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Advancing the Oman Shipping Industry: A Comprehensive Review of Digital Transformation Adoption and Regulatory Integration Using the Extended TOE Framework

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Abstract: *The shipping industry is essential to Oman's economic framework, facilitating commerce, energy exports, and geopolitical power. Oman faces the challenge of improving its marine infrastructure and operations to remain competitive amid rising global shipping demands. The use of digital technology is crucial in this shift, as it enhances operational efficiency, reduces costs, and promotes sustainability. Nonetheless, effectively executing these technologies necessitates surmounting legislative, organisational, and strategic obstacles. The Technology-Organisation-Environment (TOE) framework provides a comprehensive methodology for analysing the determinants that affect the adoption of digital advances within Oman's marine industry. This study examines the impact of digital transformation on the shipping sector, emphasising critical technologies such as IoT, blockchain, AI, and automation that enhance efficiency, transparency, and sustainability. Moreover, Oman's marine industry is expanding its capacity, particularly at Sohar Port, which is establishing itself as a competitive entity in the region. The nation's Vision 2040 emphasises the significance of digital transformation, seeking to diversify the economy while enhancing the maritime sector's role in global commerce. Oman is improving its competitiveness and geopolitical influence by leveraging technology and establishing itself as a naval leader. This paper examines the obstacles and opportunities of digital transformation in Oman's shipping sector, highlighting the importance of the TOE framework in assessing the adoption of digital technology.*

Keywords: *Shipping Industries, Oman, TOE Framework, IOT, digital transformation.*

1. INTRODUCTION

The shipping sector in Oman is a vital component of the nation's economic structure, connecting it to international trade routes and facilitating the transportation of commodities across continents. [1, 2]. With the increasing global shipping needs, nations like Oman face mounting pressure to enhance their maritime infrastructure and operations to maintain competitiveness. [3]. A key element in this change is the integration of digital technologies, which are transforming marine operations by augmenting efficiency, decreasing costs, and promoting environmental sustainability. [4-6].

Nonetheless, the effective execution of modern digital technologies transcends mere technical progress. It entails navigating intricate regulatory frameworks, tackling organisational obstacles, and aligning with strategic goals. [7-9]. The expanded Technology-Organisation-Environment (TOE) framework is crucial, providing a comprehensive model to evaluate the digital transformation process in sectors such as shipping. [10, 11].

The digital transformation of Oman's shipping sector is a complex process that incorporates technological breakthroughs, including automation, artificial intelligence (AI), the Internet of Things (IoT), blockchain, and data analytics in marine operations [12]. These technologies are anticipated to optimise operations, enhance maritime logistics management, and facilitate real-time vessel monitoring [13]. Nevertheless, using these technologies presents a series of obstacles that must be carefully evaluated [14]. Technological infrastructure, organisational preparedness, and the regulatory environment are essential elements that affect the efficacy of integrating new advances into the current marine system [15, 16]. The TOE framework, first created to investigate technology adoption across many sectors, provides a comprehensive approach by examining the interplay of three fundamental dimensions:

technology, organisation, and environment [17, 18]. Expanding this paradigm may enhance our comprehension of the broader context of digital change within the maritime industry. The technical component examines the tools, platforms, and innovations accessible to the sector. The organisational component examines elements such as leadership, culture, and resources within shipping enterprises, while the environmental dimension investigates the impact of external variables, including regulatory rules, market conditions, and global shipping patterns [19, 20].

In the context of Oman, these three elements are interrelated, and their alignment is essential for achieving the full potential of digital transformation in the maritime sector. [21, 22]. The government's responsibility in establishing a regulatory framework that promotes innovation while safeguarding safety, security, and environmental norms is crucial. Oman has made considerable advancements in establishing itself as a pivotal entity in global shipping, with significant investments in port infrastructure, logistics, and digital technology. [23]. The nation needs a well-designed plan integrating digital and regulatory advancements to preserve and develop its marine sector. This paper aims to provide a comprehensive analysis of the advancements in the Oman shipping sector facilitated by digital transformation, highlighting the significance of the expanded Total Operating Efficiency (TOE) framework. It examines the determinants influencing the adoption of digital technology, the obstacles encountered by players in the shipping industry, and the incorporation of legislative frameworks that facilitate this change. This study analyses the synergies among technology.

Adoption, organisational dynamics, and regulatory integration to provide insights on how Oman might improve the competitiveness and sustainability of its shipping sector in the global market. The investigation will also delineate a path for forthcoming digital and regulatory policies to enhance Oman’s standing in the international marine sector.

1.1. An Overview of GCC Countries' Digital Transformation Initiatives

The Gulf Cooperation Council (GCC) nations, comprising Saudi Arabia, the UAE, Qatar, Kuwait, Oman, and Bahrain, have been at the forefront of digital transformation in the Middle East [24]. These countries have made significant progress in integrating digital technology across various sectors to improve governmental services, promote economic diversification, and enhance the quality of life for their populations [24]. The digital revolution in the GCC is driven by a combination of governmental efforts, technical progress, and the need to adapt to a rapidly evolving global economy. Saudi Arabia's Vision 2030 aims to create a resilient digital infrastructure, including 5G networks, smart cities, and a digital economy. The Saudi Data and Artificial Intelligence Authority (SDAIA) is crucial in advancing these efforts [24, 25]. The UAE has consistently led in digital transformation within the GCC area, initiating programs like the UAE Vision 2021 and the National Artificial Intelligence Strategy 2031. Dubai's Smart City plan incorporates IoT, AI, and blockchain to enhance public services and citizens' quality of life [26].

