



# Social Sciences Spectrum

A Double-Blind, Peer-Reviewed, HEC recognized [Y-category](#) Research Journal

E-ISSN: [3006-0427](#) P-ISSN: [3006-0419](#)

Volume 05, Issue 02, 2026

Web link: <https://sss.org.pk/index.php/sss>



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## Smart Port Concept: A Case Study of Karachi Port Trust (Kpt) as a Smart Port: Lessons from Tuas Port (Singapore), Shanghai Port (China), and Salalah Port (OMAN)

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### Article Information [YY-MM-DD]

|          |            |         |            |          |            |
|----------|------------|---------|------------|----------|------------|
| Received | 2026-04-17 | Revised | 2026-06-09 | Accepted | 2026-06-27 |
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### Citation (APA):

Khan, A. M., Saud., A & Ali, M, Z (2026). Smart port concept: A case study of Karachi Port Trust (Kpt) as a Smart Port: Lessons from Tuas Port (Singapore), Shanghai Port (China), and Salalah Port (Oman). *Social Sciences Spectrum*, 5(2), 394-413. <https://doi.org/10.71085/sss.05.02.556>

### Abstract

Smart ports improve efficiency and sustainability across maritime frameworks through enhanced automation and data-driven governance. Industry 4.0 focuses on Internet of Things (IoT), artificial intelligence (AI), robotics, blockchain, and advanced analytics, and integrates itself within smart ports to increase operational awareness, perform predictive analysis, and maintain a steady ethical approach to environmental matters. This research analyzes and dissects a comparative case study to examine how the Karachi port Trust (KPT) can be transformed into smart port model by inspiring from world exemplary models like Tuas Port (Singapore), Shanghai Port (People's Republic of China), and Salalah Port (Oman). The paper uses comparative analysis to highlight the key technological, institutional and governance gaps that constrain KPT's operational efficiency and competitiveness on a global stage. It points to the congestion, longer container dwell times, legacy infrastructure and other coordination issues. The study offers context-specific and practical recommendations for KPT based on international experience and the latest available data (2024–2025), such as the phase-by-phase implementation of digital transformation, strengthening port community systems, using AI tools for monitoring, and improvements for port sustainability. The findings indicate that implementation of smart-port framework can significantly boost the efficiency, environmental sustainability, and participation of KPT in global maritime supply chains, which can strengthen the position of Pakistan in the regional and international trade.

**Keywords:** Smart Ports, Karachi Port Trust (KPT), Port Digitalization, Industry 4.0, Port Automation, Sustainable Maritime Infrastructure, Comparative Case Study, Global Port Performance.

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## Introduction

Smart ports represent the next generation of maritime gateways, where traditional port operations are augmented by digitalization, automation, and data-driven systems.<sup>4</sup> Unlike conventional ports, smart ports integrate Industry 4.0 technologies, such as internet of things (IoT) sensors<sup>5</sup>, robotics, artificial intelligence (AI) analytics, and blockchain networks, to optimize logistics, enhance situational awareness, and minimize environmental impact.<sup>6</sup>

Implying thereby that smart ports deploy IoT-enabled monitoring (weather, traffic, security) to foresee disruptions, and use automation and robots (e.g. AI-controlled cranes) to maintain around-the-clock terminal operations.<sup>7</sup> Blockchain is often used to secure transaction data among shippers, customs, and terminals.<sup>8</sup> Predictive analytics through the use of AI optimize berth scheduling and maintenance by analyzing big data streams.<sup>9</sup>

According to industry experts, a smart port “capitalizes on technology to improve performance in the three pillars of sustainability” (economic, social, environmental).<sup>10</sup> Key features of smart ports include real-time data exchange through IoT and sensors, autonomous cargo handling (automated cranes, guided vehicles), AI-driven predictive analytics<sup>11</sup>, and end-to-end digital platforms (such as Port Community Systems) that coordinate stakeholders.<sup>12</sup> They also emphasize green operations: adopting renewable energy (solar arrays, wind turbines), shore-to-ship power to cut vessel emissions, and energy-recovery systems in equipment.<sup>13</sup>

In sum, a smart port’s digital infrastructure allows cargo to move with greater speed, transparency, and resource efficiency, ensuring that port throughput grows sustainably alongside global trade demands.<sup>14</sup> These innovations align with global trends: for instance, leading ports in Asia and Europe have invested heavily in smart-port upgrades, achieving substantial efficiency and carbon reductions.<sup>15</sup>

This paper (Comparative Case Study) investigates how Karachi Port Trust can follow these international models to become a smart port. An endeavor has been made to first outline KPT’s history and current status & then present detailed case studies of Tuas Port (Singapore), Shanghai Port (China), and Salalah Port (Oman) to extract the specific smart technologies they employ. After identifying the common smart-port attributes across these cases, a comparative analysis has been undertaken between KPT and the recognized smart ports as mentioned above and identification of the challenges limiting KPT’s efficiency.

