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Assessment of Information System in the Prevention of Pollution in Nigerian Maritime Industry

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ABSTRACT

This study examined the effects of information systems on preventing marine pollution. In this study, 170 respondents from shipping companies in Lagos State were chosen, and a survey research design was adopted. A factorial analysis was adopted to examine factors influencing pollution in the Nigerian maritime industry. The findings demonstrated that four factors may explain 72.8% of the common variance shared by seven variables. This is the reflection of the KMO value, 0.717, which can be considered good and also indicates that factor analysis was useful for the variables. Furthermore, the result shows the rho values to be 0.759 at p equals to 0.000, which is less than 0.05; hence, there is a significant relationship existing between the examined variables, which are information systems and pollution prevention. It was concluded that the release of solid waste such as plastics, ballast water, oil spill gases, defecating in the sea, vessel collisions, and abandoned vessels are factors responsible for polluting the marine environment. It was recommended that vessels install technology to prevent the discharge of oil into the sea.

1. INTRODUCTION

The maritime industry plays a crucial role in the economic prosperity of a nation. Maritime transport throughout our evolution has played a crucial role; there is no doubt that the Seaway is the oldest road in the world. The first movement is dated to the Austronesians between 3000 and 1500 BC (Rodrigue, 2020). With a broad means of trading and colonizing, thus producing the development of humanity, maritime transport has been growing since its beginnings and is of vital importance in economic development and globalization.

Nigeria's location has strategically benefited from the maritime trade along the coast of West Africa and the Gulf of Guinea; however, these challenges impede the full realization of the maritime industry's capacity to boost the Nigerian economy. Nigerian maritime industry stakeholders' key business goal is to link maritime transportation and the government's national sustainable development strategies (Chidi et al., 2020; Raimi, 2019). Shipping has been an important human activity throughout history, particularly where prosperity depended primarily on international and

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interregional trade. In fact, transportation has been called one of the four cornerstones of globalization, along with communications, international standardization, and trade liberalization (Kumar and Hoffmann, 2002).

Port facilities, shipping lines, clearing and forwarding agencies, and connective road and rail networks all need to exchange data to move a consignment between jurisdictions for efficient cargo movement to be achieved (Balcı, 2021). In addition, one of the world's leading classification societies and leading advisors for the maritime industry has stated that "the transition towards automation and information systems application is speeding up in the maritime industry." Information systems are being used to enhance organizational competitiveness, improve operational efficiency levels, and move the industry to realize the goal of zero emissions by 2050 (DNV, 2020).

Vessel-generated waste pollution has increasingly drawn the attention of the maritime community and engaged their efforts in the promotion of safe shipping and marine environment protection (Sampson et al., 2016; Onwuegbuchunam et al., 2017). Waste generated on board vessels originates from the engine room operation, residue from cargo transported, and domestic activities done by the crew, just to mention a few. Sewage, in particular, is one of the wastes resulting from the daily operations of the vessel and contains organic compounds, nutrients, metals, and chemicals that impact human health and marine life (Jalkanen et al., 2021). Because of the impact of such waste and emissions can have on the marine environment. The shipping industry is continuously looking at means to reduce the impact of its activities on the marine ecosystem and human health (Sampson et al., 2016).

This global marine pollution problem has equally attracted concern from decision-makers over the past years. The environmental implications of ports have come more into the spotlight in recent years as a direct result of the high levels of energy consumption and pollution brought on by the expansion of port production and trade volumes. Environmental and climate change will be exacerbated by the release of pollutants from port operations (Hua et al., 2020).

Moreover, ports perform more than just quayside cargo handling. As a result of their competition, their influence extends far into the country's hinterland. Management and operational strategies are intertwined with stakeholders across multiple sectors, from local to global and corporate to government. Ports can significantly impact global transportation systems' social and environmental performance through their involvement in the supply chain. In some instances, ports have taken advantage of their capacity to address social and ecological externalities by complying with current environmental standards in their city, region, or country (Bergqvist & Monios, 2018).

In terms of operations management within the maritime industry, information technologies offer potential to improve integration between stakeholders and support information sharing, communication, and managerial processes (Agrifoglio et al., 2017). Information technology is a significant driver for organizational efficiency and effectiveness. Nigerian Integrated Customs Information System (NICIS). NICIS is used by Nigerian Customs to ensure compliance with international regulations, surveillance on all ships, and improved operational efficiency in the industry (Wiafe et al., 2019). Information technology is a vital infrastructure and access to unlock the potential for growth and wealth in delivering the benefits of global trade (Ali and Odularu, 2020).

