

Limitations and Practical Applicability of SEMIS Methodology in Intact Stability Assessment

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ABSTRACT: This paper applies the SEMIS (Simple Evaluation Methodology for Intact Stability) approach to a 13593 DWT general cargo vessel for stability assessment using only metacentric height (GM). SEMIS estimate key stability parameters through regression models and compares them with IMO Intact Stability Code criteria. Analysis of 1314 loading conditions of investigated ship shows that SEMIS method provides quick and generally accurate evaluations of stability for typical GM ranges ($GM > 0.30$ m). However, results reveal notable discrepancies for low-GM states ($GM < 0.30$ m) especially in context of weather-related criteria. SEMIS in low GM condition may incorrectly classify compliance and may underestimate critical stability parameters. These findings indicate that while SEMIS is a practical supplementary tool, its application should be limited to preliminary checks rather than final compliance verification. Additionally, we can determine the GM value associated with the critical weather criterion. At this point, the b/a ratio reaches its peak, while for lower GM values it decreases significantly, remaining a nonlinear function alongside other stability parameters.

1 INTRODUCTION

Ship stability is undoubtedly a subject of paramount importance in the field of Naval Architecture, its fundamentals having wider implications for the design and operation of ships and floating units as is argued by Bačkalov et al [2]. Ship stability assessment remains an active and evolving area of maritime research, with recent studies highlighting significant gaps and challenges in current approaches. As per Zyczkowski et al [39] the existing IMO Intact Stability Code has been criticized for relying on outdated statistical approaches that do not adequately account for dynamic stability issues and the stochastic nature of environmental conditions. According to Vidić et al [35] in research about inland passenger ship stability requirements, significant discrepancies in stability assessments performed according to different regulations have been identified, bringing into focus

the question of reliability of the present regulatory framework for ship stability. According to recent research [31], intact stability rules from IMO and classification societies typically do not address operational aspects, creating a gap between design requirements and actual ship operations. Recent developments in probabilistic damage stability assessment have revealed that ships with identical safety indices may have significantly different actual safety levels, indicating fundamental limitations in current evaluation methods [24].

Furthermore, the introduction of second-generation intact stability criteria [25,27,34] represents a recognition that traditional prescriptive regulations are insufficient, with researchers advocating for comprehensive risk analysis approaches that can account for all relevant hazards during both design and operational stages [19]. These ongoing research

efforts underscore the continued need for improved stability assessment methodologies that can bridge the gap between regulatory requirements and practical operational safety. The IMO Intact Stability Code requires ships to meet multiple stability criteria [11] and still there is a need of extension of stability assessment methods, as introducing simple ways of assessment apart from complicated and numerical methods. One of them is SEMIS concept [37] (Simple Evaluation Methodology for Intact Stability) furtherly described in section methodology, and IMSISA concept [10] (Index for Marine Ship Intact Stability Assessment) model which provides the ability to assess the intact stability of ships based on the index of ship stability performance, called the Ship Stability Index.

This study aims to comprehensively evaluate the Simple Evaluation Methodology for Intact Stability (SEMIS) as a novel approach to ship stability assessment. The specific research objectives include:

1. Assess the effectiveness of SEMIS in providing rapid, preliminary intact stability evaluation using metacentric height (GM) as the primary input parameter,
2. Validate the SEMIS methodology through implementation on a specific vessel model,
3. Conduct a comparative analysis between vessel-specific and literature-based SEMIS regression models to determine accuracy and predictive reliability,
4. Evaluate SEMIS's capability in predicting compliance with IMO Intact Stability Code.

The research addresses a critical need in maritime safety assessment through the implementation of a simplified methodology for intact stability evaluation. While previous studies [10,37] have implemented this approach for many types of ships, this study focuses on a specific 13593 DWT general cargo vessel, creating a model tailored exactly for that ship.

SEMIS offers a practical solution by enabling rapid preliminary stability checks using a single input parameter - metacentric height (GM). This approach can be particularly valuable in operational scenarios where conventional stability assessment tools are unavailable or when quick decision-making is required.

By comparing vessel-specific and generic models, this study provides evidence-based insights into the potential and limitations of simplified stability assessment approaches. The findings contribute to understanding how such methodologies can support maritime safety, offering practical recommendations for their implementation. The research also highlights the need for further development of rapid, accessible stability evaluation techniques that maintain accuracy while reducing complexity.

2 METHODOLOGY

2.1 Simple Evaluation Methodology for Intact Stability

SEMIS (Simple Evaluation Methodology for Intact Stability) was developed to provide a straightforward assessment of a ship's intact stability parameters based on the metacentric height (GM).

The purpose of SEMIS is to offer a simple supplementary method for evaluating stability to captains, officers, and crew members, particularly in situations where loading software or specialized equipment is unavailable, as calculating all intact stability parameters is usually complex.

