

Assessing the Impact of Automating the Operational Processes on Enhancing the Efficiency and the Competitiveness of Khalifa Port

Prepared By

Hazaa Aljneibi ⁽¹⁾, Hesham Helal ⁽²⁾, Mohamed Elkersh ⁽³⁾, Dragomir Cristina ⁽⁴⁾

⁽¹⁾ Chief Operating Officer, Khalifa Port

^(2,3) Arab Academy for Science, Technology and Maritime Transport, Egypt

⁽²⁾ AIN Journal Chief Editor

⁽⁴⁾ Assoc. Prof. PhD - Constanta Maritime University, AIN Journal Editorial board member

DOI NO. <https://doi.org/10.59660/52726>

Received 04/11/2025, Revised 16/12/2025, Acceptance 23/02/2026, Available online and Published 01/07/2026

المستخلص

تهدف هذه الدراسة إلى تقييم أثر أتمتة العمليات التشغيلية على تعزيز الكفاءة التشغيلية والقدرة التنافسية في ميناء خليفة، من خلال تبني منظور تحليلي متكامل يجمع بين الأبعاد الاستراتيجية والتشغيلية والتجارية والخدمية. اعتمدت الدراسة على منهج نوعي قائم على مقابلات متعمقة مع قيادات إدارية متعددة المستويات داخل الميناء، شملت الإدارة العليا، والتطوير الاستراتيجي، وإدارة المشاريع، وتطوير الأعمال، وخدمة العملاء، والشؤون التجارية، بهدف استكشاف تصوراتهم حول دور الأتمتة في تحسين الأداء المؤسسي. أظهرت النتائج وجود توافق عام على أن الأتمتة تسهم في زيادة إنتاجية العمليات، وتقليل زمن الدورة التشغيلية، وتحسين استغلال الموارد، وخفض التكاليف التشغيلية، إضافة إلى تعزيز موثوقية الخدمة وتجربة العملاء. كما أوضحت النتائج أن القيمة الاستراتيجية للأتمتة تتمثل في دعم اتخاذ القرار القائم على البيانات، وتعزيز مرونة الميناء في مواجهة الاضطرابات، وتقوية موقعه التنافسي في السوق العالمي. وفي المقابل، حددت الدراسة مجموعة من التحديات المرتبطة بتكامل الأنظمة، وإدارة التغيير، وتأهيل الكوادر البشرية، مؤكدةً أن نجاح الأتمتة لا يعتمد على التكنولوجيا فقط، بل على جاهزية البيئة التنظيمية كذلك. وتسهم الدراسة في سد فجوة في الأدبيات من خلال تقديم تحليل متعدد الأبعاد يربط بين تطبيقات الأتمتة ونتائجها المؤسسية، وتوفير إطار تفسيري يمكن أن يدعم الدراسات المستقبلية حول الموانئ الذكية والتنافسية المستدامة.

الكلمات المفتاحية: الأتمتة، العمليات التشغيلية، الكفاءة، التنافسية، ميناء خليفة.

Abstract:

This study sets out to examine the effects of automation of operational process streams on operational efficiency and competitiveness improvement at Khalifa Port using a strategy, operations, commerce and service integration analytical framework. The study uses a qualitative methodology to geopolitically capture the perceptions of Digital Transformation (DT) and automation of operational process streams to enhance institutional performance through the lens of the Port employees strategically positioned at the apex of the organization and at the levels of strategy, project management, business development, customer service and commerce. The study establishes a near consensus on DT and operational process automation as key to enhancing

operational efficiency, including, but not limited to, increased operational productivity, reduced operational cycle times, and improved resource productivity vis-a-vis unit operational cost reduction, increased service reliability and enhanced customer service experience. The study establishes automation's shift of the Port's operational strategy through the improvement of the Port's capabilities on data driven decision making, increased place/space resilience in the face of disruptive change, and in the improvement of the Port's competitiveness and operational efficiency on the global market. The study also identifies the challenges of system integration, change management, and the upskilling of the workforce, to underscore that the successful operationalization of automation is more than a technological solution within a system, but is also a function of the organization's posture. The research helps address a gap in the literature by providing a multifaceted analysis of the connections between the outcomes of automation applications and institutions, as well as offering explanatory principles that may direct future research on smart ports and sustainable competitiveness.