Qatar's National Vision 2030 emphasizes technology innovation as a catalyst for economic diversification, with investments in cybersecurity, cloud computing, and smart city technology. The Qatar Smart Nation program aims to convert the country into a smart and interconnected nation using technologies such as IoT, AI, and big data [27-29]. Kuwait's digital transformation is directed by the New Kuwait Vision 2035, which aims to establish a sustainable and diversified economy with digital technology. Oman's digital transformation plan, outlined in Vision 2040, focuses on digital innovation to diversify the economy and improve government services [30]. The Sultanate has invested in information technology infrastructure and digital platforms, with the Ministry of Transport, Communications, and Information Technology formulating laws and regulations to integrate digital technology across various sectors. Oman is prioritizing smart city infrastructure, such as the Duqm Smart City and Sohar Industrial Port, which incorporate technology into urban and industrial development [31, 32]. Bahrain has emerged as a regional leader in digital transformation, adopting blockchain technology and improving cloud computing and cybersecurity infrastructure. Technological breakthroughs in the GCC are facilitating digital transformation, altering the way companies and

governments operate. Key technologies such as AI, blockchain, IoT, big Data and cloud computing are being used to enhance efficiency, transparency, and service provision [33, 34]. Artificial Intelligence (AI) and Big Data analytics are crucial for digital transformation initiatives in the GCC, with governments and businesses allocating resources to AI to refine decision-making, streamline processes, and enhance consumer experiences [35]. The Internet of Things (IoT) is a significant catalyst for digital transformation in the GCC, with IoT devices being integrated into smart cities, residential buildings, transportation networks, and industries to gather real-time data, monitor conditions, and automate activities [36, 37]. Dubai's Smart City program relies on IoT technology to enhance urban life. However, challenges remain in implementing digital technology across various industries. Cybersecurity, digital inclusion, and workforce development are essential for successful digital transformation. The Gulf Cooperation Council (GCC) countries, comprising Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE, have launched extensive artificial intelligence initiatives to harness the transformative capabilities of AI. The GCC will examine the principal AI projects implemented by each member state, emphasising their joint efforts, strategic alliances, and long-term objectives (Figure 1).

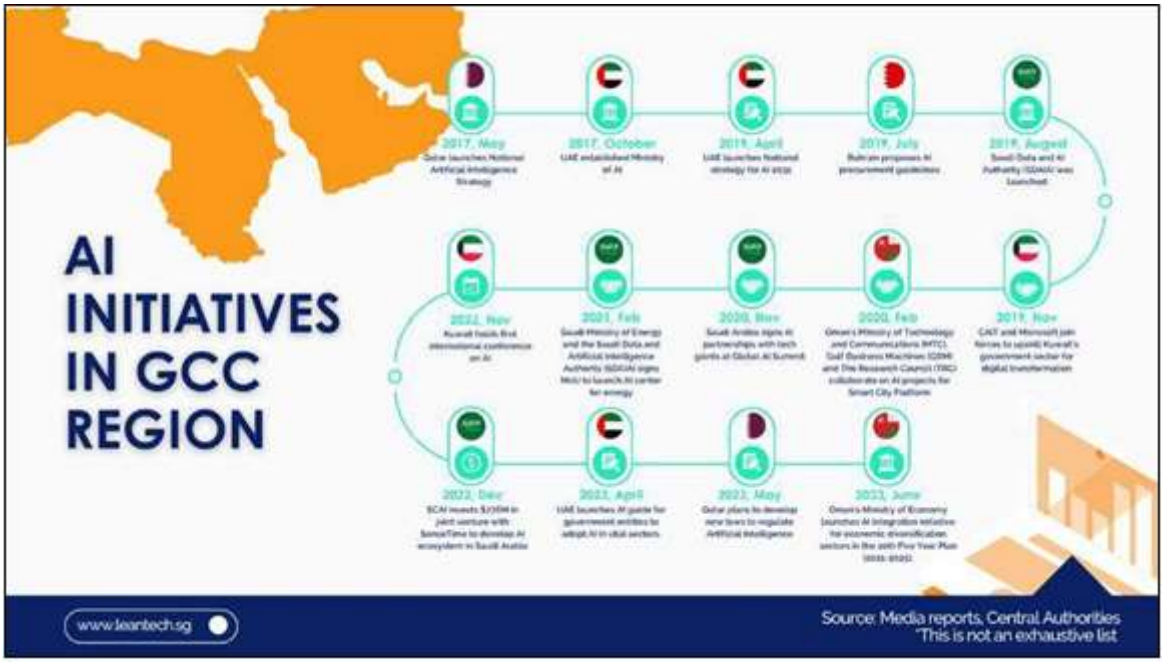

Figure 1: Artificial Intelligence Initiatives in GCC Nations: Shaping the Future

1.2. Importance of the Oman Shipping Industry

The Oman Shipping Industry is a vital component of the nation's economy and strategic position in international maritime commerce. Situated on the southeastern coast of the Arabian Peninsula, Oman has a strategically important maritime position in the Middle East, next to crucial trade routes [38, 39]. The industry underpins other economic sectors, including petroleum, commerce, tourism, and logistics [39]. The ports of Oman, including the Port of Salalah, Port Sultan Qaboos, and Duqm Port, manage substantial volumes of container, bulk, and oil exports, establishing them as pivotal nodes in international shipping networks [40]. The Oman Shipping Company (OSC) is a significant entity in this sector, managing a contemporary fleet of boats for local and international commerce. It augments Oman's proficiency in energy exports, namely petroleum products, while concurrently facilitating containerized commerce and freight transportation in international markets [41, 42]. Beyond economic advantages, the maritime sector bolsters Oman's political and strategic clout in the region. The shipping sector bolsters the nation's geopolitical interests by enhancing relationships with foreign trade partners and engaging in maritime security measures [43].