Modern ports globally are striving to achieve optimal efficiency in their operations in order to outperform their regional or global competitors in the business; this is why they invest their resources in plants and equipment to improve their services. Currently, the international shipping and port industry has adopted new technologies, such as improved fuel quality and ship engine technology, as well as operation changes at port, in order to reduce air pollution from ships and other transport modes. However, relative to other sources, controlling emissions from commercial marine vessels represents a significant political and legal challenge.

Environmental challenges have become increasingly significant worldwide, with organizations concerned about conducting business environmentally responsibly. While commitment to the natural environment has become critical today (Seroka-Stolka, 2014), the maritime transport and logistics business has received less attention from stakeholders than the sustainability concerns of the aviation and overland freight industries. Although sea transport has fewer environmental impacts than other modes of transportation per kilometer driven, this is still a significant issue when considering the global nature of international trade. (Lim et al., 2019).

Furthermore, port management is investing huge amounts in ICT infrastructure to be more efficient, not only for higher returns but to permanently win the confidence of their clients, who are often demanding better quality services. With respect to sea environment pollution, oil spills seriously affect marine ecosystems and cause political and scientific concerns since they have serious effects on fragile marine and coastal ecosystems (Nevalainen et al., 2017). Moreover, the amount of pollutant discharge and associated effects on the marine environment are important parameters in evaluating seawater quality. Consequently, there is an increased interest in both maritime safety and environmental protection.

The ever-changing market conditions, coupled with numerous uncertainties, have necessitated a need for a more aggressive digital transformation. “Organizations are required to adapt to it, whether they like it or not.” (Bengtsson, 2017). But what exactly are information systems? Quitzau et al. (2018) define information systems as a transformation—a takeover from the industrial age and a disruptor of established structures and business models. Gartner, Inc. defines information systems “as a process of transforming a business model so as to provide new revenue and added value through the application of digital technologies. That is to say, a process of moving business into digital.” It is the way business processes, operations, and data processing are automated (Tijan et al., 2021). Brennen and Kreiss (2016) defined information systems as the restructuring of life domains through the use of computers and technologies. Bloomberg (2018) makes a distinction between information systems and digitization, referring to it as a transformation of processes and information, respectively. An example of such an application is block chain technology, which improves the efficiency of ship recording, the provision of real-time cargo status, and the promotion of data sharing among shareholders, resulting in the advancement of transparency. In addition, we have the Internet of Things (IoT) and sensors that capture container numbers and vehicles at the port of the terminal gate and feed this data to the cloud environment, where this data can be analyzed and used to pre-plan needed operations. The same concept has been applied at the port of Bremen, Germany, where there is a truck identification system at the gate, and using this data, they are able to plan an optimal container pick-up, which has drastically reduced port congestion.

In regards to the LSC way of doing business, digital aspects that have been implemented so far include document management, empty container repositioning, pricing, network design, and container tracking. For example, Maersk has a customer valuation strategy where they reduce the physical distance between the customer and his or her goodies. They make the customer feel as if he or she has control over the entire supply chain through tracking and the provision of seamless data. In addition, they have embedded data into their operation planning. From this, they can plan demand, sense demand, and design networks much more efficiently than their competitors. Of vital importance is keeping pace with the fast-changing digital era, especially from a business perspective. Information systems are thus "a process that triggers reactions that lead to the adoption of strategies for the purpose of keeping up with developments, changes, and barrier management" (Vial, 2019).

It's no longer an option for the liner industry to digitalize. The market is demanding that they must. Information systems open the doors to business and customer valuation. The COVID-19 pandemic catalyzed this, where only resilient and digitally enabled liner firms were able to effectively weather the presented storm. Through information systems, LSC can: improve their performance and efficiently integrate with their supplies; strengthen their direct relationship with end consumers; enjoy cost reduction; and develop new avenues of revenue (Bengtsson 2017; BCG 2018). Information systems offer a chance for LSC to foster business growth, improve operations, enhance efficiency and effectiveness of data security, and improve internal controls. The achievement of these benefits can be optimized by adopting the seven valuable trends of digital transformation.

