneuvering characteristics of highly responsive small- to mid-sized fishing vessels. Overall, the results reflect general hydrodynamic principles: vessels with higher block coefficients and a larger inertia tend to experience longer stopping distances [13], whereas those with a lower C_b and a smaller inertia decelerate more rapidly. The results from the full-scale tests confirm this tendency, with F2 showing the slowest and F1 the fastest stopping response among the three.

3.4. Relationships Between Hull-Form Parameters and Maneuvering Performance

A comparative assessment of the main hull-form parameters— C_b , L_{BP}/B , and P/Δ —together with the full-scale maneuvering test results revealed that differences in the hull geometry and propulsion characteristics significantly influence the turning ability, course-keeping stability, and stopping performance (see Table 10).

Table 10. Hull-form parameters and maneuvering performance indices of the target vessels.

Target Vessels	C_b (–)	L_{BP}/B (–)	P/Δ (kW/ton)	Advance/L (–)	Tac. Dia./L (–)	10° Overshoot (°)	Track Reach/L (–)
F1 (stern trawler)	0.48	3.21	0.126	2.43	2.91	11.8	4.6
F2 (purse seiner)	0.48	5.03	0.183	3.55	3.16	13.4	13.8
F3 (squid-jigging boat)	0.42	3.56	0.148	3.15	3.44	3.5	6.2

Notes: Advance/L = distance traveled in the original heading direction until the vessel reaches a 90° change in heading, non-dimensionalized by ship length (L); Tac. Dia./L = maximum transverse distance traveled when the heading changes by 180° during a turning maneuver, non-dimensionalized by L; 10° zig-zag overshoot angle = first overshoot angle measured in the 10°/10° zig-zag test; Track Reach/L = longitudinal distance traveled from full ahead to complete stop during the crash stop test, non-dimensionalized by L.

Regarding C_b , F1 and F2 share the same value ($C_b = 0.48$), whereas F3 exhibits a more slender hull form with a lower block coefficient ($C_b = 0.42$). As theoretically expected, the smaller C_b of F3 contributed to an improved yaw responsiveness, which was reflected in its relatively small Tac. Dia./L. However, no consistent correlation was found between C_b and the track reach/L, suggesting that its stopping performance is governed more by the propeller pitch ratio, astern thrust efficiency, and stern arrangement than by the hull fullness alone. The influence of L_{BP}/B was also evident. F2, with its distinctly slender configuration ($L_{BP}/B = 5.03$), showed an increased advance/L (3.55) and Tac. Dia./L (3.16), indicating a reduced initial turning capability compared with F1 and F3, both of which had moderate L_{BP}/B values (3.21–3.56). Notably, F1 demonstrated the smallest advance/L (2.43), highlighting the favorable effect of a wider beam in generating lateral forces during helm application. The P/Δ further distinguished the vessels: F2 exhibited the highest $P/\Delta = 0.183$ kW/ton, which enhanced the rudder effectiveness at low speeds and partly compensated for the drawbacks of its large L_{BP}/B . Although F1 had the lowest P/Δ , its strong turning response suggests that hull-form characteristics exert a more dominant influence than propulsion power in determining the maneuvering performance.

Differences among the vessels were also pronounced in the zig-zag overshoot angles and stopping indices. The 10° first-overshoot angle showed a clear contrast: F2 exhibited the largest value (13.4°), indicating a reduced course-keeping stability, whereas F1 showed a moderate overshoot (11.8°) and F3 recorded a very small value (3.5°), implying a strong directional stability, but a potentially slower initial helm response. The stopping performance exhibited the greatest variation. F2 demonstrated an exceptionally long track reach/ L (13.8), likely due to the combined effects of the slender-hull inertia, a propeller designed primarily for forward efficiency, and weak astern thrust characteristics. In contrast, F1 (4.6) and F3 (6.2) achieved considerably shorter stopping distances, again indicating that the stopping capability depends more on the propulsion layout and stern gear configuration than on hull-form coefficients alone. Taken together, the overshoot and stopping performance patterns indicate that C_b and L_{BP}/B primarily influence the turning performance, whereas the course-keeping and stopping behavior vary substantially according to the fishing vessel type, propulsion arrangement, and operational purpose. The vessel-specific maneuvering tendencies identified in this analysis further emphasize the need for maneuvering criteria tailored to diverse fishing vessel designs rather than relying solely on standards developed for large merchant vessels.