The port of Sohar now manages the handling of break-bulk cargo, roll-on/roll-off (RORO) trucks, containers, and liquid bulk, functioning under a landlord model structure [44]. The port competes with

Jabel Ali in Dubai, the principal port of DP World (Dubai Port World), which manages millions of TEUs annually [44]. The Sohar Port and Free Zone facility is actively pursuing economic diversification by vying for traffic with other ports in the Gulf. Shipping is fundamental to Oman's economy, enabling the import and export of products, promoting international commerce, and supporting industries like oil, gas, mining, and agriculture [45]. The nation's ports are vital transit hubs for products transported from Europe, Asia, and Africa, affording it diplomatic influence in international shipping negotiations and marine security matters. Oman's neutral political position renders its ports secure refuges during regional turmoil, establishing Oman as a significant contributor to the uninterrupted flow of commerce across the Arabian Sea. The digital transformation of Oman's maritime sector is anticipated to enhance its operations, making them more efficient, sustainable, and competitive [46]. Technological innovations, including smart ports, blockchain, and Internet of Things (IoT) technologies, are transforming the global marine industry. Oman has proactively embraced modern technology, establishing itself as a progressive country. By enhancing infrastructure, adopting technical innovation, and safeguarding its marine routes, Oman is poised to fully utilise its shipping sector, yielding economic and strategic advantages for the nation [47, 48].

1.3. Digital Transformation: An Industry Perspective

Digital transformation rapidly integrates digital technologies into all business functions to improve operations, customer value delivery, and competitive engagement [49]. This involves optimising internal procedures, improving customer experience, and facilitating data-driven decision-making [50]. E-commerce platforms increasingly use AI and machine learning algorithms to customise customer experiences and optimise supply chain management. Digital transformation catalyses innovation, facilitating new opportunities in product development, service delivery, and customer interaction [51-53]. In sectors like retail, leveraging digital platforms and tools enables businesses to offer more personalised services, establishing a competitive edge in saturated markets [54, 55]. However, the path to digital transformation presents distinct hurdles, particularly in conventional industries such as logistics and energy. Industry-specific challenges include digitising supply chains, addressing legacy infrastructure and data interoperability challenges, modernising grid systems, ensuring cybersecurity, and complying with regulatory standards while utilising renewable energy technology [56].

A digital transformation framework is a strategic tool that helps organizations integrate new technologies while aligning their operational and strategic objectives. It comprises four key components: vision alignment, leadership, technology adoption, and ongoing enhancement [57, 58]. Vision alignment ensures the alignment of digital activities with the organisation's overarching objectives, while leadership plays a crucial role in steering digital transformation initiatives. Technology adoption involves selecting tools and platforms that facilitate intended changes in operations, customer service, and strategic decision-making [59]. Constant enhancement is essential since digital transformation is a perpetual process. In the logistics sector, a digital transformation framework should focus on operational efficiency and customer happiness, including supply chain digitisation and logistics automation (Figure 2). Digital technologies like IoT, AI, and cloud computing facilitate real-time tracking, predictive analytics, and efficient collaboration among supply chain partners. In the energy sector, a digital transformation framework should prioritize the implementation of smart grids, energy storage systems, and the integration of renewable energy. Assessing the success of digital transformation efforts is essential for evaluating the effectiveness of applied tactics [60].

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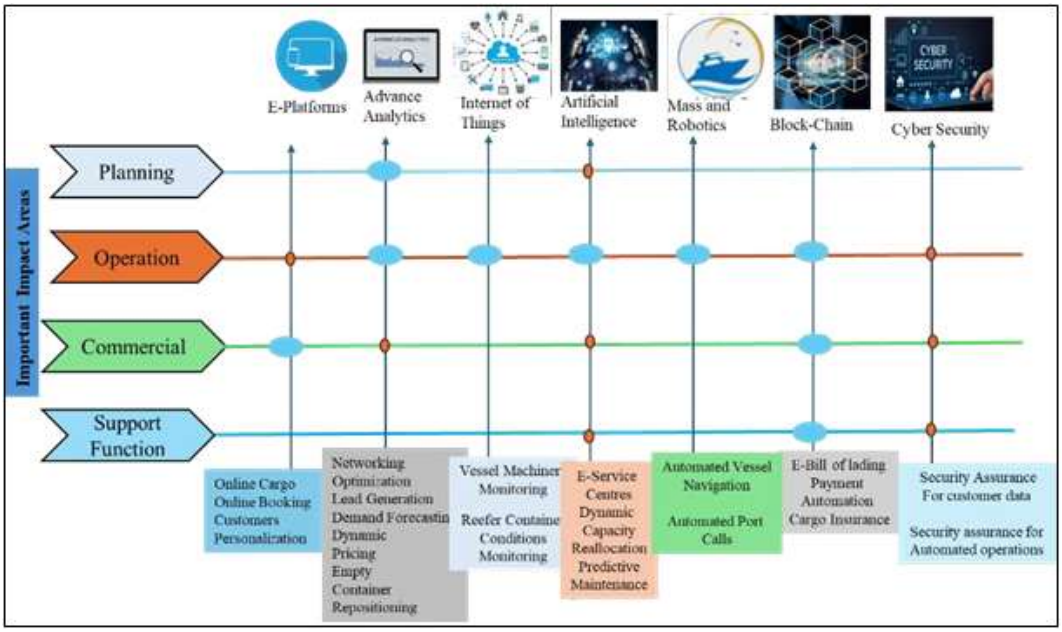

Figure 2: Emerging digital technologies in the Shipping industry

[61] Characterises transformational change as a reconfiguration of organisational processes and structure, together with a modification of vision and mission, whereas adaptive evolution pertains to alterations in operational methodologies. Supply chains and transportation costs have been optimised due to efficiency achieved through digitalisation. This will emerge as the global economic determinant that will influence international trade and propel global economic expansion. Digitalisation will not only disrupt ports and shipping businesses but is also likely to favourably alter global trade by shifting the relative advantages of countries. As technology progresses, worker costs diminish, rendering them less pertinent than in the past; instead, the efficiency of trade and innovation will assume greater importance [62].

