TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 19
Number 4
December 2025

DOI: 10.12716/1001.19.04.27

Appropriate Operational Energy Efficiency Indicator Based on the Significance of the Evaluation for Vessels in Regular Service

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ABSTRACT: In recent years, there has been a growing interest in improving energy efficiency during operations for reducing environmental impact. An indicator for evaluating operational performance, known as CII, has been proposed, but it has many issues and is currently under review at the IMO. As operational performance is strongly influenced by shippers' transport requirements, it is important to select an appropriate energy efficiency indicator that takes these constraints into account and to verify its validity to evaluate operational performance with high reliability. Therefore, this study proposes an indicator that considers the physical implications and the influence of transport requirements, as well as a validation methodology using statistical tests. A comparative evaluation of the improvement effect of Weather Routing by applying the CII and the proposed indicator, using observed data from ferries operating daily and with a large number of voyages, showed that the evaluation by the proposed method is highly significant.

1 INTRODUCTION

In recent years, there has been growing interest in improving energy efficiency in ship operations from the perspective of reducing environmental impact. In-operational performance is proposed to be evaluated by the Annual Efficiency Ratio (AER) using the Carbon Intensity Indicator (CII) [1]. However, there are many issues to be addressed, and a review is underway.

Captains operate their vessels in uncertain weather and sea conditions in order to meet the cargo and schedule requirements of their shippers. Several issues need to be addressed to properly manage ship operations from an energy saving perspective (energy saving operation management).

First, fuel consumption and CO_2 emissions relative to the work (ton-miles) done by the vessel are used as energy efficiency indicators by operators in managing operational performance. The calculation of work can be done in ton-miles of DWT, GT or Displacement ton-miles of loaded weight, but which evaluation indicator is appropriate?

The energy efficiency of each voyage varies greatly from voyage to voyage, affected by the amount of cargo carried and the schedule, which caused by transportation requirements, weather and sea conditions, and hull fouling. In the CII, such variation is evaluated using the average AER of energy efficiency over a one-year period. This treatment is understandable, since the average of a sufficient number of data is expected to converge to a certain value (Central Limit Theorem). However, it is known that the standard error, which indicates the error of the mean, depends on the data. It is considered inappropriate to use a mean value with a large standard error due to insufficient data. Confirmation of significance and validity is considered necessary. At the same time, it will be necessary to consider the influence of factors of variation and to exclude these as much as possible to improve significance and validity.

Furthermore, energy efficiency during operation can be attributed to the shipper's transportation requirements or to the operator's efforts. Energy efficiency during operation varies greatly depending on the amount of cargo carried and the required ship speed due to the requirement, but even if this results in poor operational energy efficiency, this is not the operator's responsibility.

What operators can do from the viewpoint of energy-efficient operation is to sail in compliance with the schedule for cargo requested to be transported and to operate on-time without unnecessary early arrivals. Appropriate indicators and evaluation methodologies are considered necessary to evaluate the effects of improved operations through the efforts of ship operators.

In order to evaluate reliable operational performance, it is important to select an appropriate energy efficiency indicator, and to verify the validity of the evaluation methodology and verification of the significance of the evaluation results.

In this study, first, considering the physical implications of energy efficiency, the authors adopted the Energy Efficiency of Navigational Index (EENI), which considers the work done by a vessel in displacement ton-miles as proposed by the authors in [2], [3]. Based on previous research [3], propose a methodology that describes the influence of displacements of a vessel for evaluating the energy efficiency of each voyage. Next, introduce an index suitable for evaluating the effect of energy efficiency improvements by operators that excludes the effects of displacement and required vessel speed due to transport requirements. Finally, the proposed methodology was applied to the operational data collected from the ferry in operation, and the energy efficiency of the ship's basic operation and the effect of using Weather Routing (WR) [4] [5] as a corrective action was evaluated by EENI and CII indicators, with the respective reductions (CO_2 emission reductions) results. At the same time, the reliability (significance) of the evaluation results will be presented, which was verified using the Student's t-test [6], one of the statistical test methods.

The results of the evaluation by the proposed method showed high significance. The number of data required for the required error rate was also less, it is considered that the proposed indicator is more appropriate.