Keywords: Automation, Operational Processes, Efficiency, Competitiveness, Khalifa Port.

1. Introduction:

Khalifa Port, located between Abu Dhabi and Dubai, is one of the world's most technologically advanced ports. Its deep-water facilities allow the port to act as a major gateway for the world's shipping lines. It has fully automated container terminals and modern logistics, as a result, its infrastructure can support operational efficiency and competitiveness. This strengthens its role as a vital hub for maritime and trade activities while contributing significantly to the UAE's economic growth and global trade connectivity.

In a larger context, the international maritime industry is a crucial element of economic activity and trade, given the role of shipping lines and seaports in the global supply chain by providing the means for cross-border trade. In a given port, the efficiency of its spatial organization is especially critical, as it defines the velocity at which vessels are loaded and unloaded, as well as the various ways in which cargo is moved and stored around the port. Ports which are technically advanced can provide faster and more extensive service to vessels at more economical rates than the shippers and carriers. Conversely, ports which are technically inefficient are subject to more frequent congestion and higher operational costs which reduce their competitiveness in international trade (Elgazzar and Ismail, 2021).

Miller and Hyodo (2022), describe technical efficiency in container terminals as achieving a relationship between productivity and the optimal allocation of resources, such as maximized facility utilization, the optimal assignment of labor, minimal queuing, and heightened rates of flow control to maximize throughput.

Improving technical efficiency of ports enhances global supply chain systems as it positively impacts the logistics time and costs, which are critical for international trade. That is, a port is

efficient when it reduces the time required to process cargo, thereby streamlining the volume of trade. Furthermore, it boosts output and lowers the level of expenditure on resources, which translates to reduced costs for the consumer (Baştuğ, 2023).

The rapid development and expansion of container shipping means that the demand for improved technical efficiency within the ports will continue to grow. Such ports that implement modern practices and technologies will be able to better satisfy customer demands and sustain their competitive edge. Therefore, the need to focus on technical efficiency becomes a modern day challenge to accommodate the increasing demands within a highly competitive global trade environment (Caldas et al., 2024).

2. Statement of the problem:

Ports have always been important for the movement of traded goods between countries. Khalifa Port is one of these important ports, but the competition is always changing, requiring the port to improve operational effectiveness and productivity. Khalifa Port has solid infrastructure and a good location, but that does not guarantee a competitive edge, and new strategies will be needed for the port to achieve this. Therefore, this study primarily concerns the automation of Khalifa Port to improve operational efficiency and competitive positioning, as well as any obstacles that may be present.

3. Literature review:

The last several years have seen considerable growth in research literature focused on the port sector's operational process automation. While the initial focus was on the purely technical aspects of process automation, more recently, the literature has begun to view process automation from an integrated institutional change perspective of process automation whereby institutional change affects operational efficiency and competitiveness. Brunila et al. (2021) highlighted that, from the perspective of digital transformation, the primary challenges in the port sector are not technologically driven, but rather, stems from the lack of integration of systems and restricted data sharing and interoperability among the stakeholders in the port community, which limits the automation's value. This is consistent with the findings of Henríquez et al. (2022) who, in a case study of the Port of Barcelona, pointed out that the technologies of Industry 4.0, in the absence of a port business model and service framework and operational relationship restructuring, are of little value. The technologies, in that case, may only serve as standalone technical solutions. When it comes to the quantitative element, the effect of automation on operational efficiency, with the help of analytical models, has been examined in a variety of studies.

As an example, Yen et al. (2023) used a DEA-Tobit model to determine the impact of “smart port” features on the operational efficiency of the world’s leading ports. He found that digital analytics and automation, to a considerable extent, leads to operational efficiency and decreased processing times, but the extent of the effect is predominantly a function of the digital framework and operational process interlinkage (Rafaat & Elmsar, 2025). In the same vein, Tsagkaris & Moschovou (2025) posit that automation is not synonymous with improved operational

performance unless complemented with the evolution of the people and process skills. Analogously, Nguyen & Pham (2025) proved that there is a strong positive correlation with the level of digital transformation, operational efficiency, and market share, and in doing so, they extended the relationship of automation to port's operational competitive advantage. Studies at a more specific operational level have examined the scheduling and coordination of automated systems at container terminals, as these are among the most operational cycle time.