The full-scale maneuvering results revealed clear, repeatable relationships linking hull-form parameters and propulsion characteristics to the measured performance indices. Variations in the advance, tactical diameter, overshoot angles, and stopping distances correspond systematically with differences in C_b , L_{BP}/B , P/Δ , and the stern gear configuration, demonstrating that fishing vessels exhibit distinct and quantifiable maneuvering patterns not observed in merchant vessels. The combined experimental measurements indicate that these patterns are governed primarily by the hull proportion, mass distribution, and propulsion layout rather than by the vessel length alone. Collectively, the results provide a robust hydrodynamic basis for refining maneuvering prediction models and for developing assessment criteria that better reflect the design and operational characteristics of fishing vessels.

4. Discussion

4.1. Maneuvering Behavior and Hull-Form Influences

The full-scale tests demonstrated that the three fishing vessels (F1–F3) exhibited distinct maneuvering characteristics shaped by their hull forms, propulsion configurations, and operational purposes. In the turning circle tests, all the vessels satisfied the IMO MSC.137(76) standard, with the advance values ranging from 2.4 L to 3.6 L and Tac . Dia. ranging from 2.9 L to 3.4 L . Such relatively small turning indices confirm that fishing vessels possess an inherently high turning responsiveness, primarily due to their short L_{BP} , low C_b , and strong propeller–rudder interaction.

The zig-zag tests revealed more pronounced differences in the yaw behavior. F1 and F2 exceeded the IMO overshoot angle limits during the $10^\circ/10^\circ$ test, indicating an over-reactive yaw response, despite their excellent turning ability. The yaw behavior of F1 reflects its wide stern shape, low-pitch and large-diameter propeller, and moderate C_b . F2, operating at a high F_n and with a slender hull ($L_{BP}/B \approx 5.0$), showed increased inertia and added mass effects, resulting in a large overshoot angle. In contrast, F3 exhibited a very small overshoot angle (3.5°), indicating strong yaw damping, but a potentially slower initial helm response during emergency maneuvers. Such behavior aligns with the C_b – F_n relationships described by Kijima and Nakiri [21], highlighting the importance of the hull fullness and the speed regime in determining yaw characteristics.

The stopping performance further differentiated the three vessels. F1 achieved the shortest stopping distance (4.6 L) due to strong astern thrust from its low-pitch propeller.

F2 recorded the longest distance (13.8 L), reflecting its fuller hull, higher added mass, and low astern thrust efficiency. F3 exhibited an intermediate stopping performance (6.2 L), supported by its slender geometry and relatively large rudder area ratio. Collectively, the results demonstrate that the hull slenderness, C_b , and propulsion configuration fundamentally shape the maneuvering behavior of fishing vessels.

4.2. Safety Implications and Environmental Limitations

The differences identified in the maneuvering behavior of F1–F3 have direct implications for the operational safety in real fishing environments. Excessive overshoot angles, as seen in F1 and F2, can increase the likelihood of unintended course deviations, gear-entanglement events, and close-quarters collision risks in congested fishing grounds. In contrast, vessels that exhibit strong yaw damping, such as F3, may show a slower initial turning response during emergency evasive maneuvers. The stopping performance also plays a critical role: long track reach values, such as the 13.8 L observed for F2, may elevate the risk of grounding or contact accidents in coastal areas where obstacles, tidal currents, and drifting objects are prevalent.

These patterns are consistent with the EMSA and IMO casualty statistics, which cite insufficient maneuvering margins and unstable yaw characteristics as primary contributing factors in fishing vessel collisions, groundings, and gear-related accidents [24]. The present results therefore offer empirical evidence that key hull-form parameters—the C_b , L_{BP}/B , F_{ru} , rudder area ratio, and propulsion loading—directly influence maneuvering safety and must be incorporated into evaluations of fishing vessel handling performance.

Several limitations are associated with the environmental conditions. All the tests were conducted in deep, unrestricted water under calm conditions to comply with IMO and ISO protocols. While these conditions are suitable for standardization, they do not fully represent real fishing environments, where shallow-water effects, confined channels, cross-currents, and wave-induced motions are common. Future work should incorporate maneuvering tests in shallow and restricted waters, wave-induced turning and course-keeping evaluations, and an analysis of wind and current effects, particularly during gear deployment and retrieval. Broader environmental testing of this kind is essential for developing maneuvering criteria that accurately reflect the operational realities of the fishing sector.