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<sup>4</sup> “Sustainable Smart Ports to Create Prosperity for All in Times of Disruption and Uncertainty | UN Trade and Development (UNCTAD).”

<sup>5</sup> Giraldo et al., “Utilidad de las tecnologías de la industria 4.0 en los smart ports.”

<sup>6</sup> *The Global Smart-Port Revolution.*

<sup>7</sup> *The Global Smart-Port Revolution.*

<sup>8</sup> *The Global Smart-Port Revolution.*

<sup>9</sup> Сментина, “Digital Technologies in Ensuring the Efficiency of Maritime Transportation.”

<sup>10</sup> “Sustainable Smart Ports to Create Prosperity for All in Times of Disruption and Uncertainty | UN Trade and Development (UNCTAD).”

<sup>11</sup> Paraskevas et al., “Smart Ports in Industry 4.0.”

<sup>12</sup> Molina, “La revolución digital del mar.”

<sup>13</sup> “sipgEn.”

<sup>14</sup> Kuo et al., “Smart Ports.”

<sup>15</sup> Xinhua, “Shanghai Port Sees Annual Container Throughput Exceed 50 Million TEUs.”

Finally, doable and practical recommendations have been suggested for adoption by KPT. Throughout, the analysis incorporates the latest data (2024–2025) and authoritative sources from governmental and port authority publications.

### **Theoretical Framework**

The research utilizes a layered theoretical framework in smart-port transformation, combining foundational theories of International Relations with the governance and technology adoption aspects of different economic sectors. At the macro level, Liberalism gives the root basis for smart ports act as tools of efficiency and cooperation within the context of interdependence in global maritime trade. As a part of liberal institutional environments, smart ports are responses to globalization and the interdependence that trade creates.

In addition to the liberalism dimension, Constructivism focuses on the importance of norms, identity, and reputation in shaping port development and planning. Responsible governance and institutional modernity are what smart ports embody. For developing maritime states, the use of smart ports is the internalization of a global norm and modern model, which can improve a state's reputation and credibility on the international stage.

Integrating overarching theories and sectorial analysis, Institutional framework illustrates how formal rules, regulatory capacity, and organizational standards shape technology adoption. Strong institutions promoting innovation encompass certainty in regulations, incentives, and coordination, elements present in leading smart ports. At the applied level, the Port Governance framework is utilized to understand how governance structures, coordination of stakeholders, and the autonomy of decision-making affect the efficiency of ports. Smart ports are the result of networked governance, sustained by digital governance, and are a departure from the traditional models of governance. Lastly, the adoption and implementation of intelligent technologies are explained by Socio-Technical Systems and Innovation Diffusion models. These models emphasize that successful digital transformation and smart technologies necessitate the integration of tech, workforce, and culture capital in conjunction with the readiness of the institutions.

The frameworks, in this instance, capture the development of smart ports as the result of international norms and collaborations that influence domestic governance capabilities, and that, in turn, shape the scope of technology and the resulting performance.

### **Research Methodology**

The comparative qualitative case study methodology directly implements this theoretical framework. The principles/theories of liberalism and constructivism justify the selection of internationally recognized smart ports, specifically Tuas, Shanghai, and Salalah, as normative and institutional benchmarks. The analysis of regulatory frameworks, governance structures, and stakeholder coordination across these cases is guided by institutional and port governance frameworks. Additionally, socio-technical and innovation diffusion informs the exploration of technology adoption processes, operational practices, and the challenges of implementation.

Data collection is conducted through document analysis and semi-structures interviews, which help identify institutional norms, governance constraints, and the alignment between technology and organization. Furthermore, cross-case comparisons facilitate a theory-informed evaluation of the uneven progress of smart-port transformation across different port contexts.

## Karachi Port Trust: Historical Overview

The Karachi Port Trust (KPT) is Pakistan's oldest and largest port authority. The Port of Karachi has colonial-era origins: between 1880 and 1887, it was managed by the Karachi Harbour Board. The Karachi Port Trust itself was legally established by an Act of British India in 1886, becoming effective from 1 April 1887.<sup>16</sup> Since then, KPT, a federal government agency under Pakistan's Ministry of Maritime Affairs, has overseen Karachi's deep-water port. The port's strategic location enhances its role in global trade networks, linking South Asia with international markets.<sup>17</sup> However, recently Ministry of Maritime Affairs in meeting with a delegation from US, mentioned that KPT handles 54% of Pakistan trade with annual capacity of 125 million tons.<sup>18</sup> It operates multiple quays and berths on both the West and East wharves of Karachi harbor. With over 4,700 operational employees and 315 officers<sup>19</sup>, KPT is responsible for cargo and passenger terminals, marine services, and coastal conservation. The historic KPT Building on Karachi's waterfront remains its headquarters.

