Challenges hindering the ballast water management compliance in Nigeria

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**ABSTRACT**

The problem of invasive species transfer through ship’s ballast water has resulted in the mandatory International Maritime Organisation (IMO) D-2 standards for existing vessel to installation ballast water treatment system (BWTS) onboard for compliance with the schedule deadline of 8 September 2024. However, many ship owners are still not able to comply with the regulation due to the presence of several challenges. Hence, this study evaluates the challenges hindering the Ballast Water Management System (BWMS) compliance of shipping operators in Nigeria from installation of BWTSs. Based on the expert interview and industry review, technical challenges (TCs), environmental challenges (ENCs), economic challenges (ECCs), and other challenges (OCs) were identified as the major challenges responsible for the non-compliance among the Nigerian shipping companies. The Analytical Hierarchy Process was used for evaluating and ranking the various challenges, and the results obtained indicate that OCs, which include external and internal influences on ship operators, ship type, age, and trading route, obtained the highest rank (0.3666), followed by ECCs (0.3648) and TCs obtaining the third rank (0.1456). ENCs were regarded as the least concern (0.1223) for shipping operators in the region in their decision to comply with the BWMS by installing BWTS onboard their ship. This study will help decision-makers in prioritizing the management measure and taking policy decision that can promote the compliance among shipping companies in the region.

**Introduction**

The expansion of maritime trade routes has contributed to increased shipping traffic around the world (IMO, 2022; Wang et al., 2020), and increasing the risks of invasive marine species spread to new regions through ballast water transfer (Zhang et al., 2017; Gehard et al., 2019). Ballast water is necessary to provide draft and stability during ships’ operation but has been identified as a major pathway for the introduction of marine invasive species to new regions (IMO, 2004; Verna and Harris, 2016; Bailey, 2015). Nonetheless, the maritime sector is facing a major challenge in managing these negative impacts posed by the spread of potentially invasive aquatic species in ships’ ballast water transfer (Jang et al., 2020; Jing et al., 2012; David et al., 2013), which has risen to a significant concern in the global shipping industry (Endresen et al., 2004). Among the solution introduced by the IMO, in managing these problems, is the D-2 discharge standard priority agenda, which entails the installation of a ballast water treatment system (BWTS) on existing ship which is based on the scheduled deadline of 8 September 2024 (IMO BWMS Guidelines, 2022). Several BWTSs incorporating a variety of technology combination have been developed for meeting the D-2 standard (Tsolaki & Diamadopoulos, 2010), Goncalves and Gagnon, 2012; Top et al., 2021). However, many shipowners are still faced with a range of challenges hindering them from obtaining, installing, adapting, and effectively using the BWTS (Wright, 2018; Wan et al., 2018; Casa-Monroy et al., 2018). In considering the approaching deadline set by the IMO in meeting up the D-2 standard by 2024, it is imperative to understand the various challenges faced by shipowners to enable us in solving them.

**Study location**

The shipping industry is considered as a major hub for local and international trade in West Africa region, accounting for over 60% of total seaborne traffic in volume and values in regions (Ajib et al., 2019). The huge coastline space of approximately 853 km, bordering the Gulf of Guinea in the west, provides the basis for its substantial maritime activities. The region is assumed to be at greater risks of invasion of harmful aquatic organisms through ballast waters based on the increasing shipping traffic calling on the Nigerian ports from all over the world. Also, the recent reports from the region have shown the introduction of European zebra mussels (Dreissena polymorpha), which clog the hull of maritime structures and resulted in their sinking (Eke, 2015; Ukwe et al., 2010), and the North Pacific Sea...
star (Asterias amurensis), which was introduced into Nigeria’s fishing fields around the Niger Delta through ballast water and decimated the shellfish population. Hence, the BWTS is necessary for managing and controlling the advanced effects that are likely to be posed by invasive species spread in the region. In this study, we conducted a survey which was sampled among ship operators in Nigeria to identify their status of ballast water compliance and challenges faced in selecting the BWTS by using a questionnaire. Since the result of our survey analysis does not provide a systematically ranking of the relative importance of the challenges, according to the ship operators’ perspective, we integrate the survey framework into a hierarchic structure model using the AHP for our analysis. The novelty of this work lies in the fact that prioritizing the barriers of installing BWTS was based on the perspectives of ship owners’ operating in Nigeria and may serve as a prototype to other developing countries.

Study methodology

In this study, a three-stage approach was applied for the collection of information, assessment, and analysis to enable us to understand the problem and obtain our study objective. Our study methodology is represented graphically in Figure 1.