2. Overview of the Technology-Organisation-Environment (TOE) Framework

The Technology-Organisation-Environment (TOE) paradigm is an organisational theory that focuses on the three components of a firm's context: technical, managerial, and environmental. It is the most suitable theory for analysing technological adaptation, technology utilization, and value generation from technological breakthroughs [11]. Technology serves as the primary context, examining internal and external technological issues a company must confront. The framework also includes an organizational environment, which provides descriptive metrics, such as scope, firm size, technical competencies, organizational readiness, and resources. The third context, environment, pertains to the company or industry in which the firm operates. Market factors such as industry competitors, governmental influences, market structure, and supplier competencies can influence the adoption and use of technology [63].

The TOE framework provides a fundamental base for researchers and managers in examining, evaluating, and integrating technology within an organisation. It provides a robust theoretical foundation and elucidates the impact of several factor groups on technical activities inside enterprises [64]. Managers often use the TOE framework to evaluate the benefits and potential risks while strategising the application and integration of technology into the corporate model. Recent studies have used the TOE framework to analyse factors affecting technology adoption in the marine sector. [65] Identified knowledge absorption capability as the primary facilitator of blockchain adoption within organisations, followed by perceived relative advantage in the technological domain and trading partner influence in the environmental sphere. [66] Adopting inter-organisational information systems in the maritime supply chain is significantly influenced by various factors, including industrial characteristics,

information confidentiality, the power of supply chain partners, governmental authority, and ownership structure. This research utilizes the TOE framework to examine and implement actions associated with digital transformation in marine organizations. Shipping company managers will provide a robust basis for their digital transformation decision-making by using the TOE framework to assess and evaluate the impact of technological, organisational, and environmental aspects.

Digitalisation refers to transforming sociotechnical systems using digital technology and digitised data. Industry 4.0 is a significant era of digitalization, impacting commercial operations, supply chain processes, and corporate collaboration [67]. Digital technologies enable the swift launch of innovative products and services, influencing originating and recipient nations' institutional framework and economic activities. They can affect the internationalization process, including duration, velocity, geographical dimensions, entry strategies, assimilation, and integration into foreign markets. Adopting digitalization, advanced data science, and business intelligence techniques can facilitate the development of knowledge-intensive services and processes (Figure 3). This shift towards digital transformation fundamentally alters business models, resulting in a reconfiguration of relationships among customers, enterprises, and suppliers [68].

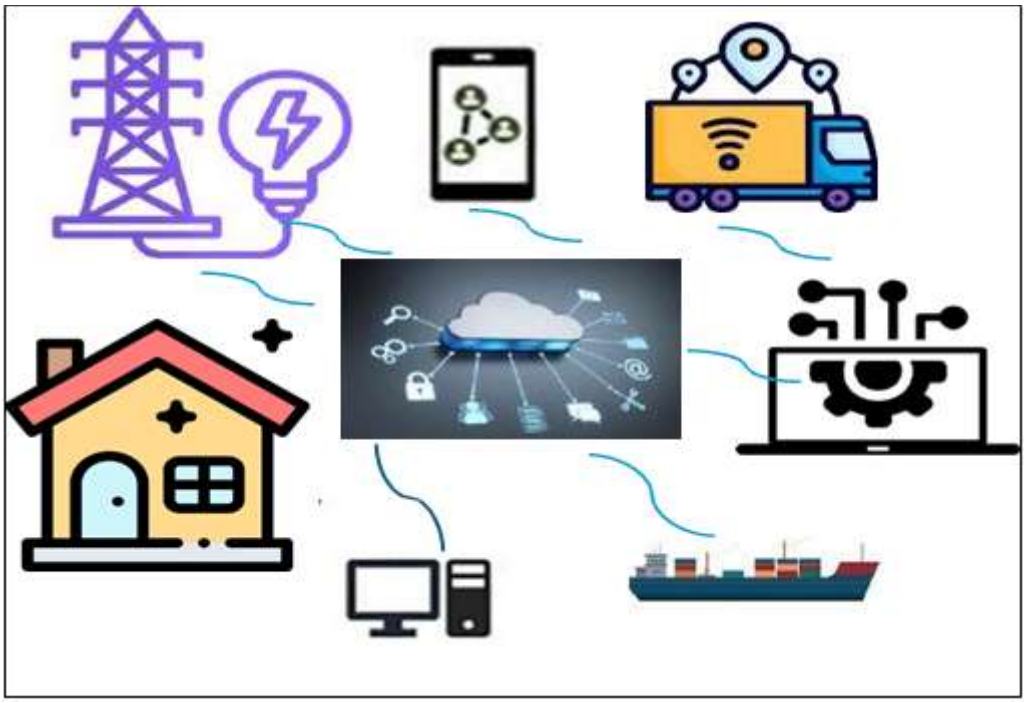

Figure 3: Platform in the cloud: connectivity and high availability in Shipment digital transformation

Pwc Norway (2017) found that digital transformation is expected to significantly influence the shipping industry and its firms in the future. The shipping business employs a diverse array of equipment and gear, and the efficiency of seaports would significantly increase if these devices communicated, gathered and analysed data, and made real-time decisions autonomously [69]Advanced digitalisation in maritime transport is applied across eight digital domains, including autonomous vehicles and robotics, artificial intelligence, big data, virtual reality, augmented reality, the Internet of Things, cloud and edge computing, digital security, 3d printing, and additive engineering. Cloud infrastructure enables ports to focus on core competencies and improve processing speed, cost-effectiveness, security, high availability, and resilience. In contrast, Iot technologies enable devices to gather and transmit operational information (Figure 3).