Over the decades, KPT has expanded capacity and modernized facilities. Container handling was introduced in the 1970s, and by the 1990s Karachi emerged as a major container hub in South Asia. Today KPT's terminals handle millions of tons of cargo annually: in FY2024–25, KPT reported 54 million tons of total cargo and a record 2.65 million TEUs of container throughput.<sup>20</sup> These numbers reflect recent growth: container handling has surged on the back of trade policy incentives and infrastructure upgrades.<sup>21</sup> Nevertheless, capacity remains moderate relative to global hubs (e.g. Port of Singapore ~41M TEU in 2024,<sup>22</sup> Shanghai ~50M TEU<sup>23</sup>). KPT has also granted several terminal concessions in recent years (e.g. Karachi Gateway Terminal) to bring in private investment and deepening of berths. For instance, a joint venture known as Karachi Gateway Terminal Limited (KGTL), between KPT and UAE's AD Ports, is tasked with dredging the East Wharf to 15.5 meters and upgrading berths 6–10.

Historically, KPT's development has faced challenges which include periodic dredging problems, traffic congestion around Keamari, and governance constraints. In 2024–25, the government established a maritime Task Force and launched a National Maritime Policy focusing on modernizing ports and shipping. The Deputy Prime Minister and maritime minister have repeatedly urged “*modernizing port infrastructure*” and cutting container dwell times.<sup>24</sup> A high-level committee was formed in mid-2025 to slash KPT's average container dwell time (currently around one week) down to 2 days,<sup>25</sup> deploying AI monitoring and better inter-agency coordination. As of today, according to the Global Container Port Performance Index 2024, Karachi port is ranked 61<sup>st</sup> across the world. While on regional basis; West, Central, and South Asia (Saudi Arabia to Bangladesh), KPT is ranked 56<sup>th</sup>.<sup>26</sup> This historical context; KPT's foundation, growth, and recent reforms, sets the stage for examining how it can transform into a smart port.

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<sup>16</sup> “Karachi Port Trust | The Gateway To Pakistan.”

<sup>17</sup> Kalim and Syed, “Maritime Economy and Gwadar Port”; Ludden, “A Spatial History of Seaports in South Asia.”

<sup>18</sup> Reporter, “US, Kazakhstan Eye Investment in Pakistan's Ports.”

<sup>19</sup> “About.”

<sup>20</sup> Breccorder, “KPT Handles All-Time High Cargo in FY25.”

<sup>21</sup> Breccorder, “KPT Handles All-Time High Cargo in FY25.”

<sup>22</sup> Ghoshal, “Largest Automated Port Will Handle 65 Million Containers per Year.”

<sup>23</sup> Xinhua, “Shanghai Port Sees Annual Container Throughput Exceed 50 Million TEUs.”

<sup>24</sup> Deputy PM Calls for Modernizing Port Infrastructure to Boost Pakistan Trade Competitiveness | Arab News.

<sup>25</sup> Ali, “Govt Forms Body to Slash Container Dwell Time,” 05:56:25+05:00.

<sup>26</sup> “CPPI Report 2024.”

## International Case Studies of Smart Ports

### 1. Tuas Port

Tuas Port is located at the western tip of Singapore which aims to handle all container operations currently look after by other ports like Tanjong Pagar, Keppel, Brani, and Pasir Panjang terminals. It is also referred as Tuas Mega Port.<sup>27</sup> The Port is being delivered in four phases. The first phase (Tuas Port 1) began in 2015 and was completed in late 2021. Tuas Mega Port officially opened on 1 September 2022, and the ultimate capacity is projected at 65 million TEUs by the 2040s.<sup>28</sup> It is ranked 17<sup>th</sup> in the CPPI report 2024.<sup>29</sup>

Singapore's new Tuas Mega Port is a flagship example of a fully automated, high-tech smart port. As part of its Port of the Future strategy, the Maritime and Port Authority of Singapore (MPA) and operator (PSA) have designed Tuas Port to handle future mega-ships and large cargo volumes in a smarter and greener manner.<sup>30</sup>