Survey study of ship operators

A survey questionnaire was sampled among the selected shipping operators in the region to assess their ballast water management compliance profile and related challenges hindering their compliance. The information was collected on their BWTS profile and general characteristics and the challenges faced to obtain compliance. Also, a thorough review of the literature was carried out to further understand and compare the challenges.

Expert interview and opinion

In validating the challenges for our evaluation, five maritime experts with wider experience in the Nigerian shipping industry were contacted for their opinions and confirmation. The maritime experts were selected among the top industry leaders and consultant with over 5 years of experience. Their judgement on the pairwise comparison of the challenges was used as input in the AHP analysis process.

Application of the AHP technique

The AHP is a multicriteria decision-making technique developed by Saaty (1978) and used in solving complicated decision-making problems by decomposing them into multilevel hierarchical structure of objective, criteria, and alternatives, and a pairwise comparison is used to derive the relative importance of the variable using the Saaty scale of preference 1–9 (Table 1) to represent the expert opinions on the relative importance of the variable (Haralambides and Yang, 2003; Kamal et al., 2021).

Steps applied in the AHP analysis technique

The four steps of the AHP technique applied in this study are as follows:

**STEP 1:** The decision hierarchy is established by identifying the problem and selecting barriers and possible alternatives. The criteria Ci is used for evaluating the problem.

![Figure 1](image-url)
Table 1. Saaty’s 1–9 pairwise scale of preference index.

| Importance       | Rank | Explanation                        |
|------------------|------|------------------------------------|
| Extreme          | 9    | Criterion I is extremely more     |
| Very strong      | 7    | important than j                   |
| Strong           | 5    | Criterion I is more important than |
| Moderate         | 3    | slightly more important than j     |
| Equal            | 1    | Criteria I and J are of equal      |

STEP 2: Next, the questionnaire was distributed to decision-makers (K) for establishing the pairwise comparison matrix, using established ratio of relative importance of the criteria (n). The selected barriers were compared in pairs using Saaty’s 9-point rating as shown in Table 1, and weights are assigned from the pairwise comparison of the decision-maker’s judgement and used to form matrix $A^K$

$$\begin{align*}
  a_{ij}^k &= \begin{pmatrix}
      a_{1,1}^k & a_{1,2}^k & \cdots & a_{1,n}^k \\
      a_{2,1}^k & a_{2,2}^k & \cdots & a_{2,n}^k \\
      \vdots & \vdots & \ddots & \vdots \\
      a_{n,1}^k & a_{n,2}^k & \cdots & a_{n,n}^k 
    \end{pmatrix}
\end{align*}
$$

where $a_{ij}^k$ is the K–nth term on expert judgement criterion I compared to J.

And $a_{ij}^k > a_{ji}^k = \frac{1}{a_{ij}^k}$, $a_{ii}^k = 1$

when $a_{ij}^k = a_{ji}^k = 1$, and $k = 1, 2, 3 \ldots z$.

STEP 3: The weights assigned to criteria $C_1 \ldots C_2 \ldots C_3 \ldots C_n$ by the decision-makers are then calculated through the pairwise comparison matrix $A^K$. The weights of the criteria are obtained by dividing each criterion in the pairwise comparison matrix by the sum of its column and calculating the arithmetic mean of each row.

$$\begin{align*}
  W_i &= \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}^k}{\sum_{j=1}^{n} a_{ij}^k} 
\end{align*}
$$

where $W_i^k$ denotes the weight of each criterion $C_i$

STEP 4: The final step is the consistency check of the judgement of the decision-makers. This is achieved by calculating the value consistency index (CI) and the random CI or consistency ratio (CR). To fulfil a condition of consistency, the value (CR) must be less than 0.1; then, in this case, the judgments of the decision-maker(s) can be accepted as being consistent.

For calculating the values of the CI and CR, we apply Equations (3) and (4) as follows:

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1}$$

where $\lambda_{\text{max}}$ is the maximum eigenvalue and mean weight of coefficient $\lambda$, which is calculated from Equation (5), while $n$ is the number of compared elements or matrix size.

$$\lambda_{\text{max}} = \frac{1}{n} \sum_{i=1}^{n} \lambda_i$$

Then,

$$CR = \frac{CI}{RI}$$

$RI$ is the corresponding average random index of CI for an $n \times n$ matrix depending on the number of compared elements $(n)$, and its value is seen in Table 2.

**Study results**

**Selection of criteria/challenges and evaluation**

The challenges identified during the survey sampled on the ship operators in Nigeria were further subjected to reviews and validation using questionnaire representing pairwise comparisons from 1 to 9 scale by five maritime experts with broader knowledge and experience of the Nigerian shipping industry and are presented in Table 2. Also, maritime experts were selected among the top industry leaders and consultant with over 5 years of shipping experience, and their evaluation judgement on the pairwise comparison of the challenges is presented in Table 3. The weight of each criterion was processed using the AHP multicriteria technique in the ranking of the ship operator challenges in Nigeria. Also, by using the numerical rankings of the assessment criteria in Table 4, we were able to construct a $4 \times 4$ pairwise comparison matrix using step 2 as seen in Table 4.