2 EVALUATION OF OPERATIONAL PERFORMANCE

2.1 *Energy efficiency for CII*

CII uses energy efficiency as an index of CO_2 emissions divided by DWT or GT and voyage distance.

$$Voyage\,Energy\,Efficiency\,of\,CII=\frac{FOC\times CF}{DWTorGT\times \mathrm{D}}\left[g\text{-}CO_2/\left(ton\cdot mile\right)\right] \tag{1}$$

2.2 *Proposed energy efficiency（EENI）*

The indexes for CII are defined as CO_2 emissions in relation to DWT ton-miles and GT ton-miles, which can also be called social work defined by the demands of society. However, the fuel consumed by a ship is not consumed only for cargo, but is used to move the displacement W, which is the total weight of the ship. For the operational energy efficiency, it is considered appropriate to use energy efficiency [3], which is calculated from the FC for the displacement tons x voyage distance miles, which is the work physically done by the ship (physical work).

$$\mathrm{EENI}=\frac{FOC\times CF}{W\times D}\left[g-CO_2/\left(ton\cdot mile\right)\right] \tag{2}$$

$$=\frac{FOC/h\times CF}{W\times Vog} \tag{3}$$

FOC : Fuel Consumption
FOC/h：Fuel Consumption per hour
CF : Conversion factor between fuel consumption and CO_2 emission
W : Displacement(ton)
D : Distance sailed (mile)
Vog : Speed over the ground(knot)

2.2.1 *Physical meaning of EENI*

According to Kano and Namie [6], the EENI has a physical meaning, and includes SFC (Specific Fuel Consumption), total resistance coefficient C_T∇, ship speed V, water density ϱ, and gravitational acceleration g, ship propulsion efficiency η, and displacement expressed in volume ▽. In this study, we assumed EENI is inversely proportion to W β, the displacement W is used instead of the displacement volume ▽ and is expressed as follows.

$$\mathrm{EENI}=\frac{SFC\times\rho\times C_{T\nabla}\times V^2\times CF}{\eta\times \mathrm{W}^{\beta}} \tag{4}$$

Equation (4) expresses the nature of EENI well.

Assuming small changes in SFC, ϱ, CF and η, it can be seen that EENI increases in proportion to the square of the ship's speed and inversely proportion to W^β.

$$\mathrm{EENI}=\frac{k\times V^2}{\mathrm{W}^{\beta}} \tag{5}$$

2.2.2 *Indicator showing improvements in operations to transport requirement (OII)*

1. Energy efficiency for transport requirement of EENIr

A transportation requirement specifies the port of departure and the port of destination as well as the respective departure and arrival times, which determines the required ship speed Vr and displacement W.

Therefore, Energy efficiency for transport requirement of EENIr is described as follows.

$$\mathrm{EENIr}=\frac{k\times Vr^2}{\mathrm{W}^{\beta}} \tag{6}$$

2. An indicator showing improvements in operations responding to transport requirement (OII)

Considering the ratio EENI/EENIr of the observed EENI and the EENIr for the transport requirement, it can be said to be the operational improvement ratio OIr (Operational Improvement Ratio), which indicates how close the energy efficiency of actual operations has come to the transport request.

$$OI_r = \frac{EENI}{EENI_r} \tag{7}$$

Since it is difficult to specifically identify k, we propose the following indicator OII (Operational Improvement Indicator), This indicator means OIr multiplied by k

$$OII = \frac{EENI}{Vr^2} \tag{8}$$

$$= \frac{k}{\mathrm{W}^{\beta}} \times OIr \tag{9}$$

2.3 *Evaluation of operational energy efficiency*

The observed energy efficiency varies depending on transport requirements from shippers and external forces such as weather and sea conditions.

Therefore, the evaluation is done by taking the average value over a certain period of voyage.

For example, CII uses the annual average energy efficiency rating (AER) as an indicator of operational performance. The property of the mean value is that it will converge to a constant value if the number of data is sufficiently large relative to the variation, even if the mean value is varied (Central Limit Theorem). Therefore, it makes sense to use this as an indicator. In addition, it is considered reasonable to obtain an average value based on a year's worth of voyage data, as this incorporates seasonal variations throughout the year. However, the number of voyages per year varies from vessel to vessel. In actual evaluations, the average energy efficiency value is obtained from data on a limited number of these voyages. In such cases, it is important to take measures to reduce and evaluate error. Therefore, we will review the mean error based on statistical findings.