For instance, Hu et al. (2025) showed that 'smart' coordination of quay cranes and automated guided vehicles (AGVs) diminishes completion time and enhances productivity. This was furthered by Zhou et al. (2023) through integrated optimization models for the scheduling of yard cranes and automated vehicles, which was cost-efficient and flowing better in storage yard operations. Furthermore, Yang & Hsieh (2024) illustrated that automation, as a technological investment, worked best in a comprehensive operational framework encompassing planning, coordination, and performance management.

Other studies analyzed automation from the perspectives of enhanced customer experience and service reliability within the service and supply chains. From this standpoint, smart gates may be exemplary. They help lessen operational bottlenecks, enhance the flow of and access to data, and facilitate transparency, which, as noted, positively impacts customer satisfaction (Basulo-Ribeiro et al., 2024). Improving the reliability of equipment and decreasing the frequency of equipment breakdowns (Garmouch et al., 2025) positively impacts the operational and commercial competitiveness of a port by increasing its capacity and improving adherence to schedules, which is a commercial concern. Collectively, the studies point to the fact that the port industry is strategically redefining the operational, service, and financial value of automation.

Although there are more smart port technologies, there are still more gaps in research because there are hardly any applied, integrated studies that include operational automation and its total institutional ramifications on efficiency and competitiveness, especially in the Middle Eastern tech ports like Khalifa port. Most studies tend to look either one way, either the more or not the automation side. Not operational singular performances. Most studies have frameworks, but are not operational or strategic, and more commercially or service integrated. Also, there are no studies that are more qualitatively focused that look more holistically and more at the middle management continuum and automate perspectives of executive leadership and the challenges of automation more than the digital transformation in ports. Also, the more focused simply to more automation, the more focused simply to more automation, not the more focused simply to more automation, not the more focused simply to more automation.

Consequently, this study aims to address this gap by offering a multidimensional perspective, grounded in detailed interviews, that connects automation applications with respective functional and strategic outcomes, thus enhancing the understanding of the positive impact of automation on operational efficiency and competitiveness in smart ports.

The originality of this study lays in developing an integrated analytical framework establishing the relationship between operational automation in ports and the multidimensional institutional impact of automation on operational and competitive efficiency from strategic, operational, commercial, and service perspectives. This functional variety provided a better balance of perspectives and organizational levels of how and what automation is evaluated, helping to fill the literature void, which is predominantly descriptive with a focus on technical or discrete operational parameters. The study also scientifically interprets using a qualitative framework the impact of organizational changes caused by the digital transformation of ports and the intersection of automation with the contemporary digital transformation of ports and the intersection of automation with contemporary sustainable competitive advantage, supply chain resilience, customer experience, and financial sustainability. This also contributes to the development of more pragmatic theoretical frameworks to assess the impact of automation in smart port settings.

4. Research importance:

- Scientific Importance:

The title's articulation of the construction of operational processes through the automation of activities in seaports and its relationship with operational efficiency and competitiveness is of utmost importance scientifically, as this is still in need of more substantive applied research, especially concerning the high-tech ports in the Middle East. In this regard, research on Khalifa Port is a unique and distinct empirical case that has the potential to enrich the domain of port management, supply chain management, and smart logistics by integrating the construction of technology with 'real' performance, as opposed to performative technology. Furthermore, the use of interviews as the main qualitative data collection tool, in addition to the quantitative data that will be derived from the surveys, will provide important organizational, human, and operational frameworks to address the influence of automation in the operational processes from the perspectives of the managers and the operators. This will enhance the explanatory power of the framework while informing the research and performance metrics in smart ports.