2.1Extension of the TOE Framework for Shipping Industry Analysis

The Technology Organisation Environment (TOE) concept, introduced by Tornatzky and Fleischer (1990), highlights the influence of multilayer technology application contexts, including an

organisation's need for technology and its relevance to organisational regulations [70]. The TOE framework categorizes the factors influencing technology application into three domains: technology, organization, and environment. The TOE framework does not delineate specific variables within the technology, organization, and environment categories. It enables researchers to adapt and modify the framework for various research domains or subjects, thus enhancing its effectiveness and applicability [71]. Consequently, researchers have used the TOE framework to enhance condition variables and develop configuration models across various domains, utilising the QCA approach [72-74]. Based on the TOE framework, this study created a configuration model with ten technical, organizational, and environmental antecedent conditions [75]. The model was tailored to Oman's institutional context and competitiveness development at hinterland ports (Figure 4). The Technology-Organisation-Environment (TOE) framework is a prevalent paradigm for comprehending the adoption and deployment of novel technologies across diverse sectors. It emphasises three fundamental dimensions: technology, organisation, and environment, significantly influencing how firms embrace innovations [76]. We can expand the TOE framework in the shipping industry to encompass various factors, such as technological infrastructure innovation capability, maritime connectivity, organisational and industrial structure, financial supply, port facilities, cost considerations, environmental, economic development, market openness, configuration alignment, port policy and management, and information systems. These aspects affect the industry's dynamics, performance, and overall sustainability. In the maritime sector, creating technology infrastructure is essential for maintaining competitiveness. The progression of digital technologies such as automation, artificial intelligence, and blockchain has transformed the operations of transportation businesses. This innovative capacity enables transportation companies to enhance operating efficiency, save expenses, and provide superior customer service.

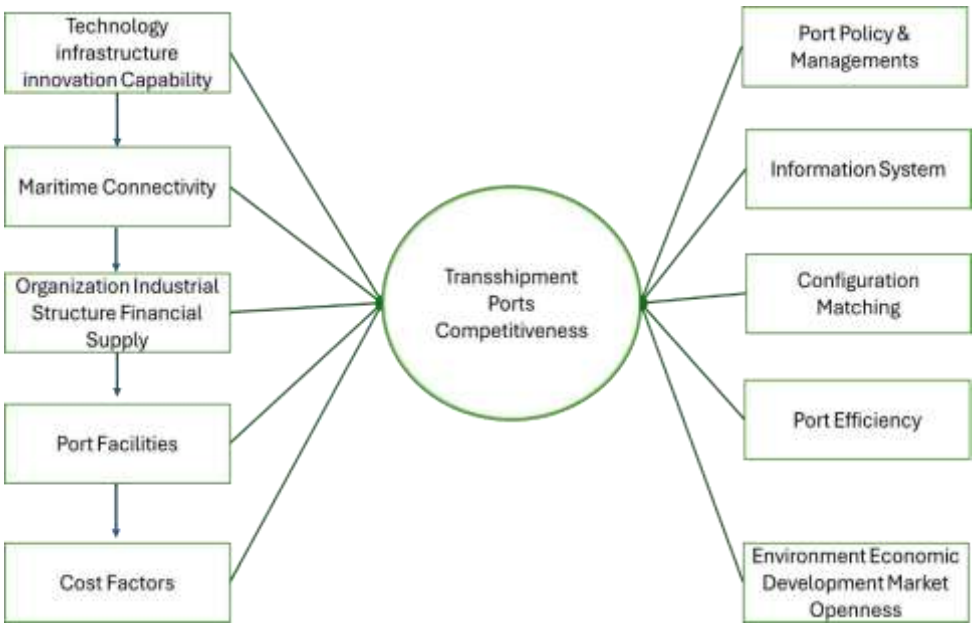

Figure 4: TOE Framework for the Shipping Industry

The shipping industry's success relies on its infrastructure, including IoT devices, real-time tracking, and intelligent ports. The ability of firms to use these technologies depends on their resources, technical proficiency, and organizational preparedness. Maritime connection allows for uninterrupted communication among vessels, ports, and global logistics networks, enabling real- time information transmission for optimizing shipping routes, cargo security, and port operations. Organizational structure influences decision-making, innovation, and collaboration with external partners. An adaptable organizational structure promotes interdepartmental cooperation and engagement with external organizations. Financial resources are crucial for the shipping industry's growth and innovation. Organizations need significant capital to implement new technology, enhance fleets, and

replace port infrastructure. Financial stability is essential for enduring market swings and global economic recessions. Ports play a significant role in the success of the maritime sector, with modern infrastructure integrating automated systems, optimized loading and unloading processes, and sustainable technology. Environmental responsibility from the International Maritime Organization (IMO) and increased focus on environmentally sustainable boats, renewable fuels, and energy-efficient technology can stimulate innovation in business while maintaining profitability.

Market openness allows shipping firms to enter international marketplaces and compete equitably. Configuration matching aligns technology, organizational resources, and operational strategies to satisfy market expectations efficiently. Port policy and management strategies are essential for enhancing port operations. Information systems are crucial for logistics management, inventory monitoring, real-time tracking of vessel movements, and supply chain oversight. The expanded TOE framework offers a comprehensive approach to analysing the challenges and opportunities in the shipping industry by integrating technological infrastructure, maritime connectivity, organisational structure, financial supply, port facilities, and regulatory elements.