2.3.1 *The term energy efficiency ratio (TER)*

From an operational management perspective, we may wish to evaluate the results over an arbitrary term, T. The term energy efficiency ratio (TER) for a given number of voyages (N) over term T is calculated as follows:

$$\mathrm{TER}_N = \frac{\sum_N FOC \times CF}{\sum_N W(ton)_n \times Dist(mile)_n} \left[g / (ton \cdot mile) \right] \tag{10}$$

2.3.2 *Standard error and error rate of TER*

When enough data is available, the mean value will typically converge to a specific error range, as demonstrated by statistical analysis (Central Limit Theorem).

The mean (μ) and standard deviation (σ) are, respectively, obtained from a sufficient number of data. Then, the difference between the mean value μN obtained from N data and μ is called the standard error (SE), which can be obtained by the following equation.

$$\mathrm{SE} = \frac{\sigma}{\sqrt{N}} \tag{11}$$

And, the standard relative error, ϵ_{SE} described as follows:

$$\epsilon_{\mathrm{SE}} = \frac{SE}{\mu} \tag{12}$$

From equation (11), the standard error of mean is expressed as the relationship between the variance, which indicates variability, and the number of data from which the mean is calculated, and that the larger the number of data and the smaller the standard deviation σ, the smaller this error becomes. In other words, reliable results with small standard relative errors can be expected if the number of observed data is sufficiently large. However, since the number of voyages per term varies from vessel to vessel, it is important to evaluate the error in the TER based on the variance of the data and the number of voyages for one's own vessel.

2.3.3 *The evaluation of operational energy efficiency and the significance*

1. The evaluation of differences in average TERs for operational energy efficiency

The improvement in operational energy efficiency due to corrective actions such as WR can be evaluated by the difference in TER. For example, using the average TERM of the energy efficiency of M voyages without WR and the average TERN of the energy efficiency of N voyages with WR, it can be expressed as follows.

The improvement rate ε due to corrective action taken is expressed as follows.

$$\varepsilon = \frac{\left(TER_N^{with\,WR} - TER_M^{without\,WR} \right)}{TER_M^{without\,WR}} \tag{13}$$

2. Significance of differences in TER

The significance of differences in means can be determined by performing statistical tests. For example, the significance can be determined by determining the P value by performing Student's T test [7],. In general, a P value is considered significant if it is less than or equal to 5%. significance of difference in TER

2.4 *Models for energy efficiency in operation*

Here, EENI is applied to the evaluation model (a Wiener-type probability model) proposed in Ref. [3], as follows. The first term indicates the influence of fouling on the hull and propeller due to biofouling, etc., and the bias term increases with time t after docking; the second term is the term of the ship's original performance corresponding to the required ship speed;

the third term expresses the variation due to weather and sea conditions; and the fourth term is a deflection term hat is caused by directional external forces such as ocean currents and westerly winds.

$$EENI_n = at + EENI_{n0} + bZ\left(n\right) + cSig \tag{14}$$

where,

a: Effect coefficient of hull fouling and other age-related deterioration

$EENI_{n0}$: EENI at calm sea in the condition of the hull at the time of dockage's hull cleaning on the nth voyage

b: Effect coefficient of variation due to weather and wave conditions

Z(n): Variation affected by weather and wave conditions

c: Effect coefficient of directional factors such as westerlies, ocean currents

Sig: Sign expressing the deflection of westerly winds, ocean currents, etc.

To reduce the variations of the observed EENI, this study as follows. Furthermore, when evaluating the impact of changes over time, the influence of weather and sea conditions before and after docking is taken into account using operational data collected on the vessel.

1. Removes the effect of differences of displacement

As equation (3), (4) shows, the value of EENI tends to decrease as the displacement increases. This effect needs to be excluded in order to evaluate energy efficiency during operation.

The energy efficiency index (EENI) can be obtained using the following formula. Since the EENI is defined for each voyage, the energy efficiency obtained from the monitoring data is denoted by the lowercase letter eeni.

$$eeni = \frac{Foc / h \times CF}{W \times Vog} \tag{15}$$

The effects of wind and waves change from time to time and the observed EENI includes the effects of ever-changing wind and waves.

The differences of the displacement in calm conditions may be made clearer by adopting the average of monitoring data from the calm sea conditions (e.g. absolute frontal wind speeds of 5 m/s or less and wave heights of 1 m or less; it should be noted that such thresholds vary depending on the size of the vessel under consideration, etc.).

Therefore, a coefficient of βis identified using the least squares method for the relationship between the measured eeni at calm sea conditions per voyage and the displacement. Using this coefficient, the eeni can be converted to the same displacement and compared.

