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Original Article

Adoption Of Drones In The Maritime And Logistics Sector: A Study With Reference To Gujarat & Kerala

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ABSTRACT

The paper examines the use of drone technology in the maritime and logistics industry and especially on the Indian states of Gujarat and Kerala. The use of drones in the maritime setting is a specific area with the great potential and, at the same time, the complexity, as the use of drones in the industry is still evolving. The study discusses the effect of drones on the efficiency of operations, attributes that affect its adoption, and regulatory and organizational issues. The mixed- methods design that included the exploratory and descriptive designs was adopted. They used structured questionnaires to gather primary data on 101 respondents who included port officials and maritime students. ANOVA and regression were statistical methods used to test hypotheses. The paper concludes that although regulatory and organizational considerations play a critical role in drone adoption, it statistically cannot be determined whether they directly affect operations efficiency. These results have practical implications on policymakers and port authorities and could imply that further improvement in infrastructure, training, and regulatory clarity would be necessary to implement drone integration in marine operations.

Keywords: Drones, Maritime Logistics, UAVs, Technology Adoption, Supply Chain, Port Operations.

INTRODUCTION

The International Civil Aviation Organization (ICAO) defines drone aircraft or unmanned aerial vehicle (UAV) as an aircraft that does not have a human pilot on board. Originally used in the military context, the usage of UAVs has grown massively as the control technologies and the cost have dropped. Currently, some of the tasks that drones can be applied in include precision farming, aerial surveillance, environmental surveillance, law enforcement, contraband detection, and more recently, logistics and maritime services.

Drones are being implemented in the logistics industry to deliver packages, medicines, food and postal mail. They were very instrumental in delivering COVID-19 vaccines and medical supplies, particularly in the remote areas. International companies like Amazon, DHL, and FedEx have launched pilot projects of drone deliveries in different regions of India including Maharashtra, Telangana, and Kerala.

In the sea, drones can offer important assistance in situations in which human inspection can be dangerous. They consist of ship inspections, port security, border surveillance, the detection of illegal fishing and the environment. The use of drones on the sea is especially beneficial in limited or dangerous areas, where they can help complete tasks at a faster and safer rate.

Regardless of such benefits, various obstacles exist when applying drones in the logistics and maritime sectors. Harmful weather patterns, low battery life, and low payloads limits their operation. Metal structures of ports may interfere with communication signals. Bigger adoption is also crippled by safety issues, threats of piracy, and untrained staff.

However, the opportunities of drone integration are still significant. They can optimize the number of manpower doing hazardous jobs and improve the overall performance of the operations because of their capabilities to simplify the checks, track the operations of ports, and make timely delivery. As the number of technological progress advances to expand drone functions and more attempts to regulate and

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train pilots are made, the maritime industry is set to revolutionize with the adoption of UAV.

This paper was conducted to examine the current application of drones in maritime and logistic environments with specific reference to the states of Gujarat and Kerala. The study will help to guide future strategic choices to consider the integration of drones into these essential infrastructure areas since it investigates the advantages and the limitations.

LITERATURE REVIEW

Introducing drones in the maritime and logistics industries has attracted the interest of many researchers. The literature review brings together the important findings of the modern research connected with the challenges, opportunities, applications and future of the drone technology in these fields.

Cikmak et al. (2024) used the Best-Worst Method to detect and rank the obstacles to the adoption of drones in logistics. They divided 34 sub-challenges into seven themes, the most noticeable of which include technical, safety, and security issues. This chronology provides a systematic plan to the stakeholders who have intentions to use UAVs.

Rejeb (2021) discussed the implication of drones on the supply chain management which included better humanitarian logistics, speedier deliveries, reduced costs of operations, and improved sustainability. Nevertheless, the regulatory, safety and organizational factors were also reported to be a barrier to wider adoption.

Johannson (2024) discussed the use of drones in ship inspection, port surveillance and naval operations. With the speed of operations and mitigation of risks, there were also mentioned infrastructure vulnerability and cybersecurity threats.Wang (2014) paid attention to the functions of UAVs in maritime search and rescue operations, emphasizing the fact that they eliminate the inefficiency of traditional ways of patrolling the ocean. UAVs were discovered to extend the operational reach and minimize response time.