According to [37] SEMIS effectively assess a ship's stability using only GM. In the study [37] the regression models of ship stability parameters were developed based on 336 loading conditions of 19 model ships, including mainly cargo ships like bulk carriers, container ships, general cargo vessels and tankers. The main particulars of model cargo ships are shown in Table 1. and the mentioned regression models are presented in Table 2.

Table 1. Model ships and loading conditions, based on Woo et al. [37], p. 3

Model Ship	Number of Scenarios	Range of displacement [t]	Range of CB [-]
Bulk carrier ship	46	3640.5–233118.5	0.731–0.841
Container ship	93	8276.2–84257.0	0.545–0.662
Tanker ship	65	13589.2–364896.0	0.728–0.813
General cargo ship	4	3498.5–6580.2	0.731–0.785

Table 2. Empirical formulas related to GM, based on Woo et al. [37], p. 6

No.Stability parameter	Empirical Formula According to GM [37],	R ²
1 $A_{0^{\circ}-30^{\circ}}$	$y_1=0.1341 \cdot GM+0.0216$	0.9942
2 $A_{0^{\circ}-40^{\circ}}$	$y_2=0.2214 \cdot GM+0.0470$	0.9870
3 $A_{30^{\circ}-40^{\circ}}$	$y_3=0.0873 \cdot GM+0.0253$	0.9676
4 $GZ_{\varphi \geq 30^{\circ}}$	$y_4=0.5261 \cdot GM+0.1145$	0.9611
5 φ_{GZmax}	$y_5=0.4775 \cdot GM+37.043$	0.0972
6 b/a	$y_6=-0.0121 \cdot GM+4.4431$	0.0009
7 $Area \setminus "a"$	$y_7=0.0766 \cdot GM$	0.9680
8 $Area \setminus "b"$	$y_8=0.307 \cdot GM$	0.9741
9 φ	$y_9=1/(0.15689 \cdot GM+0.05209)$	0.58029

In general, the SEMIS procedure consists of four phases aimed at evaluating seven intact stability parameters based on GM, followed by determining whether the criteria are met or not. The SEMIS procedure of ship stability assessment is shown in Figure 1.

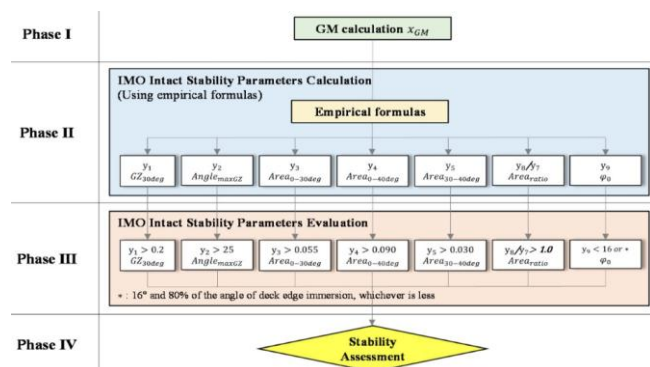


Figure 1. Concept of SEMIS [37] p. 7

Phase 1 – Calculation of the ship's GM. The metacentric height (GM) can be calculated based on the known distribution of masses on board [3,13,33,36]. It can also be estimated from the ship's roll period [8],

Phase 2 – Stability parameters are calculated according to the empirical models presented in [37]. A

summary of these empirical models is provided in Table 3.

Phase 3 – Each stability parameter is evaluated and compared with the corresponding criterion values. These values, derived from stability criteria, are presented in Table 3.

Phase 4 – The overall stability of the ship is assessed, including whether the stability criteria are met or not.

2.2 Intact Stability Assessment

The assessment of stability is fundamental to ensuring safety of ship [9,18,23]. The biggest challenge in this process is developing a loading plan, which directly affects the ship's stability, as the number of possible loading conditions during operation is theoretically unlimited due to continuous variations in parameters such as ships center of gravity being and resultant of mass distribution on board [32]. Problems related to ship stability are widely researched [1,5,14–16,19,31], which indicates that the issue is still not fully resolves. Currently, the Intact Stability code (IS code) represents the international mandatory regulation applicable to all types of ships [28]. This is a formal assessment method, an extract of stability criteria that present specific inequalities shown in Table 3. In this study, ship stability will be evaluated in accordance with the Intact Stability Code (IS Code).