2. Removes the effect of changes over time

According to References [3], the effect of change over time coefficient ‘a’ is determined by the difference in average EENI for X months before and after docking, as shown in equation (16).

$$a = \frac{\overline{EENI_{before}} - \overline{EENI_{after}}}{T} \tag{16}$$

where $\overline{EENI_{before}}$ is the average EENI before docking, $\overline{EENI_{after}}$ is the average EENI after docking and T is the time difference between dockages.

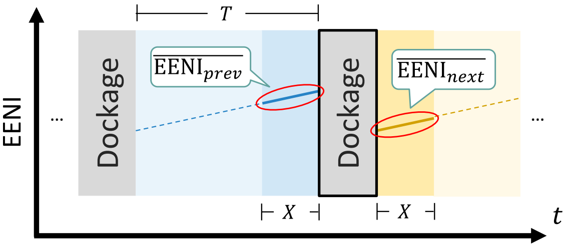


Figure 1. Changes over time for EENI

3 APPLICATION FOR A FERRY

In this section, the proposed evaluation method is applied to a ferry operating on the following regular routes to evaluate the energy efficiency of the vessel and the energy saving effects of using WR (eE-NaviPlan) [5] as a corrective measure and not using WR (eE-NaviPlan).

3.1 *Overview of target ship*

Figure 2 shows Ship A (Table1) and the regular route. This ferry is operated by Miyazaki Car Ferry Co., Ltd. (Miyazaki Car Ferry, 2024) [8] and operates daily between Miyazaki (A) and Kobe (B) according to the schedule in Table 2, with one round voyage every two days. It becomes. Additionally, sailing times differ for outbound and return voyage from Monday to Saturday and Sunday. The sailing time differs between Monday-Saturday and Sunday for outbound and return trips.

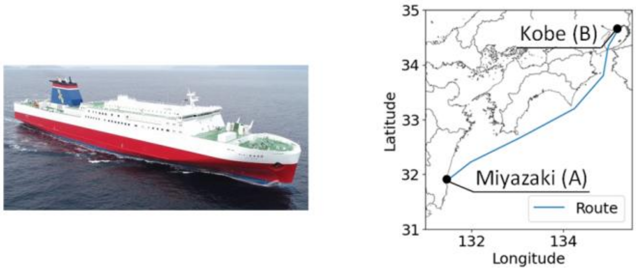


Figure 2. Ship A and regular route

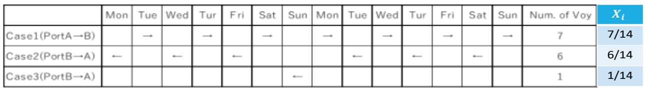
Table 1. Principal specifications

Ship Name	Route	L [m]	B [m]	GT [ton]	NAV.DIST [N.M]
TAKACHIHO	Miyazaki-Kobe	194	27.6	14006	267

Table 2. Cases, Ship’s Schedule and Required Speed of Ship A

Cases & Schedule	Port A	Port B	Nav.Time	REQ.Speed
Case1 Monday – Sunday	19:10	→7:30	12:20	21.6
Case2 Monday – Saturday	8:40	←19:10	13:30	19.8
Case3 Sunday	8:40	←18:00	14:40	18.2

Table 3. Incidence (Xi) of each case



	Mon	Tue	Wed	Tur	Fri	Sat	Sun	Mon	Tue	Wed	Tur	Fri	Sat	Sun	Num. of Voy	X_i
Case1(PortA→B)		→		→		→		→		→		→		→	7	7/14
Case2(PortB→A)	←		←		←				←		←		←		6	6/14
Case3(PortB→A)							←								1	1/14

3.2 *Investigation*

3.2.1 *Impact of displacement on EENI*

Figure 3 shows the relationship between the observed eeni at calm sea conditions and the displacement between 20 May and 15 June 2023 in the Case 1. Here, the frontal absolute wind speed is less than 5 m/s and the wave height is less than 1 m predicted by the JMA (Japan Meteorological Agency) were defined as calm conditions, respectively. The figure shows that the value of eeni is smaller and improve energy-efficient in operation the larger the displacement. The approximate curve obtained by the least-squares method is shown as a solid line in the figure. The results show that α = 37971 and β = -0.847 for the vessel as following equation.

