Journal of Engineering Science and Technology
Special Issue on STIPCON2024 Vol. 20, No. 5 (2025) 19 - 27

ANALYSIS OF SHIP'S DRAFT CALCULATION METHODS USING BASIC PERCENTAGE IN CARGO LOADING OPERATIONS

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Abstract

This study investigates how basic percentage calculations are used to determine a ship's draft during cargo loading. It focuses on analyzing simple mathematical methods commonly employed by deck officers to ensure safe and efficient loading. The main goal is to assess how effective and accurate these percentage calculations are compared to traditional methods when tracking draft changes during loading. The research used a quantitative approach, gathering data from 30 cargo ships of different sizes during their loading activities at Tanjung Priok Port over six months. It examined three key aspects: the accuracy of draft estimates using percentage methods, the time needed to perform these calculations, and their practical use by deck officers during real loading. Data was collected through direct observations, documentation of calculations, and structured interviews with deck officers. Results show that percentage-based calculations achieved 95% accuracy relative to actual draft measurements and reduced calculation time by about 40% compared to traditional methods. Additionally, 85% of deck officers felt more confident using these simplified methods. The study also suggests potential for standardizing basic percentage calculations across various vessel types. It concludes that using these methods offers a quick, reliable alternative to complex calculations, especially during time-sensitive operations. This research supports the practical use of nautical math in cargo handling and recommends including these techniques in standard procedures. Overall, the findings indicate that simplified calculations can improve operational efficiency without sacrificing accuracy.

Keywords: Basic percentage methods, Cargo loading operation, Ships draft calculation.

1. Introduction

The shipping industry represents a vital sector in the global economy, with approximately 90% of world trade conducted through maritime transportation [1]. In vessel operations, draft calculation is a crucial aspect directly related to safety and operational efficiency [2]. Ship's draft calculations are not only important for determining displacement and cargo capacity but also vital for ensuring vessel stability and compliance with international maritime regulations [3].

In daily field practice, ship officers often face situations requiring quick and accurate draft calculations during loading operations [4]. Traditional methods involving complex calculations and the use of hydrostatic tables are often time-consuming and potentially prone to human error, especially in operational conditions demanding quick responses [5]. This phenomenon creates a need for simpler calculation methods while maintaining reliable accuracy levels [6].

Previous studies by Moreno et al [7] indicated that approximately 65% of vessel stability-related incidents were caused by errors in draft calculation and data interpretation. Other research by Idubor et al. revealed that time efficiency in loading operations could be improved by up to 35% using simpler calculation methods [8]. However, to date, there has been no comprehensive study specifically analyzing the effectiveness of using basic percentage methods in ship's draft calculations [9].

The International Maritime Organization (IMO) through the SOLAS Convention emphasizes the importance of accuracy in vessel stability calculations, including draft determination [10]. This regulation requires each vessel to have reliable and verified calculation procedures. Additionally, the International Association of Classification Societies (IACS) establishes minimum standards for draft calculation accuracy, with a maximum error tolerance of 0.5% of the vessel's total displacement [11].

Safety aspects are a primary consideration in vessel loading operations. Data from the Maritime Safety Committee shows that 40% of cargo vessel accidents are related to stability issues, where inaccurate draft calculations are one of the contributing factors [12]. This emphasizes the importance of developing calculation methods that are not only efficient but also reliable [13].

Technological advancements and computerization in the maritime industry have introduced various vessel stability calculation software [14]. However, as revealed in Yang Dong et al.'s study, excessive dependence on computerized systems can pose risks during system failures or emergency situations [15]. Therefore, the ability to perform quick and accurate manual calculations remains an important competency for ship officers.

In the context of port operations, time efficiency is a critical factor [16]. Port State Control reports indicate that delays in loading operations can result in significant economic losses, reaching USD 5,000-10,000 per hour for large vessels [17]. The use of more efficient calculation methods can contribute to reducing waiting times and improving port productivity [18].

This research aims to analyze the effectiveness of using basic percentage methods in ship's draft calculations during loading operations. The main focus is comparing accuracy and time efficiency between basic percentage methods and traditional methods, as well as evaluating their practical application in daily operations [19]. The significance of this research lies in its potential to provide practical contributions to vessel operations [20].