Participation of a LSC in these trends is foreseen as an opportunity to gain a competitive edge, which, according to Balci (2021), involves resources and not products. The resources include financial assets, know-how, procedures, business relations, and processes. Nonetheless, it should be noted that this requires consistent actions, right from strategic formulation to implementation. To obtain successful future development, new architecture solutions have to be adopted and should factor in IT architecture and strategic business alignment (Maydanova et al., 2020). Poulis et al. (2020), in their study on vessel automation, mentioned that a company that adopts digital transformation creates value, a key factor in the consideration of the modern customer. The same sentiments are echoed by Maydanova et al. (2020). They identified five domains of strategic digital transformation that will enable a company to develop effectively in the context of global change, reduce its negative impacts, and take advantage of the arising change. These strategies include: customer connection; data processing and analysis; customer valuation; competition; and the innovation process.

The use of digital technology to transform the way businesses are operated is one way of defining information systems. The container shipping industry has seen many of its business processes, operations, and facilities digitalized in this information age. As indicated in existing literature, the information system of its operations and processes has had a positive impact on its performance and efficiency levels, as well as improved its integration with various stakeholders such as customers and suppliers (Balcı, 2021). In addition, software-driven automation and control systems not only improve data safety in operations but also enhance data-driven decision-making processes (Marine Digital, 2021). The introduction and use of UNCTAD's Trade Information Portal (TIP) in Kenya simplified trade procedures, reduced costs for traders by $482, and reduced waiting time by 110 hours (UNCTAD, 2021). Kosiek et al. (2021) project that ports will be automated, electrified, and use smart energy systems in the near future. The new technologies could contribute to shorter handling times at port terminals. Adoption of such innovations has made Singapore stand out as a leading transhipment port. Despite the discussion on accelerated automation and information systems in the maritime sector and their purported benefits, the findings of a study done by the International Transport Forum (ITF) in 2021 indicated that only 53 container terminals are automated to a certain degree, which represents approximately 4% of the global container terminal capacity. Most of the automated container terminals are in Asia (32%), Europe (28%), Oceania (13%), and the United States (11%), the majority of whom are greenfield terminals.

The automated systems are mostly deployed in the yards, and no terminal has completely automated its quay cranes. In addition, they concluded that automated ports are generally not more productive compared to conventional ones. Other factors, such as the geographical location, port size, port organization, and specialization, are the major determinants of port performance, as opposed to automation and information systems. Further, the comparatively high capital costs of automation infrastructure compared to the benefits do not make for a compelling case. Whether automation has led to lower overall costs is likely to be location-specific and depends on the local labor costs as well as the extent to which manual port labor has been replaced by machines (ITF, 2021).

As organizations embark on their information system journey, they need to have a digital transformation strategy, or simply a digital strategy, in place. As re-iterated by Westerman (2017), the most important aspect to focus on in digital transformation is not the “digital” part but rather the “transformation” element. This is because technology’s value is achieved by carrying on business in a different way that is enabled by technology. For instance, e-commerce platforms are not about the internet but rather enable organizations to adopt diverse ways of selling their products. Analytics, on the other hand, is not about the algorithms used but about helping organizations understand their customers better, optimize processes, and come up with more suitable product offerings. A digital transformation strategy for the purposes of this paper is a company’s overall vision in the context of information systems, including measures to achieve it. The strategy defines both short- and long-term initiatives that are expected to transform the organization’s product offering and create value (Lipsmeier et al., 2020). Consequently, the information system process is not just a technological issue but also an institutional human resource one (IAPH, 2020). A change management process must address all the challenges simultaneously. The study carried out by Balci (2021) ranked organizational and collaboration resources as the most critical resources necessary for a successful digitalization process of container shipping services to achieve a competitive advantage.

The International Transport Forum (ITF (2021) stated that whereas port automation projects generate social conflicts, there are instances where unions, port authorities, and terminal operators cooperate constructively and agree on acceptable conditions for all parties before rolling out automation projects. The results of yet another study indicated that when a digital vision is shared by top management, adequately communicated within the organization, and employees' training in digital skills is empowered, digital maturity is higher (Salviotti et al., 2019).

1.1 Marine Pollution

The direct or indirect introduction of materials or energy into the marine environment by humans that has negative consequences on the ecosystem, including risks to human health, obstructions to marine operations, deterioration of saltwater quality for different purposes, and loss of amenities. Chemicals and debris, most of which originates on land and is blown or carried into the water, make up marine pollution. The ecology, the health of all living things, and global economic systems are all harmed by this pollution.