$$eeni = 84120 \times W^{-0.847} \tag{17}$$

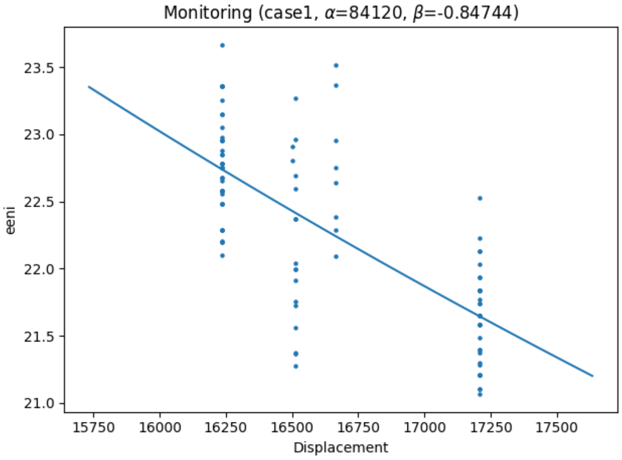


Figure 3. eeni and displacement

3.2.2 *Impact of displacement on EENI*

1. Variation in EENI and CII of the ferry

Table 4 shows the results of the evaluation of the standard deviation and other statistics of EENI excluding the effects of CII and drainage volume based on one year of data (28 Jun 2023~28 Nov 2023) recorded in the abstract logbook of the subject vessel. The EENI's variance, standard deviation, standard error and standard relative error are relatively better than those of the CII, with smaller values of 29%, 15%, 16% and 4% respectively. The frequency distribution of each is also shown in the Figure 4. Although similar in shape, the kurtosis is greater for EENI.

Table 4. Statistics values of AER for EENI and CII

	EENI (W-corrected)					CII				
	Mean	Dev.	SD	SE	SE/mu	Mean	Dev.	SD	SE	SE/mu
Average	20.9	2.92	1.71	0.0866	0.414%	23.8	4.09	2.02	0.103	0.430%

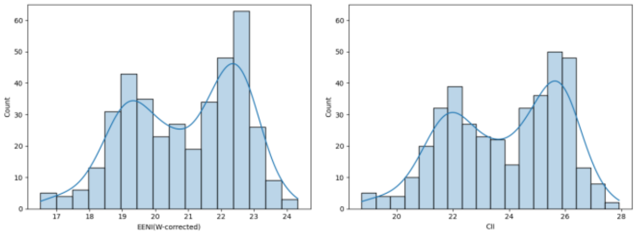


Figure 4. Frequency distribution of EENI and CII

Figure 5 shows the relationship between the standard error rate and the number of voyages determined by equation (12). It shows that the number of voyages required to reduce the error rate below 1% requires data from at least 67 voyages for EENI and 72 voyages for CII. EENI requires about 7% less data than CII.

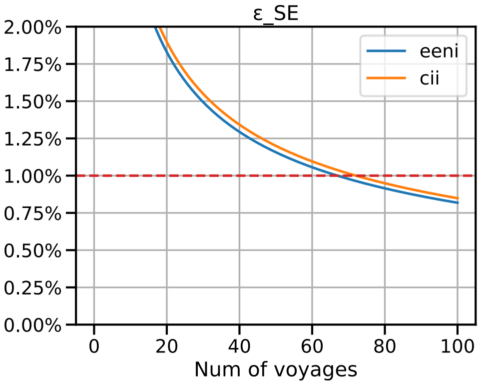


Figure 5. Standard error rate and number of voyages

2. Variation in EENI and CII of the ferry in each case

The subject vessel has different orientations and speed requirements for each Case, as shown in Table 2. Table 5 shows the statistics values for each Case, including the standard deviation for each Case, which is about 30-50 % smaller than the aforementioned results, and therefore the data is more coherent. The frequency distribution of each Case is also shown in the Figure 6.