- Practical Importance:

The practical significance of this study is that it can assist port authorities and decision makers calculate their actual return on investment with respect to operational automation—what is actionable and, in this case, manageable. The study can assist in decision making relating to the expansion and/or the upgrading of automation systems within the port by providing evidence to justify such systems and/or their upgraded versions when operational automation is first assessed in relation to its impact on container handling speed, reduction of waiting time, productivity of equipment, operational cost, and overall efficiency. The study also offers insights and how future phases of implementation can be improved by relating challenges such as the need for training, change resistance, and difficulties of system integration to the challenges of automation upstream of such practices, thereby addressing the challenges of automation. As a result, the study is able to formulate operational strategies that enhance the competitive advantage of the port within the

global marketplace and facilitate a sustainable and reliable improvement of performance in a highly competitive environment in the transport sector of the maritime industry.

5. Research methodology:

This research seeks to identify the implications of automating operational activities for improvements in efficiency and competitiveness in the study of relevant ports. Furthermore, to examine container terminals in the study and draw a conclusion regarding the efficiencies and operational inefficiencies at port(s) under study, and to provide recommendations to eliminate said inefficiencies and improve the relevant competitive efficiencies of the ports in question. Thus, this study adheres to a deductive “quantitative” framework. A single interview with each of the relevant constituents, port operator, manager, and tech provider, have been conducted. The interview serves the purpose of obtaining relevant information regarding the extent of operational automation at present, the extent to which operational automation serves to increase efficiency and competitiveness of the relevant ports, and the obstacles to automation, if any. The information collected will be vital to the development of recommendations for automation of operational processes of ports and for enhancing the competitive efficiencies of the ports in relation to the global competitive landscape.

Seven questions were generated by the researcher to identify the impact of automation at Khalifa Port. Furthermore, like other ports, to examine and provide a description of the impact of automation on the efficiency and competitiveness of Khalifa Port. The questions are as follows:

Table 1. proposed questions

| N. | Questions |
|----|---|
| 1 | What are the key automation technologies implemented at Khalifa Port, and how have they improved operational efficiency? |
| 2 | What factors hinder achieving maximum operational efficiency through automation at Khalifa Port, and how does this impact its competitiveness? |
| 3 | How has automation contributed to reducing operational costs and increasing profitability at Khalifa Port without compromising service quality? |
| 4 | To what extent has automation accelerated cargo handling and reduced vessel turnaround time, enhancing operational efficiency? |
| 5 | How has automation impacted Khalifa Port’s competitiveness compared to leading regional and global ports? |
| 6 | What role does automation play in improving the efficiency of supply chain operations and logistics services at Khalifa Port? |
| 7 | How has automation enhanced the quality of services at Khalifa Port, and how does this affect its ability to attract global customers? |

6. Empirical analysis:

Individual interviews were carried out with a specific group of senior and middle managers at Khalifa Port, with consideration given to even distribution across different levels and administrative specialties pertaining to the study. The sample comprised middle managers and senior managers from top management, strategic planning, strategic project management, business development, commercial services, and customer services. This broad sample made it possible to address the multidimensional effects of automation from an operational, strategic, commercial, and service perspective.

The interviewees were chosen based on their hands-on experience, direct decision-making involvement, and supervision of operational or strategic roles at the Port. This functional diversity among interviewees adds depth to the findings and enhances the trustworthiness of the qualitative analysis, given the variety of viewpoints brought about by divergent organizational divisions and individual responsibilities. This diversity also increases the study's scope and adaptability to assess automation's effects on the operational competitiveness of the Port. The participants included the following:

i. General Manager – Khalifa Port:

The General Manager considers automation a big opportunity to enhance the port's performance in terms of operational efficiency and financial sustainability. From this viewpoint, automation can enhance the efficiency of the use of the means of production, decrease operational failure zones, and provide uninterrupted services of the same quality. Overall, top management focuses on integrated operational and financial results that enhance the port's sustainable competitive advantage.

ii. Vice President – Strategy Development:

The Vice President of Strategy Development looks at automation from a competitive advantage perspective, defining it as a sustainable choice for the port over time. This perspective emphasizes building competitive advantage for the port by integrating automation solutions with the port's envisioned future and subsequently improving the port's structural capability to respond to global supply chain changes. The perspective importantly notes that the value of automation, in this instance, is only as part of an overarching digital transformation strategy.

iii. Director – Strategic Projects:

The Director of Strategic Projects primarily focuses on evaluating automation from a transformation perspective coupled with change management. This Executive Position is responsible for transforming automation opportunities into actionable initiatives, while also considering system integration complexities, maintaining uninterrupted operations throughout the integration, and attaining the target operational values. In this regard, operational cycle time and reduction of operational held the highest indicator of success.

iv. Director – Business Development:

The Director of Business Development associate's automation with market valuation and customer proposition. In this regard, automation is perceived as a positive facilitating factor for operational speed and accuracy; competitive service, and enhanced soft and hard linkages with line, international, and cross-border customers.

v. Senior Manager – Customer Service:

The Senior Manager of Customer Service considers automation from the customer experience and service quality perspective. In this role, automation is perceived as the enhancement of transparency, accuracy of information, speed of response, and reduction of operational complaints. Automation builds customer confidence and satisfaction and enhances the reputation of the port as a service.

6. Vice President – Commercial:

The Vice President of Commercial Affairs believes that improving profitability and strengthening the port's commercial competitiveness can be achieved through the automation of port processes. This perspective focuses on the positive aspects of automation in minimizing operational expenses, maximizing operational capacity, and enhancing profit margins that can subsequently lead the port to adopt more flexible pricing structures and enter long-term contracts. Within this context, the value of automation lies in the measurement of commercially sustainable performance.

Since operational efficiency is greatly improved by automation technologies, Khalifa Port's General Manager, refers to systems, terminals, and operational automation, including cranes, smart gating, and real-time container tracking. These technologies have improved productivity on the berth, reduced the need for manual operations, improved accurate planning for operational execution, optimally utilized resources, and reduced operational waste. However, while he appreciates the improvements, he identified the maximization of automation's benefits as a challenge. These challenges include the substantial amount of capital investment needed for the automation, the difficulty of creating and integrating systems digitally with external supply chain partners, the need for organizational change management along with the upskilling of the employees, and how this all leads to a reduction in a potential operational gain and the competitive advantage of a port that is advanced in its digital use. Khalifa Port is now operating from a digitally advanced and cost-efficient frame, and the reduction of operational costs because of the reduction in the need for manual labor, the increase in operational errors, and the utilization of equipment and operational assets, has positively impacted the financial profitability and improved the operational stability and the overall performance of the port, enabling the port to sustain its financial position in the long term.

The Port's use of automation tools has improved the scheduling of berths, increased the productivity of cranes, and reduced the turnaround time of vessels. This has solidified schedule reliability for shipping lines and has decreased the amount of time vessels wait at the Port. As a result, the Port has also gained more recognition on a regional and global level for the use of

advanced technological automation systems. The use of automation has contributed positively to the Port's supply chain activities and to the enhanced coordination of cross-docking with the logistics processes. Furthermore, operational supply chain barriers have been eliminated, which has improved the flow of information among the relevant stakeholders, and has decreased the overall time spent on logistical activities. Increased visibility, accurate and speedy data processing, and quick responsiveness have improved the quality of service and elevated the level of trust among the customers, which has resulted in the Port attracting more shipping lines and international business customers.

The Vice President of Strategy Development stated that Khalifa Port has begun viewing automation as the first step in moving towards a data driven smart port model. Technologies that support advanced analytics have aided in operational planning and have prompted more proactive decision making. However, he stated that operational automation's full strategic impact is limited by several factors, the most important of which is the strategic misalignment of certain automation solutions with the port's most valued future state, as well as challenges with integrating certain supply chain partners. Such gaps may reduce the strategic value of automation and undermine the port's sustainable competitive advantage. From an operational and financial perspective, automation has benefitted the port by digitally reengineering processes and exploiting economies of scale, all while improving service quality through enhanced operational control and compliance with service quality performance standards. Automation also improved inter-stage operational coordination, which in turn improved the integration of mid and end stage operational planning with real time operational actions, thus improving maritime operational flow and reducing the time vessels wait to be serviced. On a competitive level, automation has improved Khalifa Port's competitive advantage by improving reliability and performance predictability which has improved the Port's competitive advantage over rival Ports.