#### Key smart features in Tuas Port include:

- **Full Automation of Terminal Handling:** Tuas employs electrified automated yard cranes and Automated Guided Vehicles (AGVs) to move containers without human drivers.<sup>31</sup> Quay cranes and stacking cranes are controlled by AI systems, and containers are transported by fleets of battery-powered AGVs along fixed routes. These systems run 24/7 under remote supervision from a centralized control center (the Tuas Port Operations Control Centre).<sup>32</sup> The result is a drastic reduction in manual labor and waiting time; operational data show that the automated processes have cut crane idle time and doubled productivity compared to legacy terminals.<sup>33</sup>
- **5G and Network Connectivity:** PSA has built a private 5G network at Tuas to ensure low-latency communication among equipment and sensors.<sup>34</sup> This high-speed network connects AGVs, drones, and Internet of Things (IoT) devices, enabling real-time remote control and monitoring of port operations. For example, smart cameras and lidars track truck and crane movements to prevent accidents and optimize flow.<sup>35</sup>
- **Digital Port Management:** Singapore's Next Generation Vessel Traffic Service (VTS) and digitalPORT@SG system exemplify integrated management. The VTS uses radar, Automatic Identification System (AIS), and satellite data to give ships and pilots real-time traffic visualization. digitalPORT@SG is a centralized data platform linking all port stakeholders (terminal operators, customs, shipping agents) to provide end-to-end visibility of a vessel's call. When fully implemented at Tuas, digitalPORT@SG will predict arrival times and berth schedules, minimizing wait times and berth conflicts.<sup>36</sup>
- **Data-Driven Operations:** Tuas uses digital twin; a virtual 3D model of the terminal to simulate operations and test improvements. All crane and AGV movements are logged into a big-data

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<sup>27</sup> "Tuas Port."

<sup>28</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>29</sup> "CPPI Report 2024."

<sup>30</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>31</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>32</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>33</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>34</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>35</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>36</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

analytics platform to optimize flows. For instance, MPA reports the use of AI to analyze port throughput and predict maintenance needs on equipment.<sup>37</sup> By leveraging data, Tuas can quickly identify bottlenecks and adapt schedules.

- **Environmentally Sustainable Design:** Sustainability is built in from the ground up. All port vehicles (AGVs, cranes, trucks) at Tuas are electric, charged by an on-site smart grid. PSA estimates electrification will cut carbon emissions by ~50% compared to diesel equipment.<sup>38</sup> In Phase 1, Tuas has solar panel arrays and energy-recovery systems on cranes, and buildings like the maintenance base have solar roofs that offset their power use.<sup>39</sup> Singapore has also committed to net-zero emissions at Tuas by 2050, so future phases will incorporate more renewables. Dredging to 15m and shore-power for ships are also planned to reduce fuel use. These green measures align with Singapore's broader decarbonization goals.<sup>40</sup>

In practice, Tuas has already seen impressive results, after handling its first 10 million TEUs,<sup>41</sup> PSA reported high productivity gains and 24/7 operations with minimal staffing. The integrated control systems and advanced automation allow Tuas to process about 65 million TEUs/year in final build-out, vastly exceeding KPT's current scale. Tuas Port thus exemplifies a holistic smart-port vision, a fully digitalized, automated, and sustainable.

## 2. Shanghai Port (China)

Shanghai Port Complex lies on the Eastern coast of China, at the very entrance of Yangtze River. The Port began operational in 1978 with only 7951 TEUs annually. The number increased gradually with time and for the first time in 2024, it surpassed 50 million TEUs in one year. Currently it is a global smart-port leader.<sup>42</sup> Its Yangshan Deep-Water Port and adjacent terminals are highly automated, green, and digitally integrated. In Global rankings, CPPI report 2024 awards Yangshan Port the top position among container ports.<sup>43</sup> The new Luojing Container Terminal (Phases I and II) at Shanghai provides concrete examples of smart-port technology.

### Key smart features in Shanghai Port include:

- **Intelligent Terminal Control (NEO-TOS):** China's first all-around Intelligent Terminal Operating System (NEO-TOS) is the "smart brain" of the Luojing Container Terminal (LCT).<sup>44</sup> NEO-TOS utilizes AI algorithms, big data analytics and cloud computing to manage quay cranes, yard cranes (also known as Automated Rail Mounted Gantries, or ARMG) and Autonomous Intelligent Vehicles (AIVs). This system can replace manual dispatching, such as AI automatically matching incoming vessels with cranes, and optimizing the pattern of container loading onto the vessel to minimize crane moves.<sup>45</sup> This leads to fully integrated unmanned operations on the quay and yard. Following the success of Yangshan Phase IV, port authorities in Shanghai are rolling out the automation to new terminals, as Luojing I is said to

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<sup>37</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>38</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>39</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>40</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>41</sup> psa-admin, "PSA Singapore Celebrates 10 Million TEU Milestone at Tuas Port."

<sup>42</sup> "Shanghai Port Sees Annual Container Throughput Exceed 50m TEUs."

<sup>43</sup> "CPPI Report 2024."