Marine contamination also originates from maritime traffic in the sea. Dry bulk carriers and numerous oil tankers that travel inland and along coastal seas make up maritime traffic. The cleaning process of oil tanker vessels results in an oily mixture that could end up in the ocean. Nonetheless, a number of methods have been developed to lessen pollution coming from these sources; prominent ones include the usage of slop tanks, load on top systems (LOT), separated ballast tanks, and crude oil washing systems (COW). Anti-fouling coatings used on ship hulls are closely associated with sources of pollution related to maritime transport. Strong biocides like tributyltin are frequently present in these paints (TBT). Biocides prevent aquatic life from growing on the ship's hull.

2. METHODOLOGY

The Nigerian maritime business, and specifically the shipping industry in Lagos State, was the focus of this study. Lagos, the biggest financial hub and GDP leader in Africa, is home to the busiest and largest port on the continent. The islands, which flank the southwest mouth of the Lagos Lagoon and are divided by creeks, are found in the present-day Local Government Areas (LGAs) of Lagos Island, Eti-Osa, Amuwo-Odofin, and Apapa. Barrier islands and lengthy sand spits like Bar Beach, which stretch up to 100 kilometers (60 miles) east and west of the mouth, protect the islands from the Atlantic Ocean. In this study, 170 respondents from shipping companies were chosen in which a survey research design was adopted. Factorial analysis was adopted to examine factors influencing pollution in the Nigerian Maritime industry.

3. RESULTS AND DISCUSSION

Table 1 shows the various means through which pollution is released into the marine environment. The result further showed the mean and standard deviation of various waste released into the marine environment It was shown that release of solid waste from the vessel has a mean ($\bar{x} = 3.7824$) and the standard deviation ($\sigma = 0.64792$), the release of ballast water from the ship with the mean ($\bar{x} = 3.6765$) and the standard deviation ($\sigma = 0.7581$), oil spill with the mean ($\bar{x} = 3.6765$) and the standard deviation ($\sigma = 0.57154$), Emission of gases with the mean ($\bar{x} = 1.8118$) and the standard deviation ($\sigma = 0.92300$), Defecation with the mean ($\bar{x} = 2.9176$) and the standard deviation ($\sigma = 1.22799$), vessel collision with the mean ($\bar{x}$ =3.4118) and the standard deviation ($\sigma = .99459$) and abandoned vessel on the sea with the mean ($\bar{x} = 3.3235$) and the standard deviation ($\sigma = 0.95832$). It can be deduced that Release solid waste such as plastics has the highest means.

Factor Analysis

Let X = (X_1, X_2, ...X_p)'is a random vector with mean vector μ and covariance matrix Σ. The factor analysis model assumes that X = μ + λ F + ε, where, **λ** = {**λ** jk}pxm denotes the matrix of factor loadings; **λ** jk is the loading of the jth variable on the kth common factor, F= (F_1,F_2,....F_m)' denotes

Table 1: Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Release of plastics (Soild waste)	3.7824	.64792	170
Ballast water	3.6765	.75841	170
Oil spill	3.6765	.57154	170
Gases	1.8118	.92300	170
Defecating in the sea	2.9176	1.22799	170
Vessel collision	3.4118	.99459	170
Abandoned vessel	3.3235	.95832	170

the vector of latent factor scores; F_k is the score on the kth common factor and $\varepsilon = (\varepsilon_1, \varepsilon_2, \dots \varepsilon_p)'$ denotes the vector of latent error terms; εj is the jth specific factor.

Determinant Score

The value of the determinant is an important test for multicollinearity or singularity. The determinant score of the correlation matrix should be > 0.00001 which specifies that there is an absence of multicollinearity. If the determinant value is < 0.00001, it would be important to attempt to identify pairs of variables where correlation coefficient r > 0.8 and consider eliminating them from the analysis. There are two statistical measures to assess the factorability of the data: Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of Sphericity.

