A Review on Port Integration With 4IR Technologies
(Smart Port Development)

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ABSTRACT

The bulk of products moved across continents are handled by the global marine industry, which is essential to international trade. The smooth movement of commodities and the health of the economy depend on effective port operations. Automation and smart technology integration have transformed port operations recently, resulting in increased productivity, decreased operating expenses, and increased sustainability. This study examines the numerous dimensions of smart port operations, including essential technology, advantages, difficulties, and potential for the future. This paper shows the revolutionary influence of smart technologies on port operations and provides insights into the future direction for building smarter and more resilient ports through an in-depth review of case studies and industry trends.

Keyword: - *4IR (4th Industrial Reform), Sustainable Development Goals (SDGs), RFID (Radio Frequency Identification), WSN (Wireless Sensor Network)*

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1. Introduction

The demand for port operations to handle greater volumes of cargo efficiently has increased due to the rapid expansion of global trade. A possible approach to dealing with these issues is the fusion of automation and smart technologies. In this thesis, we'll examine how smart technologies might improve port operations and their broader effects on the maritime sector.

The fourth industrial revolution, defined by its pace, scale, complexity, and revolutionary force, is projected to considerably enhance global living standards. It does, however, bring issues like income inequality, Cyber security, and ethical quandaries. The revolution will affect society, institutions, and economies, changing the way we live, work, and interact. Understanding these new technologies is critical for all governments, particularly emerging ones. Social media platforms will be utilized to connect people, learn new things, and share information, while digital platforms will improve the quality and price of goods and services. Consumers will become more active in the manufacturing and distribution chains, which will impact consumer expectations, product quality, collaborative innovation, and organizational innovations.

1.1 PROBLEM STATEMENT

The world's shipping and logistics sector is changing rapidly due to technological advancements and the growing need for port operations that are efficient, sustainable and resilient. Smart ports, which combine digital technologies, automation and data-driven decisions, promise to improve the overall efficiency of port facilities. However, the development and deployment of smart ports comes with several challenges, including:

1. Congestion and Traffic Management 2. Inefficiencies in Supply Chain 3. Data Management and Privacy 4. Infrastructure Maintenance 5. Security and Risk Management 6. Environmental Impact
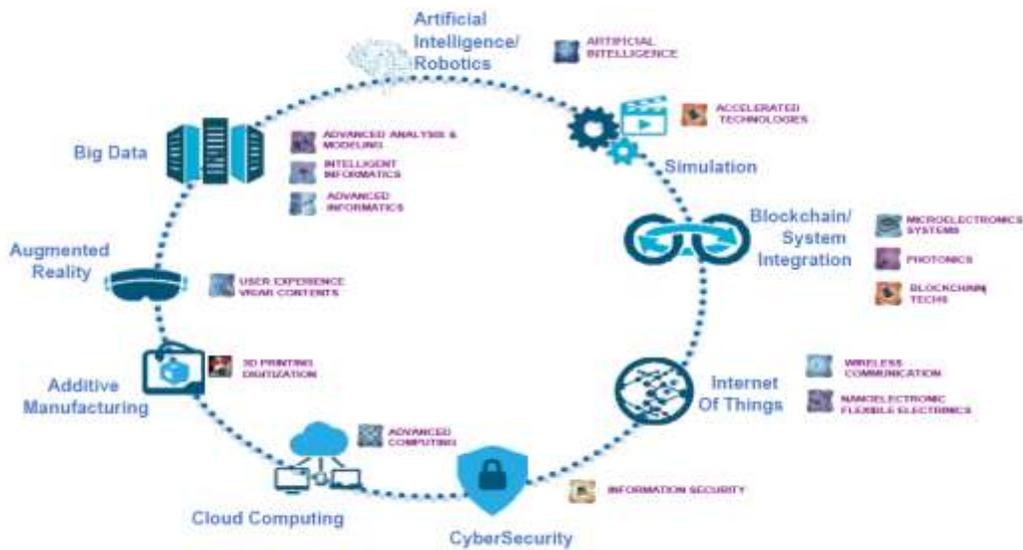
Fig -1: Research and Development (R&D) in the 4th Industrial Revolution (4IR)

By utilizing cutting-edge technologies and digitization, port development in conjunction with the Fourth Industrial Revolution (4IR) aims to improve the productivity, sustainability, and competitiveness of port operations. Following are the important components of smart port

1. IoT 2. AI and Big Data 3. Blockchain 4. Automation and Robotics

1. IoT

A key component of the Fourth Industrial Revolution (4IR) is the way digital technology are being incorporated into every sector of business and society. The Fourth Industrial Revolution is significantly supported by the Internet of Things (IoT), which allows physical items and devices to be connected to the internet and gather and exchange data. IoT impacts on following aspects

a. Smart Port Infrastructure: Cranes, gates, and container handling equipment are just a few of the port infrastructure components that Internet of Things devices are used to monitor and control. By gathering information on the functionality and condition of the machinery, these gadgets allow for more efficient operations and predictive maintenance.