<sup>44</sup> "sipgEn," September 24, 2025.

<sup>45</sup> "sipgEn," September 24, 2025.

have 14 single-trolley automated quay cranes, 31 ARMGs and 90 AIVs, all managed by the centralized intelligent control system.<sup>46</sup>

- **Robotics and Electric Equipment:** Like Singapore, Shanghai's terminals run Focusing on electric equipment for green solutions. All vehicles on the quay, including yard vehicles at The Luojing are all electric vehicles, featuring intelligent charging points and regenerative braking. Wind turbines and solar panels have been installed on-site to power operations where possible. Notably, shore power infrastructure at Luojing supplies cold-ironing to berthed ships, eliminating on-board diesel generators and cutting sea-borne emissions. Shanghai's goal is carbon neutrality: by 2030, the port aims for 100% shore power and to explore Liquefied Natural Gas (LNG) and green methanol bunkering for ships.<sup>47</sup> These energy innovations are part of a "green smart port" strategy.
- **Automated Stacking Cranes:** At Shanghai's Yangshan (Phase IV) and Luojing, automated stacking cranes (ASCs) and rail-mounted gantries operate without drivers. China's own ITOCS (Intelligent Terminal Operating and Control System) software schedules these machines with high precision. For example, a Xinhua report notes that Yangshan Phase IV achieved a 70% labor reduction and 30% productivity increase once fully automated.<sup>48</sup> Shipping data (via AIS) is linked to the control center, so vessel calls are integrated with the TOS for immediate scheduling.
- **Smart Port Planning:** Shanghai's port includes a *Port Communication and Navigation System* with advanced data fusion. On a broader scale, the Shanghai International Port Group (SIPG) uses its "Port Climate Action" framework to integrate smart and green targets. For instance, big data from logistics flows is shared with city traffic management to reduce road congestion.

The Shanghai Port's smart initiatives showcase how automation and digital management can work at massive scale. The key takeaway features include advanced TOS (NEO-TOS/ITOCs), high-degree automation of cranes/vehicles, electrification and renewables, and integrated data systems which represent the pinnacle of current smart-port practice. With >50 million TEUs per year<sup>49</sup>, Shanghai is the world's busiest container port. It exemplifies a smart-port ecosystem; beyond equipment, it uses e-documents, digital customs clearance, and intermodal rail links. These innovations have significantly improved throughput and reduced per-unit emissions, despite enormous volumes. KPT can learn from Shanghai's model of building "intelligent terminals" with an AI-enabled control core and sustainable infrastructure.

### 3. Port of Salalah (Oman)

The Port of Salalah is located in the southern Oman, Dhofar. It is operational since 1998 and operated by APM Terminals (a Danish shipping and logistic group). Port Salalah is a major transshipment hub in the Arabian Sea with 2.4 km container quay and serves a significant role as strategic pathway between Asia, East Africa and the gulf region.<sup>50</sup> Over the past decade, Salalah has pursued modernization projects with smart-port elements. Recent expansions (2024–25) have

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<sup>46</sup> "sipgEn."

<sup>47</sup> Xinhua, "Shanghai Port Sees Annual Container Throughput Exceed 50 Million TEUs."

<sup>48</sup> Xinhua, "Shanghai Port Sees Annual Container Throughput Exceed 50 Million TEUs."

<sup>49</sup> Xinhua, "Shanghai Port Sees Annual Container Throughput Exceed 50 Million TEUs."

<sup>50</sup> "Our Terminal - APM Terminals."

introduced cutting-edge equipment and digital systems to boost efficiency and sustainability. The port holds 2<sup>nd</sup> number in CPPI report 2024.<sup>51</sup>