Table 3. IMO intact stability parameters and criteria found from [11] and arranged according to interpretations in [18,33,37]

Stability parameter	Criteria
Area (A) under the righting arm curve ([11], §2.2.1)	$A_{0^{\circ}-30^{\circ}} \geq 0.055 \text{ m}\cdot\text{rad}$ (1)
	$A_{0^{\circ}-40^{\circ}} \geq 0.095 \text{ m}\cdot\text{rad}$ (2)
	$A_{30^{\circ}-40^{\circ}} \geq 0.030 \text{ m}\cdot\text{rad}$ (3)
Righting arm (GZ) ([11], §2.2.2)	$GZ_{\varphi_{z30^{\circ}}} \geq 0.20 \text{ m}$ (4)
Angle corresponding to the maximum of the righting arms ([11], §2.2.3)	$\varphi_{GZmax} \geq 25^{\circ}$ (5)
Initial metacentric height (GM) ([11], §2.2.1)	$GM \geq 0.15 \text{ m}$ (6)
Weather criterion. ([11], §2.3.1.4)	$b/a \geq 1$ (7)
List of the ship under static wind pressure perpendicular to the plane of symmetry. ([11], §2.3.1.2)	$\varphi_{\omega} \leq 16^{\circ}$ (8) $\varphi_{\omega} \leq 0.8 \cdot \varphi_{2P}$ (9)

3 RESULTS

This analysis concerns the 13593 DWT ship of B-354 series type [22] which is a multipurpose vessel for carrying bulk cargo and general cargo as well containers. The B-354 vessel has been used as a case of study in various maritime scientific research, particularly focusing on its stability and dynamic behavior, as documented in publications [12,20,21]. The main particulars of the B-354, including the analyzed displacement and block coefficient (CB), are presented in Table 4. When compared to the models analyzed in [37], this vessel generally falls within the displacement and CB ranges shown in Table 1. Therefore, the SEMIS model can be applied to this ship.

Table 4. Particulars of B-354 ship

Model Ship	Range of displacement [t]	Range of CB [-]
B-354	8159–20767	0.644–0.718

The present research work flow is as follows:

1. Calculation of stability parameters for a set of loading conditions of B-354 ship,
2. Preparation of regression lines with R^2 tests and formulation of equations as per concept described in [37],
3. Stability assessment and comparison based on degree of compliance,
4. Error analysis between models derived by [37] and those derived for B-354 ship.

Calculations of stability parameters were performed using a custom spreadsheet developed with VBA programming in Microsoft Excel, a widely adopted tool for automating data processing and implementing computational models in scientific research [4,17,26,29,40].

Stability parameters were computed for 1314 distinct loading conditions, starting from displacement and corresponding drafts ranging from 8.50 m to 9.14 m (the maximum permissible summer load draft of the investigated ship) and transverse metacentric heights between 0.08 m and 3.00 m. All data presented are the author's elaboration and are assumed to represent realistic operational scenarios that may occur during exploitation. Figures 2–10 present a comprehensive set of stability parameters, defined by Equations (1–9), for all 1314 loading conditions, illustrating their variation as functions of the ship's metacentric height.

Each graph includes the calculated stability parameters, the regression line, and the coefficient of determination (R^2) as a measure of fit quality. The use of R^2 was chosen because it provides an interpretable and standardized metric for assessing the compatibility of regression models with observed data as argued by Chicco et al [7].

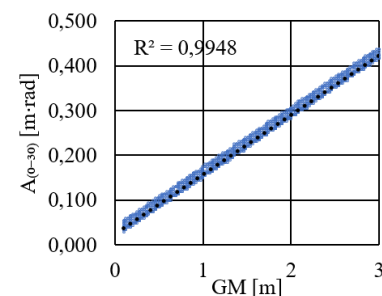


Figure 2. GM versus $A_{(0-30)}$

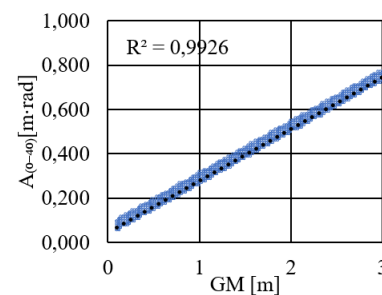


Figure 3. GM versus $A_{(0-40)}$

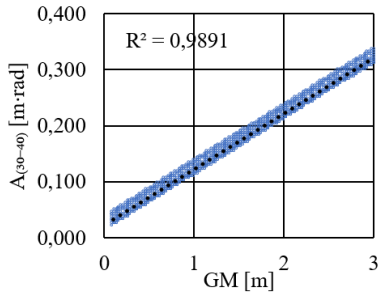


Figure 4. GM versus $A_{(30-40)}$

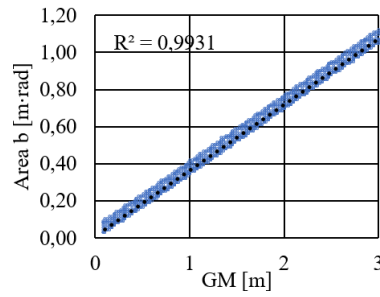


Figure 9. GM versus area „b”