2.2 Relevance of the Framework in Digital Transformation

Integrating modern digital technology with environmental sustainability assurance in the logistics industry is increasingly essential for the unique multimodal transportation concept [77]. The swift technological advancements in the Industry 4.0 era facilitate the creation of highly efficient, intelligent, and smart logistics systems, fostering new business models for value enhancement. Furthermore, this innovative system will mitigate environmental degradation and the consumption of limited natural resources that exacerbate climate change [4]. The technique of advanced digital technologies is multidisciplinary, incorporating principles from several sectors, including engineering, accounting, the humanities, and social sciences, outside the confines of computer science. The implementation of these technologies resulted in a paradigm shift towards Industry 4.0. Emerging technologies in the industrial sector encompass sophisticated digital innovations such as the Internet of Things (IoT), cloud computing, wireless sensor networks, embedded systems, and big data [78]. Manufacturers adhering to these trends should effectively produce customized products with increased profitability, exemplified by the digital transformation of seaports for efficiency validation and system optimization [79], enhanced warehouse management and forecasting accuracy through IoT [80], and sustainable improvements in smart mobility systems utilizing big data [81].

This research enhances our understanding of digital transformation processes and establishes a foundation for future studies in this domain. This research series on company digital transformation focuses on worker resistance to digital transformation procedures. One area for future research will be the higher education industry. Currently, digital transformation is a prevalent term in academic and corporate contexts. Nearly every sector, including business, education, finance, government, and manufacturing, is undergoing digital transformation during the fourth industrial revolution. Over the past 20 to 25 years, academic discourse has extensively examined elements of digital transformation, its drivers and barriers, and value creation through digital transformation [82-84]. The request for digital transformation in the Google Scholar database produced three million results. The inquiry for the keywords "digital transformation" in SCOPUS and Web of Science databases yielded substantial scientific works, with the quantity rising annually (refer to Figure 5). The European Commission (EU) prioritizes digital transformation in industry and society. The Digital Transformation Monitor and Digital Transformation Scoreboard are EU efforts designed to assess advancements in digital transformation across EU nations (European Commission, 2019). In 2017, the Organization for Economic Cooperation and Development (OECD) initiated a global initiative titled "Going Digital: Making the Transformation Work for Growth and Well-Being.

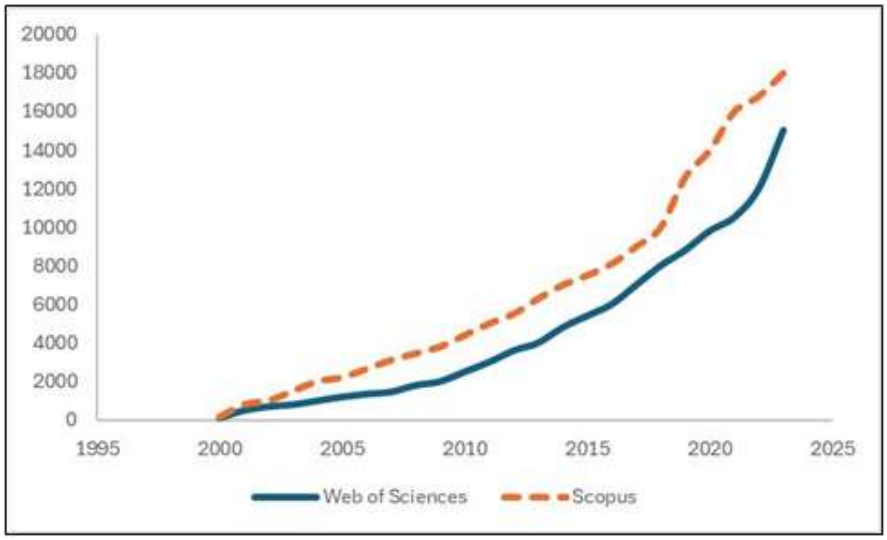

Figure 5: Count of papers focused on Digital Transformation: findings from Web of Science and SCOPUS scientific databases, 2000–2022 (source: authors' compilation)

The objective is "to assist policymakers in comprehending the ongoing digital transformation and to establish a policy framework that facilitates the prosperity of their economies and societies in an increasingly digital and data-driven world" (OECD, 2018). What accounts for the significant focus on digital transformation? Digitalization is a fundamental component of the extensive advancements of society, economics, and industry. Digitalization and globalization are the defining processes of our contemporary existence. The European Commission predicts a "transformative industrial and technological revolution" will be a significant worldwide trend by 2030. "Technological breakthroughs will transform all facets of society, including politics, governance, education, science, lifestyles, collective intelligence networks, the establishment of open systems, and health, encompassing the transformation of the human genome" (ESPAS, 2015).

The GCC nations have become leaders in adopting digital transformation, acknowledging their capacity to promote economic diversification, improve government services, and stimulate innovation across several industries. Each member nation, including Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE, has formulated its digital agenda and plans customized to its economic and social imperatives. The UAE has established itself as a regional pioneer in digital transformation, exemplified by the "Smart Dubai" initiative, which aims to provide a smooth, efficient, and user-centric urban experience for inhabitants and tourists. Saudi Arabia's Vision 2030 seeks to leverage digital technology to improve citizen services, foster entrepreneurship, and encourage innovation across several areas, including healthcare, education, and finance. The region's aspiration to establish itself as a worldwide leader in the digital domain has resulted in several revolutionary programs, including smart cities, e-government services, digital infrastructure development, and the promotion of digital skills. Digital transformation projects in the GCC span several fields, targeting the public and commercial sectors. Governments are increasingly modernizing services via e-government platforms, enabling individuals to access public services online, resulting in simplified processes and improved citizen involvement [24]. The GCC nations are significantly investing in developing smart cities, utilizing data-driven technology and IoT breakthroughs to optimize resource use, boost public safety, and elevate urban living standards. Furthermore, the region's vibrant private sector has transformed digitally, integrating advanced technology to improve efficiency, foster innovation, and compete successfully globally [85]. Notwithstanding advancements in digital transformation efforts, the area encounters hurdles. This involves promoting digital inclusion to close the digital gap, particularly for marginalized communities [86]. Moreover, cybersecurity is critical due to the escalating risks of cyberattacks and data breaches. Safeguarding data privacy, security, and the robustness of important digital infrastructure is vital for preserving confidence in digital services [87]. Confronting these challenges requires a thorough and

cooperative strategy involving governments, businesses, and civil society stakeholders working together to leverage the opportunities presented by digital transformation while alleviating potential risks.