The port's enhanced integration into global supply chains has further improved resilience and efficiency of logistics services by reducing the response time to disruptions. Finally, due to port automation, service quality improvements have increased the port's competitiveness to global firms that value a sophisticated and digitally seamless operational ecosystem.

Operational streamlining and reduced manual intervention, along with enhanced operational productivity, have been achieved through automation of Khalifa Port, as stated by the Director of Strategic Projects. Automation at Khalifa Port, however, has been complicated owing to challenges pertaining to the management of change, the merging of outdated and new technological systems, the breadth and depth of training needed, and the impact of such challenges on the operational returns. In addition to such challenges, automation has also aided in the financial aspect of Khalifa Port by reducing costs through operational, maintenance, and billing efficiencies achieved in the financial management of services rendered. In addition to these benefits, automation has also reduced the duration of operational cycles and the efficiency of process flow, thereby reducing the turnaround time for vessels and enhancing the speed of cargo

operations. Automation at Khalifa Port has also increased the operational and competitive capability of the Port by improving the integration of operational systems of the supply chain. In addition, the projects have improved reliability and reduced the margin of operational errors, which has positively impacted on the confidence of customers in the services of the Port.

The Director of Business Development stated that from a business development perspective, automation at Khalifa Port has improved the value proposition to customers by enhancing the speed and accuracy of operational processes. However, he pointed out that one of the primary constraints is the varying degrees of digital readiness of supply chain partners, which may limit fully leveraging automation at the more encompassing supply chain level. With the automation, the Port can offer more competitive prices because of reductions in operational costs while service levels remain unchanged and, in some cases, improved. The Port is more attractive to customers and shipping lines because of the improved service, which includes quicker cargo releases and less time waiting for vessels to be turned. The port is also regionally more competitive than it was due to the ability to provide consistent and timely service. It has also met the Integrated Logistics Service needs of customers internationally, which has improved service quality and provided additional competitive advantage. Ultimately, improved service quality due to automation has enhanced the attraction of the Port to new customers and to foster existing customers for long-term business relationships.

The Senior Manager of Customer Service said that the automation within Khalifa Port is helping customers since customers can track shipments in real time and receive digital updates, meaning they do not have to communicate with customers manually. However, a major challenge is the consistency and accuracy of the data, as any gaps in the data can negatively impact on the customer's trust. Despite this, automation is helping employee costs and service quality, as less complaints and quicker resolutions to issues have reduced customer service costs. It has also resulted in customers being served in a timelier manner and improved adherence to service level agreements. From the customer's view, the improved service has helped the perception of the port as an automation service. The enhanced service level has also helped supply chain coordination and logistics planning, leading customers to view the port more favorably. The port has also improved its position as a logistics center.

The Vice President of Commercial Affairs remarked that Khalifa Port's automation has encouraged commercial progress by providing greater operational efficiency and increasing the port's capacity for cargo processing. Significant challenge remains, however, in justifying long-term ROI for automation initiatives, given the pace of technological change. The operational cost savings from automation have positively impacted on the profit margin, all while maintaining high levels of service. Enhancing the port's allure commercially was speedier cargo processing and less time vessels had to wait. Additionally, Khalifa Port's competitive landscape in the global and regional port was bolstered by improved customer automation. Commercially, the Port's automated solution and position with the global supply changed was further enhanced. Finally, the

quality of digital services has attracted international clients and solidified commercial relations for the long haul.

7. Conclusion:

The findings from the interviews suggest that the role of automation in improving Khalifa Port's operational efficiency is universally accepted by all participants, although the agreement was expressed through different lines of analysis shaped by the participants' positions and roles in the organization. From a senior management standpoint, automation was viewed as a structural component of the institution's overall performance, relating it to better asset productivity, enhanced financial viability, and operational risk minimization, indicative of a management layer who views automation from a predominate institutional competitiveness prism. The strategic echelon, however, articulated an even more expansive time horizon, viewing automation as a strategic investment to engender a sustainable competitive advantage, in contrast to the integrated digital transformation, framed within Port authority organizational agility and the adaptive responsiveness to the global supply chain, consistent with prevailing literature on strategic port management. From the other end of the spectrum, in the executive tier, particularly represented by strategic project management, participants alluded to the conceptual and practical operational impediments of systems integration, and the operational management of continuity, which is indicative of a possible gap in design versus operational execution, and more critically a gap in the alignment of the intended strategic vision and the operational and practical capacity to realize the automation.