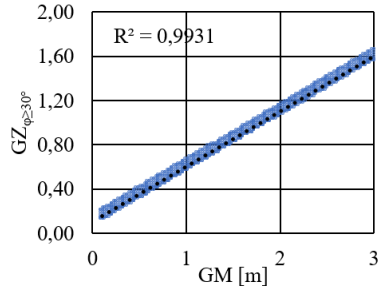


Figure 5. GM versus $GZ_{\varphi \ge 30^\circ}$

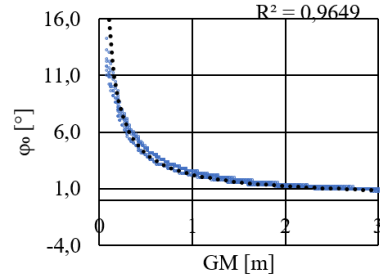


Figure 10. GM versus φ_0

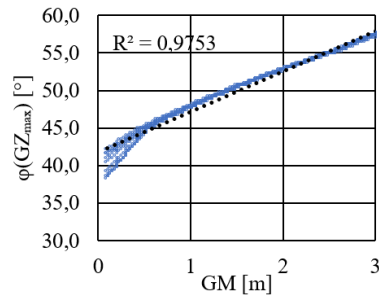


Figure 6. GM versus $\varphi(GZ_{max})$

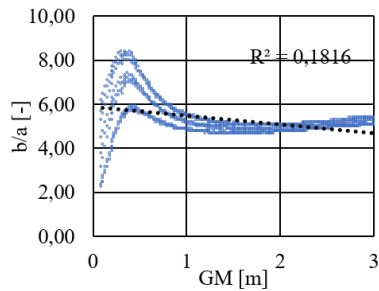


Figure 7. GM versus b/a

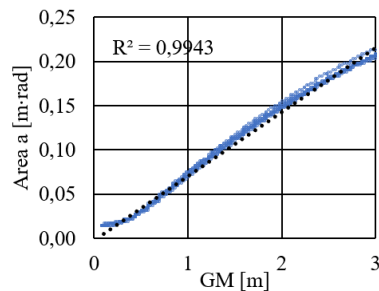


Figure 8. GM versus area „a”

Table 5 presents the regression models derived from the data shown in Figure 2–10. The high value of R^2 indicates good agreement between the calculated values and the regression model, as values of R^2 close to 1 [30], reveals to best fit, however, a low R^2 is observed for the b/a ratio parameter (Figure 7). To address this, the approach used in previous studies [37,38] was used in which we separately calculated area “a” under the GZ curve (Figure 8) and area “b” under the GZ curve (Figure 9). Such an approach shows good agreement with the R^2 value. Later, the b/a ratio for the weather criterion will be calculated according to the derived models of area “a” and “b” expressed as their quotient.

Table 5. Empirical formulas according to GM, B-354 ship. Author elaboration.

No.	Stability parameter	Empirical Formula According to GMR ²	R^2
1	$A_{0^\circ-30^\circ}$	$y_1=0.1336 \cdot GM+0.0230$	0.9948
2	$A_{0^\circ-40^\circ}$	$y_2=0.2334 \cdot GM+0.0453$	0.9926
3	$A_{30^\circ-40^\circ}$	$y_3=0.0997 \cdot GM+0.0224$	0.9891
4	$GZ_{\varphi \ge 30^\circ}$	$y_4=0.5000 \cdot GM+0.1042$	0.9931
5	φ_{GZmax}	$y_5=5.3776 \cdot GM+41.746$	0.9753
6	b/a	$y_6=-0.4005 \cdot GM+5.8894$	0.1816
7	Area \ "a"	$y_7=0.0724 \cdot GM-0.0019$	0.9943
8	Area \ "b"	$y_8=0.3550 \cdot GM+0.0090$	0.9931
9	φ_0	$y_9=2.2499 \cdot GM^{-0.869}$	0.9841

Table 6 presents the results of 15 loading scenarios evaluated for compliance with the IMO Intact Stability Criteria. It was decided to examine full load condition of the ship at design draught $T = 9.14$ m, and different GM which may appear during exploitation. Additionally, there were included 2 loading scenarios with primary non-compliance with criteria $GM < 0.15$ m (6). The second column in Table 6 indicates overall compliance, where “0” denotes non-compliance with stability requirements and “1” denotes full compliance. The remaining columns list stability parameters calculated and compared to the stability standards specified in Table 3.

Each parameter is referenced to the corresponding criterion or formula, as indicated by the numbering in parentheses (e.g., (1), (2), (3)). Cells highlighted in red

indicate non-compliance with the respective criterion. Values listed in Table 6 stands for reference purposes as exact values.

Table 6. Ship stability parameters and compliance evaluation under IMO Intact Stability Code.