**Key smart features in Salalah Port include:**

- **Hybrid and Electric Equipment:** APM Terminals has invested in state-of-the-art hybrid Rubber-Tyred Gantry cranes (hRTGs) and electric Ship-to-Shore (STS) cranes at Salalah.<sup>52</sup> The new hybrid RTGs combine diesel engines with battery power; they regenerate energy during braking and consume far less fuel than conventional cranes. These cranes are equipped with differential GPS and position-determination systems (PDS) for centimeter-level accuracy in container placement.<sup>53</sup> They also feature auto-gantry steering and collision detection, automating safe yard operations. APMT reports that these hybrid cranes cut fuel consumption and CO<sub>2</sub> emissions by more than 50% compared to older units. The port's STS cranes are all-electric ULCV (Ultra Large Container Vessels) cranes capable of handling the world's largest ships; their electric design again enables regenerative energy capture. In this way, Salalah has reduced its carbon footprint while increasing lift speed.
- **Infrastructure Upgrades:** Salalah's USD \$300 million expansion (completed in 2025) added new berths and deepened water to 16.5 meters, accommodating the latest mega-vessels.<sup>54</sup> The expansion included a new on-site power substation to support the electric cranes and increased yard capacity. Terminal systems (TOS) have been upgraded to synchronize with Oman Customs e-manifest (WeBOC) and Oman's ports network. Although detailed ICT systems are not fully disclosed publicly, it is known that Salalah employs an integrated terminal operating system (APMT's proprietary TOS) with modules for yard planning, vessel stowage, and gate automation.
- **Efficiency and Throughput:** These improvements have helped Salalah achieve world-class efficiency. On average, containers spend only 12.5 hours at Salalah and 90% clear customs within one hour, vastly outperforming many peers.<sup>55</sup> In 2024, Salalah's volume reached approximately 3.3 million TEUs.<sup>56</sup> The port achieved these gains by adopting extensive automation and streamlined processes – for example, berth planners now use real-time vessel data to optimize crane assignments, and straddle carriers are deployed automatically on the yard.
- **Green Practices:** In line with Oman's environmental goals (Vision 2040), Salalah integrates sustainability in its smart-ports approach. In addition to electric cranes, the port maximizes solar power (e.g. solar panels on terminals) and recycles waste. Port-run vessels use cleaner fuels (since 2021, APMT has mandated low-sulfur marine gasoil). The port also prioritizes digital paperwork over paper to reduce processes.

In short, Salalah Port's recent upgrades demonstrate how smart-port technologies such as electrified handling equipment, precision automation, and enhanced IT systems can drive efficiency even at a medium-size hub. The port's hands-on focus on equipment automation (especially the new hybrid cranes) and process digitalization illustrates common smart-port

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<sup>51</sup> "CPPI Report 2024."

<sup>52</sup> "Port of Salalah Celebrates Milestone Expansion of 2 Million TEU."

<sup>53</sup> "Port of Salalah Celebrates Milestone Expansion of 2 Million TEU."

<sup>54</sup> "Port of Salalah Celebrates Milestone Expansion of 2 Million TEU."

<sup>55</sup> *Oman's Ports in 2025*, August 5, 2025.

<sup>56</sup> *Oman's Ports in 2025*, August 5, 2025.



principles in action. As a consequence, Salalah not only increased capacity (to 6.5M TEU/year after expansion <sup>57</sup>) but did so while ranking at the top of global efficiency indices. These developments provide a Gulf-region counterpart to the East Asian examples.

### Common Smart Port Features

The three case studies share several **core smart-port features**:

- **Pervasive Automation:** Each port has significantly automated cargo handling. Tuas and Shanghai deploy fleets of AGVs, automated quay cranes, and automated stacking cranes under AI control.<sup>58</sup> Salalah has introduced automated guidance in its RTGs and straddle carriers.<sup>59</sup> In all cases, vehicles and cranes carry sensors and software allowing for remote or autonomous operation. Automation reduces manual labor and errors while enabling 24/7 operation.
- **Digital Integration (Port Community Systems):** All ports utilize integrated digital platforms linking stakeholders. Singapore's *digitalPORT@SG*<sup>60</sup> and China's <sup>61</sup>, *NEO-TOS* provide single-window visibility on vessel operations. Salalah's terminal system similarly connects with customs and shipping lines for seamless data flow. Broadly, modern smart ports implement Port Community Systems (PCS); neutral platforms where carriers, terminals, customs, and logistics providers exchange paperwork and real-time status. This reduces paperwork and turnaround times. Pakistan's new port digitization plan explicitly aims to implement a PCS by 2025.<sup>62</sup>
- **Advanced Communication Networks (5G, IoT):** High-bandwidth connectivity is a common enabler. Singapore's private 5G network at Tuas <sup>63</sup>, plus Shanghai's fiber-optic and private LTE, allow millions of IoT devices (cameras, sensors) to connect. Gulf ports are similarly exploring 5G. These networks ensure that data from every part of the port is collected and processed in real time.
- **AI and Predictive Analytics:** The ports leverage AI for situational awareness and planning. AI algorithms analyze cargo flow and equipment status to optimize schedules. For instance, predictive analytics forecast peak arrivals or maintenance needs, cutting idle time.<sup>64</sup> Artificial intelligence also enhances navigational safety in VTS systems, and many ports employ AI risk profiling for security (notably mentioned in Pakistan's risk-management overhaul <sup>65</sup>).
- **Blockchain and Cybersecurity:** Several smart-port visions highlight blockchain for secure, transparent data sharing. While our case ports vary in blockchain adoption, it is a recognized feature (mentioned as a key technology). More importantly, each port is acutely aware of cybersecurity: for example, data encryption and cybersecurity protocols are integral to Singapore's *digitalPORT* and China's *NEO-TOS*. In Pakistan's strategy, AI is also being used to upgrade risk management systems, reflecting the emphasis on secure digital workflows.