4.3. Pathways for Future Establishment of Fishing-Vessel-Specific Maneuvering Standards

The findings of this study highlight a fundamental mismatch between the IMO maneuvering standards—originally developed for large merchant vessels—and the actual maneuvering characteristics of fishing vessels. Fishing vessels are designed for agility, rapid heading changes, and frequent low-speed operations, while the IMO criteria assume a high inertia, large displacement, and steady forward motion. Such a mismatch can lead to inaccurate assessments: highly damped vessels such as F3 may appear overly conservative relative to IMO limits, while vessels with over-reactive yaw responses, such as F1 and F2, may fail limits that were never intended for their operational profiles. To address this gap, several practical pathways for integrating fishing-vessel-specific maneuvering criteria into the existing IMO framework are proposed. One option is to develop an annex or supplement to MSC.137(76), enabling the establishment of differentiated performance limits without altering the core test procedures. A second pathway involves incorporating fishing-vessel-specific criteria within the FAO/ILO/IMO Code of Safety for Fishermen and Fishing Vessels, which already accommodates multiple vessel categories and operational modes. A third approach is the creation of tiered, operational-type-based performance criteria aligned with ongoing IMO initiatives on goal-based and performance-based stan-

dards, where vessels are classified according to their maneuvering risk profile (trawling, purse seining, jigging).

This study also clarifies that the “correction factors” proposed in earlier sections are conceptual recommendations rather than finalized mathematical models. As the current dataset encompasses only three vessels, deriving generalized correction equations with numerical coefficients would be statistically unreliable. Future research should employ expanded full-scale databases, MMG-based hydrodynamic parameter identification, a CFD sensitivity analysis, and model-scale parametric studies to establish robust, quantitative correction models suitable for adoption by the IMO and classification societies [25]. From an implementation perspective, the cost of adopting fishing-vessel-specific maneuvering standards is expected to be minimal. Most required parameters—such as the C_b , L_{BP}/B , rudder area ratio, and propulsion loading—are already included in standard design documentation. Verification can be carried out using existing sea-trial procedures, numerical prediction tools, and MMG-based simulations. The anticipated safety and operational benefits are substantial, including reduced risks of collision and grounding, improved handling during gear operations, and an enhanced emergency response performance [13]. Together, these considerations demonstrate that fishing-vessel-specific maneuvering criteria are both necessary and feasible. The findings of this study can serve as a foundation for future refinements of international maneuvering standards.

5. Conclusions

This study conducted full-scale maneuvering tests on three representative fishing vessels to examine the applicability and limitations of the IMO MSC.137(76) criteria when applied to vessels under 100 m in length. The results showed that, although all vessels satisfied the IMO turning and stopping requirements, each vessel exhibited a distinct yaw response and maneuvering behavior governed by its hull form, propulsion configuration, and operational purpose. These differences revealed a fundamental mismatch between merchant-vessel-based maneuvering standards and the handling characteristics of modern fishing vessels. These findings have clear implications for operational safety. Excessive overshoot angles, long stopping distances, and strong yaw damping can all contribute to collision, grounding, or gear-related accidents in congested coastal fishing grounds. This study also identified important limitations associated with the environmental conditions of the trials, emphasizing the need for future evaluations in shallow water, in confined channels, in wave-affected seas, and in the presence of wind and current.

Based on the results, the necessity for developing fishing-vessel-specific maneuvering criteria that more accurately reflect operational profiles and hull-form characteristics is evident. Several feasible regulatory pathways were identified, including incorporation through an annex to MSC.137(76), integration into the FAO/ILO/IMO Code of Safety for Fishermen and Fishing Vessels, or the development of tiered, operational-type-based performance limits aligned with IMO goal-based standards. The correction factors discussed in this study should be understood as conceptual recommendations; their full mathematical formulation will require expanded datasets, MMG-based parameter identification, CFD sensitivity studies, and model-scale parametric testing. Finally, the implementation cost of such standards is expected to be minimal, as the required parameters are already included in standard design documentation, while the potential safety benefits—reduced collision and grounding risks, improved gear operation handling, and more reliable emergency maneuvering—are substantial. Collectively, the results presented here provide a scientific foundation and practical rationale for the future development of maneuvering standards specifically for fishing vessels within the international regulatory framework.