Loading scenario	Compliance with IMO	$A_{(0-30)}$ [m·rad]	$A_{(0-40)}$ [m·rad]	$A_{(30-40)}$ [m·rad]	$\varphi_{CZ(30^\circ)}$ [m]	$\varphi_{CZ_{min}}$ [°]	GM [m]	b/a [-]	$\varphi_0 \leq 16^\circ$ [°]	$\varphi_0 \leq 0.8 \cdot \varphi_{zP}$ [°]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
1	0	0.027	0.048	0.022	0.11	38.1	0.1	2.1	12.4	12
2	0	0.032	0.058	0.026	0.13	38.8	0.14	2.8	10.1	12
3	0	0.033	0.060	0.027	0.14	39.0	0.15	3.0	9.6	12
4	0	0.040	0.072	0.032	0.16	39.8	0.2	3.8	7.9	12
5	0	0.051	0.090	0.040	0.20	41.0	0.28	4.9	6.2	12
6	1	0.079	0.140	0.061	0.31	44.1	0.49	5.7	4.0	12
7	1	0.080	0.142	0.062	0.31	44.3	0.5	5.6	3.9	12
8	1	0.119	0.210	0.091	0.46	46.4	0.79	5.0	2.6	12
9	1	0.154	0.270	0.117	0.59	47.9	1.05	4.8	2.0	12
10	1	0.179	0.315	0.135	0.68	48.9	1.24	4.7	1.7	12
11	1	0.186	0.326	0.140	0.71	49.2	1.29	4.7	1.7	12
12	1	0.212	0.373	0.160	0.81	50.2	1.49	4.6	1.5	12
13	1	0.247	0.434	0.186	0.94	51.5	1.75	4.7	1.3	12
14	1	0.266	0.466	0.200	1.01	52.2	1.89	4.7	1.2	12
15	1	0.283	0.497	0.213	1.07	52.7	2.02	4.7	1.1	12

where: φ_{zP} – angle of deck immersion see ([11], §2.3.1.2).

Stability parameters were calculated for each criterion for the loading scenarios listed in Table 6 using the empirical model from Table 2 and the empirical model derived for the investigated ship, as shown in Table 5. The values in Table 7 present the percentage of fulfillment of stability criteria, calculated using Equation (1) for each model:

$$\eta = \frac{\sum_{i=1}^n \delta_i}{n} \cdot 100\% \quad (1)$$

where: η – percentage of criteria passed, n – total number of criteria (see Eqs. (1–9)), δ_i – indicator function equals 1 if criterion i is satisfied, and 0 otherwise.

Table 7. Degree of compliance with IMO stability criteria: Comparison of exact method vs model [37], and current study model.

Loading scenario	Exact assessment	Empirical model (from [37])	Empirical model (Current study)
1	33 %	44 %	33 %
2	44 %	56 %	44 %
3	44 %	67 %	67 %
4	67 %	89 %	89 %
5	89 %	100 %	89 %
6	100 %	100 %	100 %
7	100 %	100 %	100 %
8	100 %	100 %	100 %
9	100 %	100 %	100 %
10	100 %	100 %	100 %
11	100 %	100 %	100 %
12	100 %	100 %	100 %
13	100 %	100 %	100 %
14	100 %	100 %	100 %
15	100 %	100 %	100 %

Table 7 shows that the dedicated model for the B-354 ship closely matches the overall stability assessment in identifying compliance with IMO criteria. Minor discrepancies occur for loading conditions 3 and 4, where the dedicated model slightly

overestimates compliance. In contrast, the literature-based model exhibits significant deviations and, for loading condition 5, incorrectly predicts full compliance within stability criteria.

Based on definition of relative errors (RE) [6], they were calculated to show the differences between the selected methods. Figure 11–19 illustrate RE values for key stability parameters across different loading scenarios. Orange points correspond to the vessel-specific model from this study (Table 5), while blue points represent the literature-based model (Table 2).

This comparison allows for assessing the impact of model adaptation to a specific vessel on the accuracy of the results. Calculating RE enables a quantitative evaluation of how much the results of both models deviate from the exact stability calculations and in which loading scenarios the differences are most significant.