b. Environmental Monitoring: IoT sensors can be used to keep an eye on the port's surroundings and surrounding environmental conditions. This covers the state of the weather, the water quality, and the air quality. Port authorities can respond more proactively to environmental issues when they have access to real-time data.

c. Security and Surveillance: IoT cameras, sensors, and access control systems are used for enhanced security. These systems can detect unauthorized access, monitor cargo, and ensure the safety of the port premises.

d. Cargo Tracking: By using IoT Cargo container movements are monitored by GPS and RFID technologies. This improves the visibility of the supply chain, aids in logistics optimization, and lowers loss or theft.

e. Vessel Traffic Management: IoT assists in navigation optimization, ensuring safety at the port and adjacent waters, and vessel traffic monitoring. Systems for preventing collisions and tracking vessels are included in it.

f. Predictive Maintenance: Predictive maintenance of port equipment can benefit from the usage of IoT data. Maintenance technicians can reduce downtime by anticipating problems and scheduling repairs before failures occur by analysing data from sensors on cranes and other gear.[2] [3] [11]

2. AI and Big Data

AI (Artificial Intelligence) and Big Data are being increasingly applied in the context of smart ports to enhance their efficiency, security, and sustainability. These technologies enable ports to better manage their operations, optimize resource allocation, and respond to changing conditions in real-time.

a. Traffic Management: AI reduces traffic and enhances logistics by optimizing container and vessel movement through ports.

b. Container Tracking: Big Data analytics can be used to monitor and control container movement, resulting in more secure and effective cargo management.

c. Risk Management: AI models are capable of identifying and reducing risks, including supply chain disruptions, weather-related delays, and security concerns.

d. Security: Video and data analytics supported by artificial intelligence can improve port security.

e. Resource Allocation: Artificial Intelligence facilitates the real-time allocation of labour and equipment resources. By using resource allocation algorithms and optimization techniques are used.

f. Real-time Data Analytics: Real-time decision-making based on incoming data streams is made possible by big data analytics.

g. Predictive Maintenance: Reducing downtime can be achieved by using AI and Big Data to forecast equipment failures and maintenance requirements. [1] [11]

3. Blockchain

A distributed, decentralized database that safely and openly records transactions is called a blockchain. To create an unchangeable record of all transactions, each transaction is grouped into blocks and connected to the prior blockchain.

a. Supply Chain Visibility: Blockchain technology has the potential to improve supply chain traceability and transparency. It enables the recording and access of real-time data regarding the flow of goods by all parties involved, including logistics providers, port authorities, shipping firms, and customs. This can lessen delays, stop fraud, and improve supply chain efficiency.

b. Cargo Tracking: Blockchain technology can be used to track freight movement and condition in real time along its transit. This guarantees that items are handled and kept in accordance with the necessary guidelines and helps in the identification of potential problems or delays.

c. Security and Authentication: Blockchain offers an extremely safe and unchangeable record for data capture and validation. This can aid in preventing cyber-attacks, illegal access, and data manipulation—all of which are essential to preserving the integrity of smart port operations.

d. Digital Identity and Access Control: Blockchain can be used to establish and manage digital identities for all participants in the smart port ecosystem. Access controls can be implemented to ensure that only authorized personnel can access specific data or systems.

e. Data Sharing and Collaboration: Blockchain makes it easier for numerous parties to share secure data. This holds particular significance in the context of smart ports, wherein multiple companies must cooperate and share data in order to maximize operational efficiency.

f. Digital Identity and Access Control: All members of the smart port ecosystem can create and maintain digital IDs using blockchain. Access controls can be put in place to guarantee that certain data or systems are only accessible by authorized persons.

g. Environmental and Compliance Reporting: Environmental standards and sustainability are becoming more and more important to smart ports. Blockchain technology can facilitate the transparent reporting of environmental data while guaranteeing compliance with legal requirements.

h. Payment Settlement: Blockchain technology has the potential to optimize payment procedures by automating and safeguarding financial transactions among many parties, hence decreasing the necessity for middlemen and their related expenses.[7] [11]

4. Automation and Robotics

Robotic systems that port terminals utilize to handle goods. It examines the increases in productivity and security brought about using robotics. Port container handling operations can be enhanced by the application of automation and optimization approaches, such as decision support systems and simulation models.[8][9]

2. RELATED WORK

There are few studies to directly address "The Duo of Artificial Intelligence and Big Data for Industry 4.0: Review of Applications, Techniques, Challenges, and Future Research Directions". Senthil Kumar Jagatheesaperumal , Mohamed Rahouti, Kashif Ahmad, Ala Al-Fuqaha, Mohsen Guizani (2020) proposed a related work this paper analyses the role of AI and Big Data in Industry 4.0 applications, focusing on key applications, technologies, and challenges like security, adversarial attacks, communication, understandable, and data-related issues. It provides a detailed analysis of the benchmark data set for AI-based solutions and identifies open research issues, providing a baseline for future research. [1].