Ensuring efficiency and competitiveness is crucial. Oman is advancing its technology landscape, with the logistics industry leading the adoption of new initiatives and technologies to improve operations. The adoption of digital frameworks in logistics aims to enhance procedures, refine supply chain management, save expenses, and optimise delivery durations. An approach involves employing Internet of Things (IoT) devices and sensors for real-time tracking of commodities, facilitating improved visibility and predictive maintenance of vehicles and infrastructure. The use of artificial intelligence (AI) and machine learning (ML) for demand forecasting and route optimisation is revolutionising logistics operations. Blockchain is recognising the potential of blockchain technology to facilitate transparent and secure transactions, particularly in cross-border Digital platforms, such as integrated management systems, offering a central control hub for logistics operations, improving coordination and communication among stakeholders. By integrating these technologies with strategic frameworks, Omani logistics firms may enhance customer satisfaction and promote operational excellence. Moreover, these advances correspond with the nation's Vision 2040, which seeks to diversify the economy and establish a sustainable, technology-oriented future, rendering the digital transformation of logistics a crucial area in Oman's economic development.

2.3 Technological Infrastructure and Digital Maturity

The fourth industrial revolution aims to apply efficient technology like blockchain and artificial intelligence, making maturity models potentially beneficial. Maturity models are tools for assessing the digital readiness of organizations and corporations across diverse industries [88, 89]. They are used to conceptualise and assess the maturity of any entity and formulate a developmental trajectory [90]. Several models in the current literature highlight the necessity for directed assistance in formulating a smart manufacturing vision and project planning. An example is the three-stage maturity model for small and medium-sized firms (SMEs) regarding Industry 4.0. Another model is the IMPULS model, which comprises six maturity levels of Industry 4.0, encompassing 18 things pertinent to the domain [91]. Forrester's digital maturity model is introduced to monitor a company's progression in digitalization across four maturity stages. Digital transformation (DT) is an ongoing evolutionary process that differs among implementing organizations and is contingent upon their digital maturity. Increased digital maturity correlates with improved corporate performance [92]. Digital maturity comprises two distinct yet interconnected characteristics: digital intensity, which pertains to digital competencies and investments in technology-driven projects that transform a company's operations, consumer interactions, internal processes, and business models, and the intensity of transformation management, encompassing the vision, governance, and leadership competencies required to propel digital change within the organization [93].

Organizations with inadequate digital competencies and ineffective transformation management capabilities are classified as digital novices. Conversely, companies possessing robust digital capabilities alongside practical transformation management skills are the digital natives that understand how to generate value through digital transformation and attain a competitive advantage by investing in the critical components of transformation management: vision, governance, and engagement. Cultivating digital maturity, or digital DNA, is significant across all industries, revealing that, on average, digital natives achieve greater profitability than their industry counterparts. They generate increased revenue through their workforce and tangible assets, resulting in greater value creation and higher market valuation ratios [94]. Unlike conservatives, who emphasize control and conformity, digital natives possess digital competencies and have cultivated a robust transformative vision that inspires people to enact change.

Figure 6. The digital maturity matrix is adapted from [94]

3. DIGITAL TRANSFORMATION IN SHIPPING: A GLOBAL PERSPECTIVE

The logistics sector encompasses several services, including transportation, insurance, customs clearance, handling, storage, packaging, inventory management, and customer interactions. The Council of Supply Chain Management Professionals [95] defines logistics management as proactive, effective, and efficient planning, execution, and oversight of goods, labour, and information from origin to consumer. Transportation (shipping) is a crucial element in logistics, and the advancement of shipping infrastructure plays a significant role in the global economy.

Investment by relevant companies in minimising shipping expenses and enhancing efficiency has become significantly important, particularly at the national level [96]. Progress in information and communication technology, combined with advancements in transportation methods, has led to globalisation in the global economy. This led to an expansion of multinational corporations' stake in the global economy and the rise of the international commerce and logistics sector. The logistics sector has a favourable influence on the economy. The effectiveness of logistics businesses has enhanced the competitiveness of firms and national economies. Several studies examined the relationship between logistic expansion and economic growth [97, 98]. Key disruptive elements in the logistics business include evolving consumer expectations, technological advancements, new market entrants, and innovative methods of competition and collaboration. Individual and industrial clients anticipate expedited shipping, more flexibility, increased transparency, and reduced costs. Technology is transforming every facet of operations into logistics organisations [99, 100].