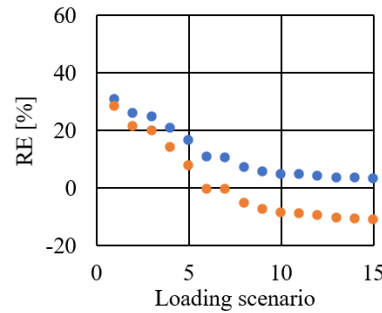


Figure 11. RE for parameter $A_{(0-30)}$

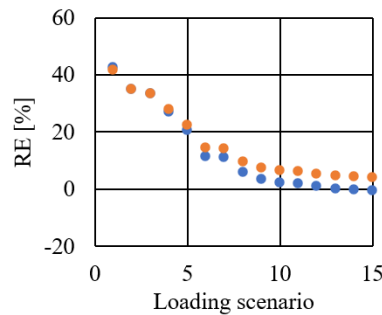


Figure 12. RE for parameter $A_{(0-40)}$

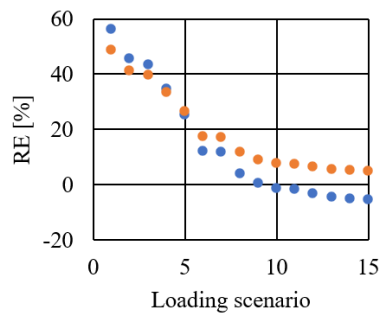


Figure 13. RE for parameter $A_{(30-40)}$

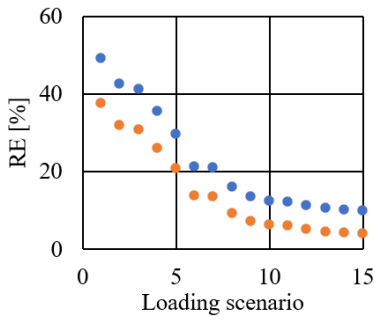


Figure 14. RE for parameter $GZ_{\varphi \geq 30^\circ}$

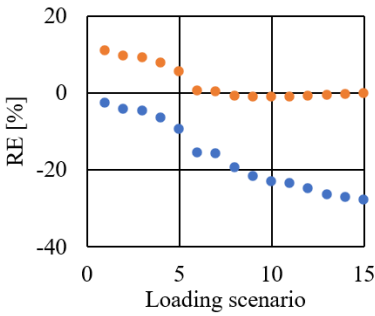


Figure 15. RE for parameter $\varphi(GZ_{max})$

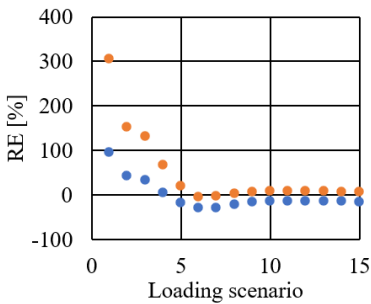


Figure 16. RE for parameter b/a

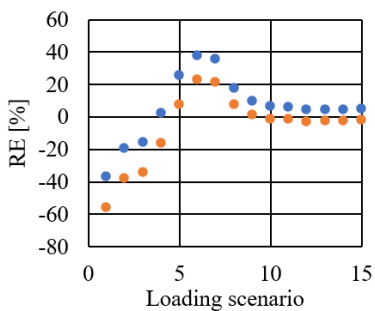


Figure 17. RE for parameter area "a"

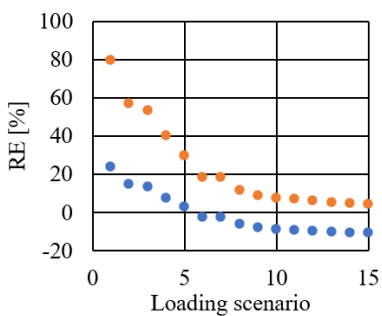


Figure 18. RE for parameter area "b"

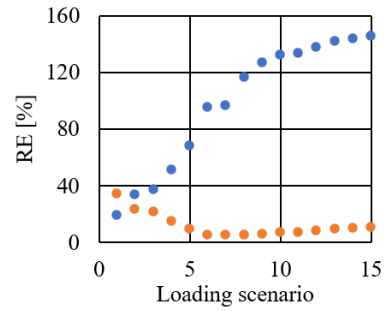


Figure 19. RE for parameter φ_0

Analysis of Figure 11–19 shows that the dedicated model (orange points) achieves consistently lower relative error (RE) values across most loading conditions, particularly for weather criterion parameters illustrated in Figure 16–19. In contrast, the literature-based model (blue points) exhibits substantially larger deviations, limiting its applicability for precise stability assessments.

Both models demonstrate a pronounced increase in discrepancies for loading scenarios 1 to 5, where RE values differ substantially compared to scenarios 6 to 15. This pattern suggests that both models are less reliable under conditions where the metacentric height falls below approximately 0.30 m. The analysis identifies $GM \approx 0.30$ m as a critical threshold below which prediction errors increase sharply.

The largest errors are observed for stability parameters related to weather criteria, where both models show significant deviations from exact calculations. Despite the differences in absolute RE values between the models, a similar trend in error variation with respect to loading condition is observed. In both cases, errors are largest at low GM levels (scenarios 1–5) and decrease progressively as GM increases (scenarios 6–15). This consistency in error trends indicates that both models correctly capture the general influence of loading condition on stability parameters, although they differ significantly in the magnitude of deviation from reference values.