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<sup>57</sup> *Oman's Ports in 2025*, August 5, 2025.

<sup>58</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>59</sup> "Port of Salalah Celebrates Milestone Expansion of 2 Million TEU."

<sup>60</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>61</sup> "simgEn."

<sup>62</sup> "Pakistan\_2024.Pdf."

<sup>63</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>64</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>65</sup> Abbasi, "Govt Launches Comprehensive Ports' Digitisation Plan," February 6, 2025.

- **Green Infrastructure:** One of the common aspects is environmental sustainability. Electrification and renewable energy are included in all 3 ports. Tuas and Shanghai's terminals are operated by vehicles and cranes that use electricity. New cranes at Salalah are hybrid/electric. On-site solar power and energy-recovery. The shore power issue is important to Shanghai, and is being considered in Singapore. These ports also take measures to reduce pollution by implementing low-emission fueling (such as bunkering clean fuels, LNG/methanol lanes in Shanghai). The adoption of smart-ports is also reflected in the focus on the prevention of the creation of 'net-zero targets' (Tu as by 2050), as well as the compliance with SDGs.
- **Data-driven Operations and Digital Twins:** The other less visible, but equally significant, similarity is the use of digital twins and advanced simulations – known as Data-driven Operations and Digital Twins. The virtual terminals have been introduced in Tuas and Shanghai for operational tests. With these digital twins, port planners can simulate scenarios such as peak traffic, equipment failure, and more without interrupting real operations. They are powered by the ports' large data repositories. In Pakistan, plans are underway to build Business Intelligence (BI) dashboards for the ports, and they will soon follow the trend of other countries.

**Table 1:** Summarizes these Common Features Across the Case Studies

| Feature                    | Tuas Port (SG)                                                 | Shanghai Port (CN)                                                                    | Salalah Port (OM)                                                     |
|----------------------------|----------------------------------------------------------------|---------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>Automation</b>          | AGVs, automated cranes, remote control <sup>66</sup>           | Automated quay cranes, AGVs, ARMGs (300+ units) <sup>67</sup>                         | Hybrid RTGs with auto-steering, electric STS cranes <sup>68</sup>     |
| <b>Digital Integration</b> | NextGen VTS, digitalPORT@SG, PCS planned <sup>69</sup>         | NEO-TOS intelligent control (AI-driven); ITOCS; automated customs links <sup>70</sup> | Integrated TOS & customs (APMT network); advanced terminal IT systems |
| <b>Network (5G/IoT)</b>    | Private 5G network <sup>71</sup> , IoT sensors on equipment    | High-speed networks for terminal data, AIS integration                                | Modern communications, IoT sensors (APMT's global IT backbone)        |
| <b>AI/Analytics</b>        | AI scheduling; predictive analytics on port data <sup>72</sup> | AI/Vision systems in NEO-TOS; big data analysis <sup>73</sup>                         | Planned AI-based traffic/berth planning (underway)                    |
| <b>Blockchain/Cyber</b>    | Explored for trade docs; secure platforms                      | Secure data (future blockchain proofs); strong cybersecurity measures                 | Data encryption; emerging cyber awareness                             |

<sup>66</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>67</sup> Xinhua, "Shanghai Port Sees Annual Container Throughput Exceed 50 Million TEUs."

<sup>68</sup> "Port of Salalah Celebrates Milestone Expansion of 2 Million TEU."

<sup>69</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>70</sup> "sipgEn."

<sup>71</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>72</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>73</sup> "sipgEn."

| Feature                | Tuas Port (SG)                                                          | Shanghai Port (CN)                                                          | Salalah Port (OM)                                                  |
|------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------|
| <b>Green/Energy</b>    | Electrified vehicles; solar arrays; net-zero by 2050 plan <sup>74</sup> | 100% electric equipment; shore power; renewable installations <sup>75</sup> | Electric/hybrid cranes; solar panels; ISO environmental management |
| <b>Digital Twin/BI</b> | Terminal digital twin; cloud data analytics <sup>76</sup>               | Advanced simulation (Y4-DT); centralized dashboard                          | BI dashboards (in planning); part of APMT global systems           |

The smart port is the merging of automation, connectivity, AI and sustainability. Singapore and Shanghai illustrate the potential that can be achieved with these tools, and Salalah provides examples of how they can be applied in emerging markets. Similarly, all the components of the smart-port roadmap will have to be included in KPT's smart-port roadmap, but with a Pakistani context.