Xing (2023) has provided an extensive technical examination of the use of drones in the marine setting. He discussed the applications in navigation, communications, safety and monitoring the environment, and established design-level issues and proposed scalable solutions.

Kumar (2019) evaluated the use of blockchain in managing underwater drones. His research highlighted the problems of coordination and security and suggested ways of how safe data exchanges can be realized in a difficult underwater environment.

The article by Praest (2018) explored the application of drones to offshore operations in Denmark. The study presented the stakeholder collaboration using qualitative data and identified regulatory gaps that require immediate redressing.

Bartlett (2018) and Pastra (2024) both talked about the legal issues of UNCLOS regarding the classification and regulation of drones. Such studies require global systems to regulate the use of drones in common sea areas.

Singh (2022) evaluated a UAS ship-shore delivery project in Trinidad and found economic, technical, and environmental challenges and provided practical lessons concerning the coastal geography.

Gromadzinsca (2021) provided some of the successful experiences of maritime drone's implementation worldwide and noted the spheres where drones are already helping with the inspection, SAR (Search and Rescue), and cargo operations.

Mazzeo (2020) has criticized the application of drones to the European border surveillance, especially in terms of migrant control and questioned the ethics of human rights and technological militarization.

Liu (2019) suggested drone base location optimization models to facilitate the ongoing SAR at sea and eliminate energy limitations, as well as efficient location of bases.

Doytsher (2019) developed a vision-based drone landing system to transport vessels, which is a significant technological breakthrough in autonomous drone functioning in dynamic sea conditions.

According to Estrada (2024), the presence of drones on strategic threats response started with the introduction of DNDP (Drones National Defense Platform), which advocated the use of data as the foundation of national defense models.

Camilli (2015) combined chemical and radiological sensors with surface drones and monitored marine pollution and proposed a real-time threat detection model based on autonomous sensors.

In the Emission Control Areas (ECAs) Tian (2023) demonstrated the use of drone technology in monitoring shipping emissions to provide drone-based solutions to expensive monitoring facilities.

Rus (2024) also talked about the application of drones during the naval activity in the Russia-Ukraine conflict and demonstrated the utility of drones in military operations and their changing functions in modern naval strategies.

Smith-Godfrey (2020) stressed the use of drones in preventing maritime crime in Africa, expressing the need to modernize the laws and use technology to enforce environmental protection.

A drone landing model, which is based on SLAM, was proposed by Janssens (2022) to handle the issue of navigation challenges due to motion on moving ships.

Estrada (2023) announced a prototype of MAR35, a drone with sophisticated propulsion and AI technologies to complete missions at sea.

Kyamakya (2022) conducted a survey of drone logistics performance and found gaps in the research on route optimization, fleet dynamics, and accuracy in deliveries.

Di Paolo (2018) discussed more general topics of UAV logistics, such as sustainability, last-mile shipping, and environmental effects.

Krasevac (2023) developed the GNSS-independent approaches to detecting vessels with the help of the fixed-wing UAVs in the maritime surveillance operation.

Abusulaiman (2024) examined literature gaps in drone logistics, in particular the user behavior and food delivery logistics.

Bahareh (2024) also highlighted the importance of using drones in multimodal logistics systems, pointing to the opportunities of the devices in models of pandemic response and urban freight.

Jung (2024) identified systems based on drone-trucks, drone-ship, and drone-robot systems and highlighted the technological and operation requirements in these modalities.

All these sources help to highlight the idea that drones promise a lot in maritime logistics, however, systemic challenges that include regulatory clarity, technical constraints, and ethical concerns have to be considered to unleash their potential.

OBJECTIVES

The research objectives underlying this study are as follows:

- To measure the effect of the drones on the efficiency of the maritime operations and logistics.
- To assess the changes that influence the use of drones in the maritime and logistics sectors.
- To analyse the regulatory and organizational issues that affect the use of drones in the maritime and logistic sectors.

Hypotheses Formulation

Goal 1: Effectiveness Influence.

Null Hypothesis (H0): There is no significant difference in the efficiency of the maritime operation and logistics with the use of drones.

Alternative Hypothesis (H1): Drones are an effective way of enhancing maritime operations and logistics.

Objective 2: Influencing Factors.