Table 5. Statistics values of AER for EENI of each Case

	EENI (W-corrected)				
	Mean	Dev.	SD	SE	SE/mu
Case1	22.2	0.692	0.832	0.0591	0.266%
Case2	19.8	1.28	1.13	0.0878	0.445%
Case3	18.0	0.866	0.930	0.186	1.03%

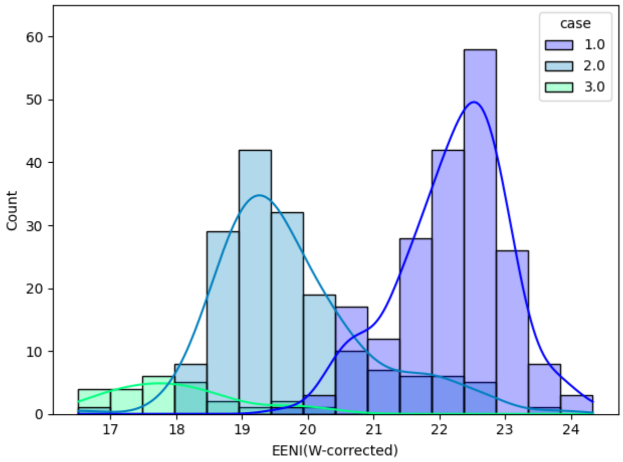


Figure 6. Frequency distribution of EENI

The Figure 7 shows the relationship between the number of voyages and the standard error rate against the EENI obtained for each Case. It can be seen that the number of voyages required to reduce the standard error rate below 1% is significantly reduced from 67 voyages when all data are handled to 14, 33 and 27 voyages in Case 1, Case 2 and Case 3.

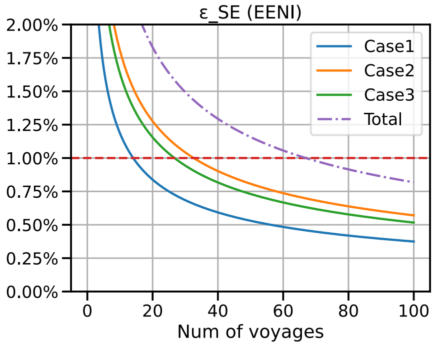


Figure 7. Standard error rate and number of voyages of each case

3.3 *Application of the proposed mode*

3.3.1 *The effect of changes over time*

From the relationship between displacement and average of EENI, the following table compares the difference 30days before and after docking for EENI at a displacement of 16000 tons for each Case. Case 3 was excluded for analysis because of the small number of 3 data.

Table 6. Average of EENI before and after dockage and number of data

EENI: Calm sea/ Displacement correction	Before Dockage（Num. of Data）	After Dockage（Num. of Data）	Improvement effect
Case1	22.4 (15)	21.2 (12)	5.41%
Case2	21.0 (13)	20.1 (13)	4.33%
Case3	18.1 (1)	18.2 (2)	-0.211%

3.3.2 *WR service for the ferry*

The WR service 'eE-Navi Plan' provided by NPO Marine Technologists [9] is a system that supports voyages by sending voyage plans (arrival/departure ports, arrival/departure times, etc.) from ships to shore in advance, and then providing optimal control variables and a weather forecast information (weather/sea condition prediction). The system supports navigation by providing optimum control variables (RPM/wing angle), etc. from shore to ensure that the ship arrives in time for the planned arrival time.

This system enables ships to sail at the minimum necessary speed without being late for the required arrival time, avoiding unnecessary early arrivals, avoiding the rush-to-wait phenomenon and avoiding offshore waiting, thereby achieving a significant reduction in CO2 emissions from vessels and on-time operation. CO2 emissions from vessels can be significantly reduced and on-time operations can be achieved.

It is also possible to check the monitoring data transmitted from the ship and the results of analyses of voyage planning and fuel savings, which will be useful for improving the efficiency of future operations.

3.3.3 *Evaluation on improvements from WR as a corrective action*

The average EENI (Energy Efficiency of Navigational Index) at a displacement of 16000 tons and corrected changes over time）of the vessel's basic operational performance with WR (BAU; Business As Usual) and without WR (Project) can be determined by equation (10) using the operational data corresponding to the respective schedules, where the deflection and time-dependent terms have been removed. Eventually, the improvement rate ε due to WR can be calculated by equation (13).

1. Data to be analyzed

The operational data for the analysis was obtained from 2023/6/28~2023/11/30 after leaving the dock, taking into account that the performance will not completely return to the level immediately after entering service. During this period, Ship A was provided with WR services, but as the WR planning and operations were not properly planned and operated, so on September 14, 2023, the captain and crew were explained how to operate it. Since then, the voyage planning and operation had generally been done correctly. The voyages where the WR was correctly planned and operated as shown in Table 7 for the use of the WR are defined as those voyages where the WR was used (w/o WR) and those where the WR was not used (w/o WR).