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy

KMO test is a measure that has been intended to measure the suitability of data for factor analysis. In other words, it tests the adequacy of the sample size. The test measures sampling adequacy for each variable in the model and for the complete model. The KMO measure of sampling adequacy is given by the formula:

$$KMO = \frac{\sum_{i \neq j} R_{ij}^2}{\sum_{i \neq j} R_{ij}^2 + \sum_{i \neq j} U_{ij}^2}$$

where, Rij is the correlation matrix and Uij is the partial covariance matrix. KMO value varies from 0 to 1. The KMO values between 0.8 to 1.0 indicate the sampling is adequate. KMO values between 0.7 to 0.79 are middling and values between 0.6 to 0.69 are mediocre. KMO values less than 0.6 indicate the sampling is not adequate and the remedial action should be taken. If the value is less than 0.5, the results of the factor analysis undoubtedly won't be very suitable for the analysis of the data.

Hence, the KMO indicate that the sampling is adequate as shown in table 2

The eigenvalues and total variance explained were analyzed in Table 3. Principal component analysis is the factor analysis extraction technique utilized in this investigation. Within the data collection, seven linear components are found prior to extraction. The data set with an eigenvalue > 1 is divided into four separate linear components after extraction and rotation. A total of 72.8% of the variance is accounted for by the four identified components. It is recommended that the retained components account for a minimum of 50% of the overall variation. The outcome demonstrates that four factors may explain 72.8% of the common variance shared by seven variables. This is the reflection of

Table 2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.717
Bartlett's Test of Sphericity	Approx. Chi-Square	3139.612
	Df	21
	Sig.	.000

KMO value, 0.717, which can be considered good and also indicates that factor analysis is useful for the variables.

Table 3: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.676	23.940	23.940	1.676	23.940	23.940
2	1.218	17.399	41.339	1.218	17.399	41.339
3	1.186	16.936	58.275	1.186	16.936	58.275
4	1.017	14.527	72.802	1.017	14.527	72.802
5	.721	10.304	83.106			
6	.657	9.381	92.486			
7	.526	7.514	100.000			

Extraction Method: Principal Component Analysis.

Table 4: Relationship between Information System and Pollution Prevention

Correlations

		Information systems	Pollution prevention
Information systems	Pearson Correlation	1	.639**
	Sig. (2-tailed)		.000
	N	170	170
Controlled Prevention	Pearson Correlation	.639**	1
	Sig. (2-tailed)	.000	
	N	170	170

**. Correlation is significant at the 0.01 level (2-tailed).

The result in Table 4 shows that there is a relationship between information systems and pollution prevention. The result shows the rho values to be 0.639 at p equals to 0.000 which is lesser than 0.05, hence, there is a significant relationship existing between the examined variables. It simply means there is a relationship between the examined variables which are information systems and pollution prevention.

Furthermore, this study agreed with Jalkanen et al., (2021), who asserted that the most significant environmental harms are brought by dumping bilge water and household waste, dumping ballast water and wash water from tankers, emitting exhaust fumes, allowing anti-foul paint to leach, polluting with toxic materials, removing and introducing organisms, as well as causing acoustic and visual disturbances. Elenwo (2015) asserted that sewage, industrial effluents, plastics that float on water and abandoned objects other than vessel-based ones, as sources of pollution. It was opined that the specific effects of these sources on the marine environment include: degradation and thermal pollution which adversely affects the ecosystem. Others include: eutrophication arising from untreated waste which can kill sea animals, plants and cause the depletion of dissolved oxygen which affects Biochemical Oxygen Demand (BOD). These findings are consistent with Bournoun and Nabbout (2016). A similar study Umoh and Nitonye (2015) identified additional marine pollutants namely: oily water discharge from tanker accidents, accidental oil discharge during routine operations, wastewater, garbage and solid waste from vessels. Additional sources also include: ballast water or that from machinery spaces, exhausts and antifouling paints from vessel hulls. Sampson et al., (2016) opined that the use of technology via MARPOL convention is crucial to preventing marine pollution.

4. CONCLUSION

It was concluded that the release of solid waste such as plastics, ballast water, oil spill gases, defecating in the sea, vessel collisions, and abandoned vessels are factors responsible for polluting the marine environment. It was also concluded that information systems play a significant role in reducing marine pollution, especially with the release of ballast water, emission of gases, vessel collisions, and oil spills that contaminate the marine environment.

It was recommended that vessels install technology to prevent the discharge of oil into the sea. Seafarers should be trained and retrained to handle sophisticated technology and be well equipped with the International Convention for the Prevention of Pollution from Ships (MARPOL).

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