Automation, from a Business Development perspective within a market-oriented framework, was viewed in the context of value generation, which, by virtue of its capability to facilitate swift and dependable service provision, enhances the port's commercial viability and fosters business growth and enduring commercial relationships. As with Customer Perspective, the success of automation should not only be measured by the operational performance, but by the impact on the service dimension, such as quality, transparency, accuracy of information, speed of response, and other issues, which are critical to customer trust and competitive position from the end-user's perspective. Certainly, from the commercial perspective, automation, in the case of ports, was directly related to profitability and return on investment, as it lowered the costs of operations, and increased the capacity of the ports, which combined with service quality, offered the flexibility to the pricing and more competitive operational structures. All the above viewpoints indicate that, when considering the phenomenon of automation in the ports, it should be treated as a complex, multidimensional phenomenon that transcends the boundaries of purely technological solutions to address the strategic, operational, commercial, and service aspects of the phenomenon simultaneously. The diversity of viewpoints, in the author's opinion, is a manifestation of functional complementarity, as opposed to contradiction, in that each perspective adds to a more complete picture of the role that automation plays in enhancing operational efficiency and, more importantly, the competitive position of the ports.

The following recommendations have been constructed in line with the interviews conducted with the leaders in each function at Khalifa Port. These recommendations seek to optimize the impact of automation on operational efficiency and competitiveness.

- **Strategic Recommendations:** In terms of digital strategy, there will be a need to align all automation projects with a comprehensive integrated long-term digital strategy. This is to make sure that automation projects do not become siloed and instead, each project aligns with a pathway providing a roadmap to the development of a data-driven smart port. Another suggestion offered is the establishment of a digital governance framework to align automation stewardship with the strategic objectives of competitiveness, sustainability, and operational resilience.
- **Operational Recommendations:** System integration and digital platform unification should be enhanced to streamline and minimize redundancy in the digital architecture. Increased seamless data flow will be facilitated. In order to reduce unplanned outages and improve the utilization of copes, increased investment in smart maintenance and predictive analytics will reduce operational cycles and increase productivity on the berths and with the equipment.
- **Managerial and Implementation Recommendations:** Across interviews, a recurring theme is the challenge of managing change when it comes to automation. Thus, institutional approaches to workforce training and building a digital culture at the port are necessary. Also, applying adaptive project management practices will likely promote the seamless merging of legacy and modern systems while maintaining operational flow.
- **Commercial and Market-Oriented Recommendations:** Automation should be viewed as a competitive advantage to positively market the port in terms of reliability and turnaround times. It is also suggested that the port operator implement approaches that optimize pricing as operational efficiency improves. Additionally, enhanced digital connectivity with shipping lines and logistics partners is likely to support the provision of composite, intelligent, and prompt services.
- **Supply Chain-Related Recommendations:** Enhanced digital interconnection with external supply chain partners through shared data systems and standardized data exchange protocols will help eliminate blind spots in cargo movement and visibility. It also improves the port's adaptive capacity and responsiveness to international shocks.
- **Customer Service Recommendations:** We recommend the continued advancement of real-time tracking systems, digital gateways, and customer dashboards to improve transparency and responsiveness. Also, customer satisfaction metrics should reflect the outcomes of automation performance indicators to align technological advancements with improvements in user experience.

- Financial Recommendations: Stronger frameworks should be in place to assess the ROI of automation, including a regular cost versus operational and commercial benefit assessment. Furthermore, to sustain a competitive advantage, it is necessary to reinvest the savings generated into more sophisticated automation systems.