Null Hypothesis (H0): The variables that affect the use of drones in the maritime and logistics industry do not make a significant difference.

Alternative Hypothesis (H1): The variables shaping the adoption of drones in the maritime and logistics industry play a decisive role.

Goal 3: Organizational and Regulatory Impression.

Null Hypothesis (H0): There are no significant regulatory and organizational factors that influence drone adoption in the maritime and logistics industry.

Hypothesis: (H1): Regulatory and organizational variables have a considerable influence on the adoption of drones in the maritime and logistics industry.

It is such hypotheses that underpin the statistical analysis in this study based on statistical techniques like ANOVA and regression analysis.

RESEARCH METHODOLOGY

Research Design

Both exploratory and descriptive research designs are used in this research. The exploratory design was adopted to employ some preliminary knowledge about the growing use of drones in the maritime and logistics industries, whereas the descriptive design offered a conceptual framework to quantify, observe, and interpret particular variables.

Exploratory Research Design: This design helped with the preliminary knowledge and discovery of themes based on literature reviews and informal feedback on maritime stakeholders (Creswell et al., 2018).ni

Descriptive Research Design: It involves data collection and analysis of quantifiable data of a specific population through the help of structured questionnaires to answer research questions of what, when, and how (Babbie et al., 2020).

Sources of Data

Primary Data: The primary data was gathered via using Google Forms with the help of a structured questionnaire consisting of open- and closed-ended questions. Students and professionals in the maritime industry were the respondents.

Secondary Information: The relevant academic articles, governmental reports, academic journals and technical documents were analyzed to facilitate the theoretical base and contextual insights (Smith, 2020).

Sampling Design Process

Target Population: Port officials, maritime students and professionals.

Sampling Units: The maritime organizations, universities (e.g., GMU, PDEU), and port authorities located in Gujarat and Kerala.

Limit and Time: The research was carried out between January and March, 2025 in India with particular references of Gujarat and Kerala.

Sampling Frame

The sampling frame also covered respondents who are in a position to make valuable information on the adoption of drones, such as those with some experience in maritime logistics, whether operational/managerial or academic.

Sampling Technique

The non-probability convenience sampling technique was considered the most convenient sampling technique in this case because it is very practical and time-saving since there was very limited access to the entire population. When the respondents were chosen, it was according to their availability and topicality to the topic of the study.

Sample Size

The number of respondents who participated in the study was 101. This figure was decided to give a balance between the richness of the data and manageability (practical) so that there would be enough statistical reliability in case of an exploratory study (Taherdoost, 2016).

Statistical Tools

ANOVA (Analysis of Variance): Used to determine whether there are significant differences between group means.

Regression Analysis: Applied to identify the relationship between independent (predictor) variables and the dependent outcome variables.

Regression Equation:

$$Y = a + bX$$

Where:

Y = Dependent variable

X = Independent variable

a = Intercept

b = Slope of the line

These tools were selected to test the hypotheses and determine statistical significance related to drone efficiency, adoption factors, and organizational/regulatory influences.

Data Analysis and Interpretation

Demographic Profile of Respondents

Age Distribution:

- 18–30 years: 82.2%
- 31–40 years: 10.9%
- 41–50 years: 4.0%
- Above 50 years: 3.0%

Gender:

- Male: 45.5%
- Female: 55.4%
- Other: 0.0%

Marital Status:

- Married: 20.7%
- Unmarried: 74.2%
- Prefer not to say: 4.9%

Nationality:

- Indian: 100%

Educational Qualification:

- 10th Pass: 8.9%
- 12th Pass: 11.8%
- Graduation: 43.5%
- Post-Graduation: 35.6%

Experience:

- Less than 10 years: 75.2%
- 11–20 years: 13.8%
- 21–30 years: 7.9%
- Above 30 years: 2.9%

Annual Income:

- Less than 3 lakhs: 53.4%
- 3–10 lakhs: 32.6%
- 10–20 lakhs: 6.9%
- Above 20 lakhs: 6.9%

Reliability Test

Cronbach's Alpha = 0.708

This score indicates a moderate level of internal consistency among the questionnaire items, exceeding the acceptable threshold of 0.7.