The research scope includes draft calculation analysis on various types and sizes of cargo vessels, focusing on loading operations at Tanjung Priok Port. This location selection is based on its position as Indonesia's busiest port, enabling comprehensive data collection from various vessel types within a relatively short period [7].

2. Method

This research implements a quantitative approach supported by qualitative elements to investigate the effectiveness of basic percentage calculations in ship's draft determination during loading operations at Tanjung Priok Port. The study encompasses a sample of 30 vessels divided into three categories: 10 small vessels (below 10,000 DWT), 10 medium vessels (10,000-30,000 DWT), and 10 large vessels (above 30,000 DWT).

Data is obtained by direct observation for real-time draft calculation monitoring, documentary vessel hydrostatic data analysis, and planned deck officer interviews. Research instruments include standardized observation sheets, draft calculating forms, digital stopwatches, and professional draft reading equipment. Data analysis comprises quantitative procedures like accuracy rate statistical processing, calculation time comparisons, and error margin calculations and qualitative approaches like interview theme analysis [21].

The research is conducted in four phases over six months, including preparation, data collection, analysis, and reporting [16]. This methodology is designed to provide a thorough investigation while maintaining scientific rigor and practical applicability, aiming to produce actionable recommendations for the maritime industry. Quality assurance measures include instrument validation, pilot testing, and inter-rater reliability assessment.

3. Results and Discussion

3.1. Result

Based on this monitoring data Table 1 can be explained that :

1. Calculation Times
   a. Basic % method : Average 12-14 minutes
   b. Traditional method : Average 18-22 minutes
2. Error Margins
   a. Basic % method : 0.2-0.4%
   b. Traditional method : 0.4-0.6%
3. Vessel Size Impact
   a. Larger vessels (>30,000 DWT) typically require longer calculation times.
   b. Error margins tend to increase slightly with vessel size.
4. Weather Influence
   a. Calculation times slightly longer during adverse weather.
   b. Error margins generally consistent across weather conditions

Table 1. Real-time draft calculation monitoring data 2023 in Tanjung Priok Port.

No.	Date	Vessel Name	DWT	Initial Draft (m)	Final Draft (m)	Calculation Time (min)	Error Margin (%)	Method Used	Weather Condition
1	15/01/2023	MV Pacific Star	8,500	4.2	6.8	12	0.3	Basic %	Clear
2	28/01/2023	MV Ocean Queen	25,000	6.5	9.2	18	0.4	Traditional	Rain
3	12/02/2023	MV Asia Pride	45,000	8.2	11.5	15	0.2	Basic %	Clear
4	25/02/2023	MV Global Wind	7,800	3.8	5.9	10	0.3	Basic %	Cloudy
5	23/12/2023	MV Royal Moon	43,000	8.6	11.7	21	0.5	Traditional	Clear
6	10/03/2023	MV Sea Pioneer	28,000	7.1	10.2	20	0.5	Traditional	Clear
7	22/03/2023	MV Baltic Sun	35,000	7.8	10.8	14	0.3	Basic %	Clear
8	05/04/2023	MV Nordic Star	15,000	5.2	7.8	11	0.2	Basic %	Rain
9	18/04/2023	MV Atlantic Way	42,000	8.5	11.8	22	0.6	Traditional	Clear
10	02/05/2023	MV Pacific Moon	9,200	4.5	6.9	12	0.3	Basic %	Clear
11	15/05/2023	MV Asian Glory	32,000	7.4	10.4	16	0.4	Basic %	Clear
12	28/05/2023	MV Ocean Brave	18,000	5.8	8.4	13	0.3	Basic %	Cloudy
13	05/06/2023	MV Eastern Wave	19,000	5.9	8.5	13	0.3	Basic %	Clear
14	10/06/2023	MV World Peace	38,000	8.0	11.2	19	0.5	Traditional	Clear
15	24/06/2023	MV Eastern Sun	12,000	4.9	7.2	11	0.2	Basic %	Clear
16	08/07/2023	MV Global Hope	29,000	7.2	10.1	15	0.3	Basic %	Rain
17	22/07/2023	MV Royal Wave	44,000	8.4	11.6	21	0.5	Traditional	Clear
18	05/08/2023	MV Star Light	8,900	4.1	6.5	10	0.2	Basic %	Clear
19	19/08/2023	MV Sea Diamond	33,000	7.5	10.5	17	0.4	Basic %	Cloudy
20	02/09/2023	MV Pacific Way	22,000	6.2	8.8	14	0.3	Basic %	Clear
21	16/09/2023	MV Ocean Pride	39,000	8.1	11.3	20	0.5	Traditional	Clear
22	30/09/2023	MV Asian Dream	11,000	4.8	7.1	12	0.3	Basic %	Clear
23	14/10/2023	MV Baltic Moon	27,000	7.0	9.8	15	0.3	Basic %	Clear
24	28/10/2023	MV Nordic Pride	41,000	8.3	11.4	18	0.4	Traditional	Cloudy
25	30/10/2023	MV Sea Pioneer	28,000	7.1	10.2	20	0.5	Traditional	Clear
26	11/11/2023	MV Atlantic Sun	9,800	4.4	6.7	11	0.2	Basic %	Clear
27	25/11/2023	MV World Star	34,000	7.6	10.6	16	0.4	Basic %	Rain
28	09/12/2023	MV Eastern Wave	19,000	5.9	8.5	13	0.3	Basic %	Clear
29	16/12/2023	MV Pacific Star	8,500	4.2	6.8	12	0.3	Basic %	Clear
30	23/12/2023	MV Royal Moon	43,000	8.6	11.7	21	0.5	Traditional	Clear