4 DISSCUSSION

The comparative analysis between the SEMIS-based empirical models and exact stability calculations reveals significant insights into the methodology's practical applicability. The dedicated model developed specifically for the B-354 vessel (Table 5) demonstrates markedly superior performance compared to the literature-based model from Woo et al. [37]. This superiority is particularly evident in the relative error (RE) analysis presented in Figures 11–19, where the dedicated model (orange points) consistently achieves lower RE values across most loading conditions. The high R^2 values obtained for the vessel-specific model validate the fundamental SEMIS approach, with coefficients ranging from 0.9753 to 0.9948 for most stability parameters.

Notably, the R^2 value for the angle corresponding to maximum GZ reaches 0.9753, while area parameters A_{0-30} and A_{0-40} achieve exceptional correlations of 0.9948 and 0.9926, respectively. These values significantly exceed those reported in the original

SEMIS study [37], where corresponding R^2 values were 0.0972, 0.9942, and 0.9870, demonstrating the clear benefits of vessel-specific calibration.

The analysis of Figures 11-19 reveals a pronounced pattern in model accuracy that correlates directly with loading conditions. Both the dedicated model (orange points) and literature-based model (blue points) exhibit substantially increased relative errors for loading scenarios 1-5, corresponding to metacentric heights below approximately 0.30 m. This critical threshold is consistently observed across all stability parameters, as demonstrated in the RE plots. For the area under the righting arm curve from 0° to 30° (Figure 11), the dedicated model shows RE values exceeding 20% for loading conditions 1-3, while maintaining errors below 10% for loading scenarios 6–15. Similarly, Figure 12 illustrates that the A_{0-40} parameter exhibits comparable behavior, with the literature model showing even more pronounced deviations, reaching RE values above 40% in critical loading conditions.

The weather criterion parameters present the most challenging assessment scenario within the SEMIS framework. Figure 16 demonstrates that the b/a ratio exhibits the highest relative errors among all parameters, with both models showing substantial deviations that exceed 50% for low-GM conditions. This finding is particularly concerning given that the direct b/a regression yielded an unacceptably low R^2 value of 0.1816 (Table 5), necessitating the separate modeling approach for areas "a" and "b" illustrated in Figures 8-9. Despite the improved individual correlations achieved for areas "a" and "b" ($R^2 = 0.9943$ and 0.9931 , respectively), the calculated b/a ratio continues to exhibit substantial errors, suggesting that weather criterion assessment requires more conservative approach.

The compliance analysis presented in Table 6 illustrates the practical implications of these findings. Loading scenarios 1-5, characterized by GM values below 0.30 m, consistently fail to meet multiple IMO criteria (highlighted in red), particularly criteria (1), (2), and (3) related to area under the righting arm curve. The transition to full compliance occurs at loading scenario 6 (GM = 0.49 m), establishing a clear operational threshold for safe loading conditions.

Table 7 provides compelling evidence of the dedicated model's superior performance in compliance assessment accuracy. The vessel-specific model demonstrates remarkable agreement with exact assessments, correctly identifying compliance status in 13 out of 15 loading scenarios. The minor discrepancies occur in loading conditions 3 and 4, where the dedicated model slightly overestimates compliance (56% vs. 44% and 89% vs. 67%, respectively). In stark contrast, the literature-based model exhibits significant deviations, most notably in loading condition 5, where it incorrectly predicts 100% compliance when the exact assessment indicates only 89% compliance. This false positive represents a critical safety concern, as it could lead to operational decisions based on incorrect stability assessments.

According to the histogram of metacentric heights presented in Jachowski et al. [8] (p. 179), the most frequently occurring GM values in operational practice range from 0.25 to 2.2 m. This operational range

corresponds to loading scenarios 5-15 in the current study, where the dedicated model demonstrates acceptable accuracy with errors generally remaining within $\pm 20\%$. Figure 19, showing RE values for the initial list angle φ_0 , illustrates this operational reliability, with the dedicated model maintaining errors below 15% for the typical operational range. However, the sharp increase in errors below GM = 0.30 m (loading scenarios 1-5) coincides with the lower boundary of typical operational conditions, highlighting the critical importance of accurate assessment.

The comparison between vessel-specific and literature-based models clearly demonstrates the substantial benefits of model adaptation. While the original SEMIS model was developed using 336 loading conditions from 19 different vessel types (Table 1), the current study's approach using 1314 conditions specific to the B-354 vessel yields substantially improved accuracy across all assessed parameters. However, this improvement comes with practical limitations, as the vessel-specific approach requires extensive computational effort to generate the necessary database of loading conditions, potentially limiting widespread implementation.

The findings presented in Table 6 and Table 7, combined with the RE analysis in Figure 11–19, have significant implications for maritime safety. The SEMIS methodology's tendency to overestimate compliance in critical loading conditions poses potential safety risks if used as a primary assessment tool.