Hypothesis Testing and Interpretation

Objective 1: Impact on Efficiency

Test: Brown-Forsythe Test (used due to violation of homogeneity)

Result: $p = 0.068 > 0.05$

Interpretation: Since the p-value is greater than 0.05, the null hypothesis is accepted. Therefore, drones do not significantly improve the efficiency of maritime operations and logistics, based on this dataset.

Objective 2: Factors Influencing Adoption

Test: Linear Regression

Result: $p = 0.000 < 0.05$

Regression Equation: $Y = 1.105 + 0.657X$

Interpretation: The null hypothesis is rejected, indicating that influencing factors have a statistically significant impact on the adoption of drones.

Objective 3: Regulatory and Organizational Influence

Test: Linear Regression

Result: $p = 0.000 < 0.05$

Regression Equation: $Y = 0.918 + 0.615X$

Interpretation: The null hypothesis is rejected, suggesting that regulatory and organizational factors significantly affect drone adoption in the maritime and logistics sector.

Limitations

This study in spite of its insights has the following limitations:

Small Sample Size: The sample could be too small to be representative as it included only 101 respondents the variety of the maritime and logistics industry in India.

Geographic Scope: The research is restricted to Gujarat and Kerala which is limiting applicability to other states or countries.

Respondent Bias: Self-reported Data: Self-reported data can be subject to individual perceptions and resulting in possible biases to responses.

Absence of Technical Expertise: There are the participants who might lack technical information on drones, which may influence their responses.

Time Constraints: The study was carried out within three months and it was a study limited longitudinal study.

Recommendation

Depending on the study results, as well as its limitations, the following recommendations can be offered:

Training Programs: Organizations must develop standardized training programs in order to ensure safe and efficient use of drones on the sea.

Technology Integration: AIS (Automatic Identification System) and GIS (Geographic Information System), are some of the maritime systems that should be incorporated with drone data to aid in decision-making.

Infrastructure Development: Port infrastructure should be brought up to scale with investments required to make the process of using drones smoother.

Regulatory Support: Well laid down regulatory guidelines should be framed and distributed to make compliance and facilitate innovation.

Public-Private Partnerships: Partnerships with the government, academia and companies can help fast-track the adoption of drones and transfer of technology.

CONCLUSION

The introduction of drones in the maritime and logistics industry is a major breakthrough in digitalization and efficiency in operations. Drones have the potential to revolutionize the operation of maritime logistics by providing new solutions in the routine inspections, search and rescue operations, monitoring of the environment, and deliveries during the last mile.

Nonetheless, the use of drone technology is limited by issues relating to insufficient technical capacity, infrastructural disparities, regulatory uncertainties and the necessity of skilled personnel. The results of the study emphasize the idea that drones might not yet show statistically significant effects on the operational efficiency, but the facilitating conditions the technological, organizational, and regulatory ones are important factors of successful implementation.

In the case of India and maritime industry, especially in Gujarat and Kerala states, the issue of drone technology is a prospective opportunity. Education of stakeholders, development of infrastructure and clarity of law will be important proactive measures in harnessing this potential.

More extensive studies and pilot applications will further prove and optimize drone applications that will be regionally and industry specific.

Declaration

"All authors declare that they have no conflicts of interest".

Annexure: Sample Questionnaire (Extract)

Demographic Questions

- Age: 18–30, 31–40, 41–50, Above 50
- Gender: Male, Female, Other

- Marital Status: Married, Unmarried, Prefer not to say
- Nationality: Indian, Non-Indian
- Qualification: 10th Pass, 12th Pass, Graduation, Post-Graduation
- Experience: <10 years, 11–20 years, 21–30 years, >30 years
- Annual Income: <3 lakhs, 3–10 lakhs, 10–20 lakhs, >20 lakhs

Opinion-Based Questions

- How familiar are you with drone technology? (Very Familiar – Not Familiar)
- Does your organization provide training for drone operations? (Yes/No)
- What is your organization's primary goal for drone adoption? (Cost, Efficiency, Safety, Sustainability, Other)
- Drones are used effectively for decision-making and process optimization. (Likert scale)
- The organization adheres to all legal and regulatory requirements for drone operations. (Likert scale)

Key Multiple-Choice Question

- What is the primary limitation of drones in this industry?
  - Battery Life
  - Limited Payload Capacity
  - High Cost
  - Regulatory

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