In the future, researchers must develop both the quantitative and qualitative dimensions of the understanding of automation's impact on port performance—especially operational efficiency, financial returns, and supply chain resilience. Important dimensions include developing frameworks for assessing the financial performance of automation, understanding how digital technologies impact responsiveness to global disruptions, and understanding the automation impacts on employability skills and the adaptive capacity of organizations. Additional research is also needed on smart ports and their integration with extended logistics networks, the use of artificial intelligence and predictive analytics for operational decision-making, and automated ports across the globe to develop comparative analyses and best practice frameworks. Also, research on customer experience, digital governance, environmental sustainability, governance, and the cyber resilience of ports will contribute to informing an understanding of automation as the main driver of strategic, operational, and sustainable transformation in modern ports like Khalifa Port.

Reference:

- Baştuğ, S., 2023. Port efficiency evaluation of Turkish container ports based on DEA-SCOR model: An effective sea gateway in Türkiye for one belt and one road initiative. *Marine Science and Technology Bulletin*, 12(1), pp.27-38. <https://doi.org/10.1016/j.ajsl.2016.01.006>
- Basulo-Ribeiro, J., Pimentel, C., & Teixeira, L. (2024). *Digital transformation in maritime ports: Defining smart gates through process improvement in a Portuguese container terminal*. **Future Internet**, 16(10), 350. <https://doi.org/10.3390/fi16100350>
- Brunila, O.-P., Kunnaala-Hyrkki, V., & Inkinen, T. (2021). *Hindrances in port digitalization? Identifying problems in adoption and implementation*. **European Transport Research Review**, 13, Article 62. <https://doi.org/10.1186/s12544-021-00523-0>
- Caldas, P., Pedro, M.I. and Marques, R.C., 2024. An Assessment of Container Seaport Efficiency Determinants. *Sustainability*, 16(11), p.4427. <https://doi.org/10.3390/su16114427>
- Elgazzar, S. and Ismail, A., 2021. Enhancing Egyptian container terminals performance through managing efficiency and competitiveness. *Marine Economics and Management*, 4(1), pp.59-75. <https://doi.org/10.1108/MAEM-12-2020-0006>
- Gattuso, D., & Pellicanò, D. S. (2023). *Perspectives for ports development, based on automated container handling technologies*. **Transportation Research Procedia**, 69, 360–367. <https://doi.org/10.1016/j.trpro.2023.02.183>

- Henríquez, R., Wiegmans, B., Jaimurzina, A., & van der Lugt, L. (2022). *Technological drivers of seaports' business model innovation: An exploratory case study on the port of Barcelona*. **Research in Transportation Business & Management**. <https://doi.org/10.1016/j.rtbm.2022.100803>
- Kim, B., Kim, G. S., & Kang, M. H. (2022). *Study on comparing the performance of fully automated container terminals during the COVID-19 pandemic*. **Sustainability**, **14**(15), 9415. <https://doi.org/10.3390/su14159415>
- Knatz, G., Notteboom, T., & Pallis, A. A. (2022). *Container terminal automation: Revealing distinctive terminal characteristics and operating parameters*. **Maritime Economics & Logistics**, **24**(3), 537–565. <https://doi.org/10.1057/s41278-022-00240-y>
- Nguyen, P. N., & Pham, T. Y. (2025). *Assessing the impact of digital transformation on port efficiency and market positioning in Southeast Asia container port system*. (Elsevier journal page/DOI) <https://doi.org/10.1016/j.ajsl.2025.11.002>
- Rafaat, A., & Elmsar, I. (2025). *Assessing the Impact of Implementing Green Sustainability Practices in Ports on Environmental and Economic Performance*. *AIN Journal*, *49*(1). DOI NO. <https://doi.org/10.59660/49104>
- Tsagkaris, P. (2025). *The impact of automation on the efficiency of port container terminals*. (**MDPI Journal: Ports**), **5**(4), 155. (DOI as listed on the article page).
- Yen, B. T. H., Huang, M.-J., Lai, H.-J., Cho, H.-H., & Huang, Y.-L. (2023). *How smart port design influences port efficiency – A DEA-Tobit approach*. **Research in Transportation Business & Management**, **46**, 100862. <https://doi.org/10.1016/j.rtbm.2022.100862>
- Zhou, S., Wang, J., & (as listed in article). (2023). *Joint scheduling optimization model for yard cranes and AGVs considering running routes*. **Marine Development**. <https://doi.org/10.1007/s44312-023-00012-z>