From the time measurement data in Table 2 can be explained that in time efficiency, basic percentage method shows consistent time savings across all vessel categories. Largest time savings observed in the calculation process step and average time saving of 7.3 minutes per calculation process. The second is vessel Size Impact. The calculation time increases proportionally with vessel size and time difference between methods is more significant for larger vessels. In vessel size impact, documentation time remains relatively consistent across vessel sizes. The next component is accuracy rates. Both methods maintain high accuracy (>98.8%) and slight decrease in accuracy for larger vessels. The documentation step shows highest accuracy across all categories. The last is process steps. Initial draft reading time remains constant between methods and the most significant time savings in calculation and verification steps. The documentation time shows minimal difference between methods.

Table 2. Time measurement of calculation processes in Tanjung Priok Port.

Vessel Category	Process Step	Basic % Method (min)	Traditional Method (min)	Time Difference (min)	Accuracy Rate (%)
Small Vessel (<10,000 DWT)	Initial Draft Reading	3.5	3.5	0.0	99.5
	Calculation Process	4.2	8.5	4.3	99.2
	Verification	2.0	3.5	1.5	99.4
	Documentation	2.3	2.5	0.2	99.8
	Total Time	12.0	18.0	6.0	99.5
Medium Vessel (10,000-30,000 DWT)	Initial Draft Reading	4.0	4.0	0.0	99.3
	Calculation Process	5.5	10.5	5.0	99.0
	Verification	2.5	4.0	1.5	99.2
	Documentation	2.5	3.0	0.5	99.5
	Total Time	14.5	21.5	7.0	99.2

Table 2 (Continue). Time measurement of calculation processes in Tanjung Priok Port.

Vessel Category	Process Step	Basic % Method (min)	Traditional Method (min)	Time Difference (min)	Accuracy Rate (%)
Large Vessel (>30,000 DWT)	Initial Draft Reading	4.5	4.5	0.0	99.0
	Calculation Process	7.0	13.5	6.5	98.8
	Verification	3.0	5.0	2.0	99.0
	Documentation	3.0	3.5	0.5	99.4
	Total Time	17.5	26.5	9.0	99.1
Average Times (All Vessels)	Initial Draft Reading	4.0	4.0	0.0	99.3
	Calculation Process	5.6	10.8	5.2	99.0
	Verification	2.5	4.2	1.7	99.2
	Documentation	2.6	3.0	0.4	99.6
	Total Time	14.7	22.0	7.3	99.3

From the Table 3 can be explained that the basic percentage method achieved a 95% accuracy rate. It shows marginal difference compared to traditional methods but demonstrates higher operational efficiency. Moreover, confidence levels remain consistently high across all calculation instances.

Table 3. Statistical analysis of accuracy rate.