The consistent pattern of increased errors in low-GM conditions across all parameters indicates that SEMIS reliability deteriorates precisely when accurate stability assessment is most critical for safety. This limitation necessitates careful consideration of the methodology's appropriate application scope and the implementation of safeguards to prevent misuse in critical stability scenarios.

The regression-based approach underlying SEMIS assumes linear relationships between GM and various stability parameters. While this assumption holds reasonably well for most parameters within typical operational ranges (as evidenced by high R^2 values in Table 5), the deteriorating accuracy at low GM values suggests that non-linear effects become significant in critical stability states. The particularly poor performance of weather criterion assessment (Figure 7) indicates that the b/a ratio may be influenced by factors beyond GM alone. According to Figure 20–21 the GZ curve range changes rapidly in function of GM (from 55 degrees to 60, as well GZmax 0.14 m up to 0.26 m).

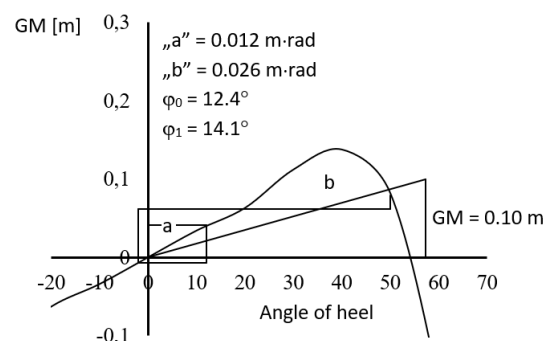


Figure 20. GZ curve of B-354, T=9.14 m, GM = 0.10 m. Author elaboration

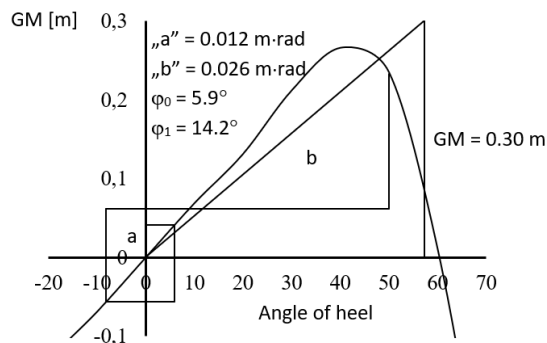


Figure 21. GZ curve of B-354, T=9.14 m, GM = 0.30 m. Author elaboration

As well angle of roll to windward due to wave action φ_1 changes rapidly in function of GM as shown on Figure 22. According to Figure 7, derived using the SEMIS method, it can be observed that with respect to the weather criterion, when the b/a ratio over the GM value is less than 0.30 m, the b/a ratio decreases rapidly going towards b/a going to zero.

This is an important consideration for vessel operation, as it may justify introducing additional regulatory criteria related to the weather criterion for a particular vessel. Furthermore, the angle of roll to windward due to wave action φ_1 determined by the ISC also has an impact: at low GM values, the amplitudes are small, whereas an increase in GM tends to make the roll amplitude more stable which briefly gives an explanation of nonlinearity of b/a ratio as well its peak value.

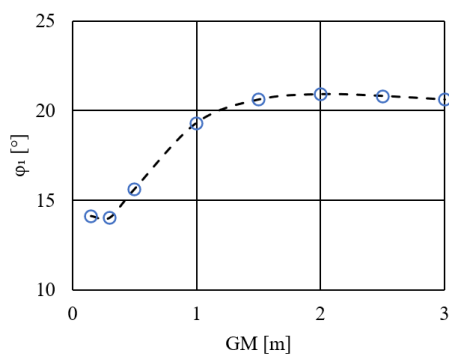


Figure 22. Angle of roll to windward due to wave action of a ship B-354 with T = 9.14 m for various values of transverse GM

5 CONCLUSIONS

The SEMIS methodology provides a practical and rapid approach for preliminary intact stability assessment based solely on metacentric height (GM), offering potential benefits in operational scenarios where conventional stability software is unavailable. For the analyzed 13593 DWT general cargo vessel, SEMIS demonstrated strong correlation with IMO Intact Stability Code criteria within typical operational GM ranges, confirming its usefulness for quick checks under normal loading conditions.

However, significant limitations were identified in low-GM states, which may occur due to atypical loading or emergency situations. In such cases, SEMIS can produce misleading results, overestimating compliance and underestimating critical stability risks,

thereby creating a false sense of safety. This behavior is linked to the nonlinear nature of stability parameters at low GM values and cannot be fully corrected by vessel-specific linear regression models. Consequently, SEMIS should never be considered a substitute for comprehensive stability calculations or as a design or emergency assessment tool; its application must remain restricted to preliminary evaluations in intact conditions with GM above safe thresholds.

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