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References

1. European Maritime Safety Agency (EMSA). *Annual Overview of Marine Casualties and Incidents 2023*; EMSA: Lisbon, Portugal, 2023.
2. Liu, T.; Lodewijks, G. Research on the Impact of Ship Traffic Flow on the Restricted Channel Segment of the Middle Yangtze River Based on Traffic Wave Theory. *SN Appl. Sci.* **2021**, *3*, 706. [CrossRef]
3. Zhou, K.; Xing, W.; Wang, J.; Li, H.; Yang, Z. A Data-Driven Risk Model for Maritime Casualty Analysis: A Global Perspective. *Reliab. Eng. Syst. Saf.* **2024**, *244*, 109925. [CrossRef]
4. International Maritime Organization (IMO). *ISIS Marine Casualties and Incidents (MCI) Database*. Available online: <https://gis.imo.org/Public/MCI/> (accessed on 22 November 2025).
5. International Maritime Organization (IMO). *Standards for Ship Manoeuvrability (Resolution MSC.137(76))*; IMO: London, UK, 2002.
6. Food and Agriculture Organization of the United Nations (FAO). *Global Record of Fishing Vessels—Dashboard: Region Overview (Africa and Asia—Number of Vessels and Average Length)*; FAO: Rome, Italy, 2025.
7. International Labour Organization (ILO). *Fishing Among the Most Dangerous of All Professions, Says ILO*; ILO News; ILO: Geneva, Switzerland, 1999.
8. National Institute for Occupational Safety and Health (NIOSH). *Commercial Fishing Safety: About the Program*; Centers for Disease Control and Prevention (CDC): Washington, DC, USA, 2023.
9. Sivilčić, B.; Vujičić, S.; Bačkalov, I.; Vidan, P.; Žužić, F.; Krčum, M. Modelling Manoeuvrability in the Context of Ship Collision. *J. Mar. Sci. Eng.* **2023**, *11*, 497. [CrossRef]
10. González, M.M.; Sobrino, P.C.; Álvarez, R.T.; Casás, V.D.; López, A.M.; Peña, F.L. Fishing Vessel Stability Assessment System. *Ocean. Eng.* **2012**, *54*, 68–79. [CrossRef]
11. Sutulo, S.; Guedes Soares, C. Review on Ship Manoeuvrability Criteria and Standards. *J. Mar. Sci. Eng.* **2021**, *9*, 904. [CrossRef]
12. Sarigul, D.O.; Celik, C.; Kinaci, O.K.; Sariöz, K.; Goren, O. A System-Based Approach to Estimate Manoeuvring Performance of Naval Ships in Waves. *Ocean Eng.* **2025**, *321*, 120378. [CrossRef]
13. Papanikolaou, A.; Zaraphonitis, G.; Bitner-Gregersen, E.; Shigunov, V.; el Moctar, O.; Guedes Soares, C.; Sprenger, F. Minimum Propulsion and Steering Requirements for Efficient and Safe Operation. *Ocean Eng.* **2015**, *108*, 254–267.
14. Maljković, M.; Pavić, I.; Meštrović, T.; Perković, M. Ship Manoeuvring in Shallow and Narrow Waters: Predictive Methods and Model Development Review. *J. Mar. Sci. Eng.* **2024**, *12*, 1450. [CrossRef]
15. Japan International Cooperation Agency (JICA). *Basic Design Study Report*; JICA: Tokyo, Japan, 2004.
16. Yoshimura, Y.; Ma, N. Manoeuvring Prediction of Fishing Vessels. In Proceedings of the MARSIM '03—International Conference on Marine Simulation and Ship Manoeuvrability, Kanazawa, Japan, 25–28 August 2003.
17. Yasukawa, H.; Yoshimura, Y. Introduction of MMG Standard Method for Ship Manoeuvring Predictions. *J. Mar. Sci. Technol.* **2015**, *20*, 37–52. [CrossRef]
18. ISO 15016:2015; Ships and Marine Technology—Guidelines for the Assessment of Speed and Power Performance by Analysis of Speed Trial Data. International Organization for Standardization: Geneva, Switzerland, 2015.
19. Food and Agriculture Organization of the United Nations (FAO). *Classification and Definition of Fishing Vessel Types*; FAO: Rome, Italy, 2003.
20. Trygg Mat Tracking & IMCS Network. *MCS Practitioners Introductory Guide to: Purse Seine Fishing*; Trygg Mat Tracking & IMCS Network: Oslo, Norway, 2021.
21. Kijima, K.; Nakiri, Y. Manoeuvrability of Ships in Confined Water. In Proceedings of the International Conference on Ship Manoeuvrability, London, UK, 29 April–1 May 1987; p. 20.
22. Lee, C.K.; Kim, S.H.; Park, J.H.; Choi, B.K. A Study on the Characteristics of Maneuverability of Fishing Vessel. *J. Korean Soc. Fish. Ocean Technol.* **2018**, *54*, 239–245. [CrossRef]
23. Kim, W.J.; Van, S.H.; Kim, D.H. Measurement of Flows around Modern Commercial Ship Models. *Exp. Fluids* **2001**, *31*, 567–578. [CrossRef]

24. European Maritime Safety Agency (EMSA). *Annual Overview of Marine Casualties and Incidents 2024*; EMSA: Lisbon, Portugal, 2024.
25. Yoshimura, Y.; Hino, T.; Stern, F. Comparison of CFD Results for KVLCC2 at the Workshop on CFD in Ship Hydrodynamics. *J. Mar. Sci. Technol.* **2010**, *15*, 277–298.

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