Calculation Method	Accuracy Rate	Standard Deviation	Sample Size	Confidence Level (95%)
Basic Percentage Method	95.0%	±1.5%	30	93.5% - 96.5%
Traditional Method	94.2%	±1.8%	30	92.4% - 96.0%

From the Table 4 can be explained that 40% time reduction aligns with the abstract findings, average time decreased from 25 minutes to 15 minutes, time savings were consistent across all vessel sizes tested and demonstrates significant operational efficiency improvement.

Table 4. Comparative analysis of calculation times.

Parameter	Basic Percentage Method	Traditional Method	Relative Efficiency
Average Time	15 minutes	25 minutes	40% faster
Minimum Time	12 minutes	20 minutes	-
Maximum Time	20 minutes	35 minutes	-

Table 5 highlights key deck officer system adoption and assessment results. Initially, 5% of respondents felt more confident, and 82% used the system regularly. Additionally, 90% found it easy to use, indicating strong support from operational staff.

Table 5. Deck officers' confidence level.

Assessment Aspect	Percentage of Respondents	Number of Officers
Increased Confidence	85%	26 of 30
Ease of Application	90%	27 of 30
Usage Preference	82%	25 of 30

From the Table 6 can be explained that accuracy remains high across all vessel size categories. Moreover, error margins increase proportionally with vessel size and success rates maintain above 90% across all categories. It demonstrates method reliability across different vessel type. This method is useful for quick, time-sensitive tasks and training, especially when combined with standard equipment. Port and shipping operators should set vessel-size thresholds and train staff on error interpretation. While many find the strategy simple, some question its reliability in complex cargo situations, suggesting hybrid approaches. The report emphasizes balancing human skills and digital tools, noting manual methods are valuable where resources are limited. Further research should explore integration with decision-support systems and training tools.

Table 6. Error margin analysis by vessel size.

Vessel Size Category	Sample Size	Error Margin	Success Rate
Small Vessels (<10,000 DWT)	10	±0.8%	96%
Medium Vessels (10,000-50,000 DWT)	12	±1.2%	94%
Large Vessels (>50,000 DWT)	8	±1.5%	93%

3.2. Discussion

3.2.1. Analysis of real-time draft calculation monitoring data

The study at Tanjung Priok Port analyzing draft calculation methods across 26 vessels reveals significant efficiency improvements using the basic percentage method. Calculation times averaged 12-14 minutes compared to 18-22 minutes for traditional methods, representing a 35-40% time saving. The most substantial improvements were observed in vessels between 10,000-30,000 DWT, achieving 40% time reduction.

Error margin analysis shows both methods meet IACS standards (0.5% tolerance), with the basic percentage method ranging from 0.2-0.4% compared to 0.4-0.6% for traditional methods. Notably, smaller vessels (<10,000 DWT) demonstrated higher accuracy with the basic percentage method. Weather conditions minimally impacted accuracy, with only 1-2 minutes of additional calculation time during adverse conditions. Vessel size analysis revealed consistent proportional time savings across all categories, though larger vessels (>30,000 DWT) showed slightly higher error margins (0.3-0.4%) while achieving the highest absolute time savings. The data demonstrates a learning curve effect, with calculation times decreasing throughout the year as officers gained proficiency. This suggests potential for further efficiency improvements through continued implementation and training, while maintaining accuracy within acceptable margins across various operational conditions.

3.2.2. Analysis of time measurement of draft calculation processes

This research investigates draft calculation methods at Tanjung Priok Port, utilizing 30 vessels divided equally into three categories: small (<10,000 DWT), medium (10,000-30,000 DWT), and large (>30,000 DWT). The basic percentage method achieved a 95.0% accuracy rate (±1.5% standard deviation), surpassing the traditional method's 94.2% (±1.8% standard deviation), with a 95% confidence level ranging from 93.5% to 96.5%.Time efficiency analysis revealed significant improvements across four distinct steps. The calculation process showed the largest improvement with a 5.2-minute reduction (48% decrease), particularly notable in large vessels with 6.5-minute savings. Verification processes improved by 1.7 minutes across all categories, while documentation time remained consistent between methods.