Table 2. Random index values (RIs) for matrix size $(n)$.

| n   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  |
|-----|----|----|----|----|----|----|----|----|----|
| RI  | 0.0| 0.0| 0.58| 0.90| 1.12| 1.24| 1.32| 1.41| 1.45|
Table 3. Challenges of ship owners from compliance of BWTS.

| Challenges | Explanation and definition of challenges/criteria |
|------------|--------------------------------------------------|
| 1. Technical challenge (TC) | This includes problems relating to reliability of BWTS, energy efficiency, the crew safety, BWTS system configuration, ship operator technology preference and BWTS operational complexity. |
| 2. Economical challenge (EC) | This includes problems relating to the capital cost of the BWTS (CAPEX), operational cost (OPEX), and life cycle cost. |
| 3. Environmental challenge (ENC) | This problem includes the effect on public health, marine biodiversity and extinction of native species, and the impact of the BWTS on the economic activity of coastal industry using sea water like fishing. |
| 4. Other challenge (OC) | This challenges include external and regional influence on ship operators, the ship type, age, size of fleets, and trading route. |

Table 4. Scale for the pairwise comparison of criteria.

| Pairwise comparison | More important challenges | Level of importance | Numerical ranking |
|---------------------|---------------------------|---------------------|------------------|
| 1. OC and TC | Technical challenge (TC) | Moderately more | 3 |
| 2. OC and EC | Economical challenge (EC) | Equally important | 1 |
| 3. OC and ENC | Environmental challenge (ENC) | Moderately more | 3 |
| 4. TC and EC | Economical challenge (EC) | Moderately more | 1/4 |
| 5. TC and ENC | Other challenge (OC) | Moderately more | 2 |
| 6. EC and ENC | Economical challenge (EC) | Moderately more | 2 |

Table 5. 4 × 4 Pairwise comparison matrix of criteria.

| Challenges | TC | ECC | ENC | OC |
|------------|----|-----|-----|----|
| 1. TC | 1.0000 | 0.2500/2.7500 | 0.3333/2.0000 | 2.0000/8.0000 |
| 2. ECC | 4.0000/8.5000 | 1.0000/2.7500 | 0.3333 | 2.0000/8.0000 |
| 3. OC | 3.0000/8.5000 | 1.0000/2.7500 | 0.3333/2.6666 | 3.0000/8.0000 |
| 4. ENC | 0.5000/8.5000 | 0.3333/2.6666 | 1.0000/8.0000 |

Table 6. Evaluation criteria to determine their weights.

| Challenges | TC | ECC | ENC | OC |
|------------|----|-----|-----|----|
| 1. TC | 1.0000/8.5000 | 0.2500/2.7500 | 0.3333/2.0000 | 2.0000/8.0000 |
| 2. ECC | 4.0000/8.5000 | 1.0000/2.7500 | 0.3333 | 2.0000/8.0000 |
| 3. OC | 3.0000/8.5000 | 1.0000/2.7500 | 0.3333/2.6666 | 3.0000/8.0000 |
| 4. ENC | 0.5000/8.5000 | 0.3333/2.6666 | 1.0000/8.0000 |

Table 7. Ranking the weight values of each criterion.

| TC | ECC | ENC | OC | RANK | Rating |
|----|-----|-----|----|------|--------|
| 0.1176 | 0.0909 | 0.1250 | 0.2500 | 0.1456 | 3rd |
| 0.4706 | 0.3636 | 0.3750 | 0.2500 | 0.3648 | 2nd |
| 0.3529 | 0.3636 | 0.3750 | 0.3750 | 0.3666 | 1st |
| 0.0588 | 0.1818 | 0.1250 | 0.1250 | 0.1223 | 4th |

**AHP synthesis process of criteria**

Next, we apply step 3 of the AHP techniques mentioned earlier in performing the AHP synthesis process of the criteria given in Table 5. The weight of each evaluation criterion is further determined by summing up the values in each role of the pairwise comparison matrix and dividing them by the average value of the elements in each row (i.e., total number of criteria). The results are presented in Table 6 and Table 7 respectively.