Digitalisation is vital for success; an integrated digital strategy inside the company plan is required. The majority of recent entries in the logistics sector are start-ups employing innovative technologies. Horizontal collaboration in last-mile delivery exemplifies the redefinition of collaboration. FedEx and DHL have collaborated with national postal services and local enterprises for several years. Labour is a fundamental component in logistics operations. Digitalisation enables companies to enhance service quality while simultaneously reducing costs [101, 102]. The most labour-intensive activities in the industry are progressing towards complete automation. Warehousing is already equipped with automated solutions; more advancements are being implemented [103]. This study will evaluate relevant research and identify the influence of the logistics industry as a service sector on economic development. The shipping business, a significant element of logistics, will be examined. The significance of digitisation and innovation in advancing logistics, namely within the shipping sector, was recognised. This analysis will focus on Group, a prominent global provider of innovative and comprehensive supply chain solutions. The inaugural specialised cellular container was shipped in

1968. In the 1970s, the containerization process proliferated rapidly due to the adoption of standardised container dimensions and the recognition among industry stakeholders of the benefits and cost efficiencies that containerization provided. Despite being a modest portion of the overall marine fleet (about 12 percent), container shipping is the most rapidly increasing industry and presently accounts for over half of global trade value, consistently extending to further commodities. Globalization has significantly amplified transcontinental trade via container transportation. In 2014, the international shipment of containers reached 182 million TEU (twenty-foot equivalent units). As China emerged as the global manufacturing hub, commerce escalated correspondingly. In 2015, the container-shipping business facilitated significant commerce, with China importing and exporting 52 million twenty-foot equivalent units (TEUs), a fourfold growth from the 13 million TEUs in 2000.

Digitization is emerging as a potent economic instrument and significant disruptor [104-106]. Advancements in information technology facilitated several technical advancements, leading to the designation of the 1990s as the age of information. The contemporary comprehension of digitalization has evolved beyond mere computer usage to the application of technology for managing commercial interactions in both business-to-business and business-to-consumer contexts. Companies formulate and implement a diverse array of innovation-driven strategies aimed at enhancing competitiveness and company success [107, 108]. Various forms of innovations can be introduced and executed based on the strategy to attain certain objectives [109]. Two categories of innovations may be identified: product innovations and technical process innovations [110]. Creating new goods will allow organizations to enhance and sustain their position in a current market or establish themselves in a nascent one. When organizations enhance procedures, they augment production and efficiency. Furthermore, they reduce manufacturing costs by enhancing flexibility, adaptability, and agility [111, 112]. Digital supply chain management solutions enhance coordination beyond within production organizations, facilitating the increasing need for output tailored to unique client specifications. Digitalization enhances data interchange and processing within vertical and horizontal networks. Enhanced collaboration with suppliers, consumers, and distributors will be realized through the implementation of digital technology [113- 115]. This tight engagement with partners may greatly enhance the efficacy of their resource, supply chain, and logistics management system. Digitalization and innovation influence society on several levels. In the production sector of the economy, digitization and innovation facilitate the automation of business processes, resulting in operational savings, including decreased transaction costs, which affect productivity [116]. Furthermore, digitization and innovation create novel commercial prospects, influencing employment and entrepreneurship. Digitalization and innovation positively influence the delivery of public services, enhancing the supply of healthcare and education. Digitalization influences human interactions by enhancing social inclusion and communication. Nonetheless, digitalization may also lead to adverse consequences, including workforce upheaval, corporate dissolution, cybercrime, and societal anomie. The shipping industry's digital transformation is profoundly altering global trade, and Oman is adopting these advances to strengthen its status as a vital maritime center. Oman, as a major entity in global shipping, is investing in sophisticated technologies such as automation, data analytics, and the Internet of Things (IoT) to optimize port operations, enhance logistics, and increase efficiency. The Sultanate's ports, notably the Port of Sohar and Port Sultan Qaboos, are incorporating advanced technology, including automated container handling systems and real-time shipment tracking.

Oman is prioritizing the digitalization of its supply chain to improve connection with international markets, optimize fleet management, and save expenses. This transition is enhancing Oman's operational competitiveness while preserving environmental sustainability. Furthermore, the implementation of blockchain technology is augmenting transparency in shipping transactions. As Oman advances in its Vision 2040, digital transformation is essential for enhancing its marine industry and securing its position in the changing global shipping arena.

4. CONCLUSION

The Shipping sector of Oman is essential for the country's economic advancement, facilitating vital connections for international trade, energy exports, and geopolitical leverage. As worldwide demand for shipping services increases, Oman is compelled to modernize and improve its marine infrastructure. The use of digital technology is essential for this change, facilitating enhancements in operational efficiency, cost savings, and sustainability. Technologies, including IoT, blockchain, AI, and automation, can transform operations by refining procedures, optimizing cargo management, improving transparency, and mitigating environmental impact. The digital transformation of Oman's marine industry faces hurdles. Addressing legal complexity, organizational opposition, and integrating technical improvements with strategic objectives are critical obstacles to effective adoption. The enhanced Technology-Organization- Environment (TOE) paradigm provides a comprehensive method for assessing these concerns. It underscores the necessity of synchronizing technology, organizational competencies, and the external environment to facilitate effective digital adoption. The shipping sector must evaluate both the technical dimensions of digital technology and the organizational preparedness, alongside larger environmental considerations, including market competitiveness, governmental regulations, and economic conditions.

The Sohar Port instance, characterized by strategic investments in augmenting container capacity and implementing smart port technology, exemplifies Oman's potential to bolster its competitiveness in the Gulf region. Oman, under its Vision 2040, aims to establish itself as a significant participant in global maritime trade, emphasizing economic diversification and environmental sustainability. The effective digital transformation of Oman's maritime sector is essential for its sustained growth, allowing the country to enhance its worldwide standing and fulfil its strategic objectives. In summary, Oman's marine industry is at a pivotal point, where the integration of digital technologies will profoundly impact its future competitiveness, sustainability, and geopolitical significance. Utilizing the TOE framework, Oman can effectively manage the intricacies of digital transformation, guaranteeing that its marine sector continues to be a fundamental element of its economic and strategic goals.

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