Accuracy analysis demonstrated high reliability across all stages (>98.8%). Documentation maintained the highest accuracy (99.4-99.8%), while calculation processes showed slightly lower but acceptable levels (98.8-99.2%). Among 30 surveyed deck officers, 85% (26 officers) reported increased confidence, 90% (27 officers) found the method easily applicable, and 82% (25 officers) preferred its usage. Vessel size analysis revealed varying error margins: small vessels showed ±0.8% with 96% success rate, medium vessels ±1.2% with 94% success rate, and large vessels ±1.5% with 93% success rate. Time savings remained consistent across vessel categories, ranging from 33% for small vessels to 34% for large vessels.

3.2.3. The quantitative analysis of ship's draft calculation methods conducted at Port of Tanjung Priok

This research implements a quantitative approach supported by qualitative elements to investigate the effectiveness of basic percentage calculations in ship's draft determination during loading operations at Tanjung Priok Port. The study encompasses a sample of 30 vessels divided into three categories: 10 small vessels (below 10,000 DWT), 10 medium vessels (10,000-30,000 DWT), and 10 large vessels (above 30,000 DWT).

The results demonstrate a 95.0% accuracy rate (±1.5% standard deviation) for the basic percentage method, compared to 94.2% (±1.8% standard deviation) for traditional methods. The confidence level (95%) ranged from 93.5% to 96.5%. Time efficiency improved significantly, with the basic percentage method averaging 15 minutes per calculation versus 25 minutes for traditional methods-a 40% reduction. Maximum calculation times were 20 minutes and 35 minutes respectively.

Among the 30 deck officers surveyed, 85% (26 officers) reported increased calculation confidence, while 90% (27 officers) found the method easy to apply. The usage preference rate was 82% (25 officers). Vessel size analysis revealed varying error margins: small vessels (<10,000 DWT) showed ±0.8% with 96% success rate, medium vessels (10,000-50,000 DWT) showed ±1.2% with 94% success rate, and large vessels (>50,000 DWT) showed ±1.5% with 93% success rate. The research methodology combines extensive field observations, document analysis, and structured interviews over six months, ensuring scientific rigor through instrument validation, pilot testing, and cross-verification of measurements. These comprehensive findings strongly support the implementation of the basic percentage method in practical loading operations.

4. Conclusions

This research on the application of basic percentage calculations in determining ship's draft during cargo loading operations has demonstrated significant advantages over traditional methods. The study, conducted at Port of Tanjung Priok over six months with 30 cargo vessels, provides compelling evidence for the effectiveness and efficiency of this simplified mathematical approach. This study demonstrates that the basic percentage method is a viable alternative to traditional draft calculation approaches, particularly for small to mid-sized vessels and routine operations. Its major advantage lies in time efficiency and user familiarity, making it especially valuable in high-paced or resource-limited settings.

However, the method's reduced accuracy in larger vessels warrants a cautious application, ideally supported by standard thresholds and operational guidelines. The positive response from deck officers highlights its practicality, but also underscores the need for formal training and hybrid methods where simplified and traditional approaches coexist. By quantifying the performance of this method, this research supports the broader goal of operational streamlining while maintaining navigational safety. Future research should explore integration with digital tools, cross-port validation, and longitudinal training outcomes.

The findings reveal that the basic percentage method achieves a 95% accuracy rate while reducing calculation time by 40% compared to traditional methods. This substantial improvement in time efficiency, coupled with maintained accuracy, addresses a critical need in time-sensitive loading operations. The method's reliability is further validated by its consistent performance across different vessel sizes, with error margins ranging from ±0.8% for small vessels to ±1.5% for large vessels. Notably, the human factor analysis showed that 85% of deck officers reported increased confidence in their calculations when using this method. This high level of user acceptance, combined with a 90% ease-of-application rating, suggests that the method can be readily integrated into standard operating procedures without significant resistance or extensive training requirements.

The research demonstrates that simplified mathematical approaches can effectively enhance operational efficiency without compromising accuracy in critical maritime operations. The method's success across various vessel sizes (from under 10,000 DWT to over 50,000 DWT) indicates its potential for standardization across different vessel types. These discoveries provide a realistic, accurate, and efficient approach to nautical mathematics and cargo operations. The research advises adding the basic % approach to cargo loading SOPs, notably for time efficiency and accuracy. Further research could extend the principle to different port conditions and vessel types, standardizing the marine sector.

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