Table 7. Number of data with / without WR

Num. of Data	w/WR	W/o WR
Case1	22	49
Case2	29	33
Case3	3	8
Total	54	90

2. Evaluation result

Table 8 shows the average EENI values with and without the use of WR per Case. The effectiveness of the WR calculated by the equation (13). Furthermore, the significance of this reduction effect was statistically tested by Student's t-test (Student, 1992).

The significance of the evaluation results of each reduction effect can be determined by the p value, and it is often determined that it is significant if this value is 5% or less. For Case1, the p-value is less than 5%, indicating high significance and 95% reliability. For Case2, the p-value is 6.7%, it is above 5% but also below 10%, which is considered to be an acceptable range. However, in Case3, the p value exceeds 70%, so it is unreasonable to judge it as significant. This may be due to the fact that the amount of data for the evaluation was as small as 3 and 8 data.

Therefore, the results of Case3 were excluded and the value of the EENI reduction effect obtained by averaging the ratios of Case1 and 2 as 7:6 respectively, was evaluated as the reduction in operational energy efficiency due to WR during the evaluation period. The results show that the operational energy efficiency has been reduced by 2.9%.

Table 8. EENI savings from WR in Ship A

Case		Num. of Data	EENI (W-corrected)	EENI saving
Case1	w/ WR	22	21.1	-3.01%
	w/o WR	49	21.7	
	p-value		0.023	
Case2	w/ WR	29	19.6	-2.86%
	w/o WR	33	20.2	
	p-value		0.067	
Case3	w/ WR	3	19.4	+2.17%
	w/o WR	8	19.0	
	p-value		0.714	
Average	=(-3.01×7-2.86×6) /13			**-2.9%**
	P-value：The probability that such an outcome will occur by chance.			

3.4 *Operational Improvement Indicator (OII)*

Table 9 shows the Operational Improvement Indicators (OII) for Cases 1 and 2. These indicators show how far the energy efficiency of the actual operation has come in relation to the transport requirements. This shows that Case 2 is less energy efficient than Case 1 due to its larger value. This may be due to the influence of ocean currents and prevailing winds.

Table 9. OII （Operational Improvement Indicator）

$\frac{EENI_{corrected}}{Vr_{og}^2}$	w/ WR	w/o WR
Case1	0.0449	0.0463
Case2	0.0501	0.0516
Case2/Case1	1.12	1.12

4 CONCLUSION

Energy efficiency during operations, which is considered to represent operational performance, is strongly influenced by the transport requirements of shippers and daily changing weather and sea conditions on a voyage-by-voyage basis, and has a large degree of variation, so in order to conduct a reliable evaluation of operational performance, it is necessary to select appropriate evaluation indicators and to verify the validity of the evaluation method and evaluation results using these indicators. The following are some of the key issues that need to be addressed.

In this study, the following results were obtained on operational performance, using observation data from ferry that operate daily and for which data on a large number of voyages are available, and investigating the validity of the evaluation indices, methods and evaluation results.

1. EENI was shown to be appropriate as an index for evaluating energy efficiency during operations.
2. Component-separated models were introduced, which influence the effects of changes over time, such as hull fouling, and the effects of deflections, such as ocean currents and prevailing westerly winds, and energy efficiency on a voyage-by-voyage basis, such as weather and sea conditions. The model was applied to evaluate the effects of changes over time on the data before and after docking, and by treating Case separately for each route/schedule, it was possible to evaluate the energy efficiency of the operation with reduced variation.
3. Energy efficiency during operations can be derived from transport requirements from shippers, or from operational improvements made by captains and other operators. Operational improvement indicator (OII) was proposed, suitable for evaluating the impact of energy efficiency improvements by operators, excluding the impact of transport requests.
4. A comparison of EENI and CII statistics derived from ferry operation data shows that EENI has less variation than CII, and the number of data required for a standard relative error of 1% is also 7% less 67 for EENI than compared to 72 for CII. The proposed EENI indicator is considered to be an appropriate and reasonable indicator for the evaluation of operations.
5. Furthermore, the effectiveness of the WRs used on this ferry as a measure to improve operational efficiency was evaluated and a reduction of 2.9% was achieved with acceptable confidence (p-value ≦ 7％)
6. Although the study was conducted for ferries in regular service, the proposed indicators and methodologies are considered to be applicable to tramp vessels, so the next step is to evaluate the applicability of the proposed indicators and methodologies to tramp vessels.

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