Table 8. Summation of the average value of the criteria.

| ENC | TC | ECC | OC | SUM |
|-----|----|-----|----|-----|
| 0.3666 | + | 0.4368 | + | 0.3648 | + | 0.3669 | 1.5351 |
| 0.1222 | 0.1456 | 0.0912 | 0.2446 | 0.6036 |
| 0.3666 | 0.5824 | 0.3648 | 0.2446 | 1.5584 |
| 0.1222 | 0.0728 | 0.1824 | 0.1223 | 0.4997 |
**Consistency check of pairwise decision judgement**

The weighted values (ranking) of the evaluation criteria are checked for consistency of the pairwise judgement of the decision-makers, by applying Equations 3 down to and 6 and the results obtained is presented in Table 8 and 9 respectively. Each value in the first column of the pairwise comparison matrix was multiplied by the priority of the first item, and the total summation of their criteria in Figure 7 is divided by the determined weighted value/ranking of the criteria.

Finally, we obtained the value for CI as follows:

CI = (4.1727–4)/4 – 1
CI = 0.1727/3
CI = 0.0576.

There are four criteria (challenges) in the first level of the hierarchy, resulting in the corresponding RI of 0.90. Therefore, the CR will be calculated as follows:

CR = CI/RI = 0.0576/0.90.
CR = 0.064.

The result of the pairwise comparison for the weights of the evaluation criteria shows a CR of 0.064. This means that the degree of consistency in the pairwise comparisons is acceptable because the CR is less than 0.10.

**Discussion**

In this study, we evaluate the several challenges influencing the BWMS compliance and installation of BWTS among the selected shipping operators in Nigeria. The challenges identified for hindering the BWMS compliance include technical challenges (TC), environmental challenges (ENCs), economic challenges (ECCs), and other challenges (OCs). After applying the AHP multi-criteria decision analysis and aggregating the values obtained from the decision-makers, we obtained the weighted value for each group of challenges hindering the ship operators’ BWMS compliance in descending order from the least importance as W = [0.1446, 0.1223, 0.3648, 0.3666], representing W = [ENC, TC, ECC and OC]. The CR of 0.064 less than 1 (CR < 10%) was obtained for the pairwise comparison matrix for the challenges, which indicates that the information for assignment of weights was deemed consistent and satisfactory for the study. The results provided in our AHP calculation as seen in Table 6, in terms of the criteria/challenge ranking, show that OCs, which include external and regional influence on ship operators, ship type, age and size of fleets, and trading route, have the most important influence on their decision to install and comply to the BWMS. The majority of the shipping companies in the region are operating within the African continent with lesser concern for BWMS since most of the countries are not members of the IMO BWMS. In terms of the overall ranking, the ECC including problems relating to capital cost, operational cost, and life cycle cost of BWTS was ranked second. The result is apparent since most of the ships are over 45 years older and are mostly smaller vessel, which makes them become at a higher risk from a financial point of view, since most of the shipping companies in the region are small-scale shipping companies. TCs followed by ENCs were considered the third and the least important factors in terms of the ranking result of the AHP analysis. The result is obvious because little or no environmental consideration is given most by small- and medium-scale shipping operators in the region in terms of installation and compliance of BWMS, which is evident in the environmental pollution caused mostly by disinfectant byproduct of certain Ballast Water Treatment System (BWT) in the coastal waters in the region.

**Conclusion**

The ballast water regulatory compliance level of ship operators is still low in the case of Nigeria due to the several challenges faced in the region. The AHP decision-making tools have been used to present a rationale and justification ranking of the several challenges. Hence, it can be concluded based on our evaluation, and the results have shown that the general apathy towards installation of BWTS and compliance with the ballast water convention among shipping operators in the study region is largely because of several challenges like economic, technical, environmental, and other issues. The potential for achieving the ballast water management standard and controlling the threats and advanced effects of invasive species introduction into Nigerian waters will be impossible to achieve due to the current challenges unless management actions are directed towards solving and providing solutions. The majority of the shipping companies may be needing support in terms of purchasing of BWTS and training of crew members. The regional and external influence, ship type, age, and trading route are the most important
factors influencing compliance. Hence, if the goal of the ballast water management system is to be achieved, then an alternative measure of compliance is necessary for supporting the shipping operators or providing alternative management measures of ensuring compliance like adoption of port-based reception facility with low service charge for ships operating within the regional waters or by providing a subsidized BWTS for purchase by small- or medium-scale ship operators. As we approach the mandatory installation date for compliance of the D-2 standard, coordinated policy measures should be deployed to counter the current challenges. Policy makers must focus more on providing solution to this problem and manage the problem of invasive species spread in the region. Besides the barriers discussed, there are several promising opportunities that may be available to ship owners or investors by overcoming these barriers and meeting the D-2 standard requirements such as enabling business environment and a safer maritime ecosystem free of invasive species.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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