According to a comprehensive review of the existing literature related to "The internet of things for smart ports", Amine BOUHLAL, Rachida AITABDELOUAHID, Abdelaziz MARZAK. Smart ports are becoming a strategic necessity due to competition in container ports. IoT technology is crucial for providing data and information to stakeholders in the maritime sector. Integration can occur during construction or reorganisation of existing ports. Research questions include applying quality models in maritime environments, assessing IoT adoption protocols, and helping actors master and mature their IoT adoption [2].

In this paper it provides the details about "Internet of Things for Smart Ports: Technologies and Challenges" by Yongsheng Yang, Meisu Zhong, Haiqing Yao, Fang Yu, Xiuwen Fu, and Octavian Postolache study results that smart ports use advanced sensing systems like RFID and cameras to improve performance and safety in container terminals. These technologies reduce time and improve structural health monitoring for quayside cranes. Robust wireless networking and internet connectivity are crucial for port terminals, with ZigBee WSN being a key solution for strain monitoring. Smart sensing and IoT technologies will play a significant role in port development [3].

This study "Smart port: a systematic literature review" Basma Belmoukari , Jean-François Audy and Pascal Forget proposes a new updated definition of a smart port, encompassing seven activity domains (operations, social, environment, energy, human resources, safety and security, smart infrastructure, equipment, and technologies) and characteristics related to each domain. The transition to an intelligent port requires port authorities to prioritise innovative technologies and management practices, addressing their specific challenges and limited resources. This definition may serve as a guide for designing decision-making tools and a roadmap for future research [4].

According to Silvia Battino, and Maria del Mar Muñoz Leonisio "Smart Ports from Theory to Practice: A Review of Sustainability Indicators." Smart port is a concept involving organizations and long-term commitment, focusing on economic growth and social responsibility. This work examines seaports' evolution under sustainability and smart

paradigm principles, port city relationships, and mechanisms to reduce undesirable port activity output. Transparent management and smart strategies improve operational efficiency and port city relationships. The true scope of smart port is voluntary actions, leading to future improvements. The research identifies responsible behaviour within each port environment and applies Key Performance Indicators (KPIs) to Spanish and Italian ports to assess their commitment to smart development goals [5].

The study analysis of Thi Yen Pham a comprehensive review of 53 smart port studies using bibliometric analysis and systematic literature review. The findings indicate growing interest in smart port studies from 2016 to present, with China being the most active country with the highest number of publications. The main research themes in smart port studies are the applications and implications of digital transformation technologies in various aspects, smart port performance evaluation using different indexes, and addressing challenges and barriers of smart port development. The main theme of current studies focuses on analysing the feasibility of new digital technologies in port operations. However, identifying challenges and barriers incorporating empirical cases on increasing transparency, collaboration, and trust is crucial for a dramatic transformation of smart port operations. The study outlines both academic and industrial implications, contributing to a better understanding of the concept of smart port and supporting seaport stakeholders in making critical decisions about applying advanced technologies to improve port performance [6].

This article reviews the limited research on the application of Information and Communications Technology (ICT) in smart ports, highlighting its potential to enhance port activities and services, increase national economy competitiveness, and reduce greenhouse gas emissions. The article highlights the importance of information systems in smart ports, but there is limited research on this topic. Recent works focus on Internet of Things, cold ironing, renewable energy generation, energy management, and resource management. Future research could explore new smart port applications, collaboration platforms, enhanced terminal operating systems, digitized autonomous smart ports, big data analytics, blockchain, and cyber security solutions [7].

The article shows robotic automation in container terminals Nikolay V. Malyshev, Evgenii K. Koroviakovskii, Svetlana A. Rostovceva "Robotic automation of inland container terminals" [8].

According to JEAN-PAUL RODRIGUE, THEO NOTTEBOOM "Automation in Container Port Systems and Management" in study of automation in container port [9].

In the research article Dr.I.Parvin Banu, Aravind babu.K"A Study on Competitiveness of Rotterdam Port and Chennai Port" compared the different infrastructures, investments, governance, geographic locations, capacities and distance from the major sea routes have contributed largely towards ineffective competitiveness of Chennai and Rotterdam port.[10]

The study analysis of Adrianna Karas "Conceptualization of Smart Ports" it reveals about the smart port smart port integrates a number of port operations components to boost port competitiveness, boost the effectiveness of port operations, cyber security, energy and environmental efficiency, digitization and automation, and stakeholder integration. Big data, artificial intelligence, the Internet of Things, automation, digitalization, digital twins, block chains, 5G, and sensors are some of the components used by intelligent ports.[11]

3. CONCLUSIONS

A smart port is a comprehensive concept that strengthens automation, logistics optimization, energy efficiency, and connection with Eco-friendly hinterland cities etc., by incorporating the 4IR technologies with maritime transport. Now is the right time to establish future oriented smart ports in which technology and humans, nature and the environment, logistics and economy co-exist. In addition, it will be possible to improve the efficiency and safety of marine transport and reduce logistics costs through the automation of maritime transport infrastructure and intelligent port operation systems

4. ACKNOWLEDGEMENT

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