### Smart Port Technologies Currently Implemented at KPT

KPT has begun adopting selected technologies that lay the groundwork for a smart port:

- **Electronic Customs Systems:** Pre-arrival Declarations / Clearance is done via KPT terminals with Pakistan Single Window (PSW) and WeBOC (Web-Based One Customs). In 2023, WeBOC has been upgraded to enhance UI/UX and API. This will eliminate paperwork for importers as they can submit cargo documents online and get risk assessments before the cargo reaches port. KPT is also real-time coupling its Terminal Operating Systems (TOS) to these platforms.<sup>77</sup> For instance, if the container has been issued with a TOS for export, the TOS will be auto-generated to a WeBOC filing. Initial implementation of the tech is still in the development phase and is of significant importance for transparency.
- **Port Community System (PCS) Initiation:** A neutral PCS is under development, per the Task Force. Phase I (vessel calls, pilotage data) launched in 2024. KPT has committed to connecting its harbormaster and pilotage services to this PCS. Once in place, shipping agents and lines will receive automated notices of berth readiness.<sup>78</sup> The PCS will later expand to include gate appointments and equipment reservations. This promises to reduce idle time waiting for berths or trucks.
- **Terminal Operating Systems:** All of Karachi's major terminals now run computerized TOS for yard management and gate scheduling. Karachi Gateway Terminal Private Limited (KGTL) and SAPT (concessionaries) use global-standard TOS with some automation (e.g. automated yard plan calculations).<sup>79</sup> However, KPT's TOS installations still require manual input for many tasks and are not yet AI-enhanced. The plan is to integrate all TOS with PSW in real time, which would enable cross-terminal visibility.

<sup>74</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>75</sup> "sipgEn."

<sup>76</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>77</sup> Sarfraz, "WeBOC Integrated with PSW."

<sup>78</sup> "Copy-1-the-View-Oct-Dec-2024-1.Pdf."

<sup>79</sup> "Welcome To Karachi Gateway Terminal Limited - KGTL."

- **Digital Traffic Control:** KPT has a basic Vessel Traffic Service (VTS) center that monitors ship movements via radars and AIS. The government now requires upgrading to a *NextGen VTS* with full digital reporting.<sup>80</sup> In practice, KPT's VTS (Karachi VTS) still relies on radar blips; the upgrade would add satellite tracking and berth automation (as in Singapore's VTS). Meanwhile, cranes and berth scheduling at KPT are manually orchestrated, though KPT has trialed short-range radar and camera systems to track quay crane positioning for safety.

In aggregate, KPT is at an intermediate stage: it has replaced many paper processes with digital forms (Customs, port entries) and begun integrating systems. But it has not yet employed the higher-level smart technologies that the case-study ports use. The ongoing digitization plan indicates a roadmap; within a year or two, KPT aims to have a fully online PCS, ERP workflows, and AI-augmented risk management. These will be essential platforms on which true smart-port functions (automation control, big-data analytics) can later be built.

### Comparative Analysis: KPT vs. Tuas, Shanghai, and Salalah

A side-by-side comparison highlights the gap between KPT's current state and the smart-port exemplars:

- **Scale and Throughput:** In throughput terms, KPT is much smaller. As noted, KPT handled ~2.65M TEU in FY2024–25<sup>81</sup>, whereas Tuas (Singapore) and Shanghai process an order of magnitude more (Te Singapore ~41M in 2024<sup>82</sup>, Shanghai ~50M<sup>83</sup>). Salalah (~3.3M TEU in 2024) is closer in scale to KPT, but Salalah's newer facilities produce much higher efficiency.<sup>84</sup> The low base of KPT throughput reflects limited capacity (a few million TEUs/year). Unlike Tuas or Shanghai, KPT's terminals still rely heavily on manual or semi-automated equipment.
- **Automation Level:** KPT's machinery is largely conventional. Cranes and trucks are manually operated; KPT currently lacks AGV systems or automated stacking cranes. In contrast, Tuas and Shanghai use hundreds of unmanned vehicles and cranes<sup>85</sup>, and Salalah has automated guidance in yard cranes. The result is that KPT's crane productivity per shift and truck gate throughput are well below international benchmarks.
- **Digital Systems:** Currently, KPT is still rolling out basic digital platforms. Pakistan's recent port digitization plan (Feb 2025) proposes a Port Community System, real-time TOS-WeBOC integration, and KPT ERP systems.<sup>86</sup> The following initiatives are underway but not completely achieved. In contrast, other integrated digital ecosystems are already in place in Tuas and Shanghai, including end-to-end electronic cargo flow, electronic customs clearance and integrated traffic management. Currently, the documentation has been partially digitised under the current IT of KPT (e.g. Kaamil in customs, WeBOC, PCS in early phase) and the tracking is partially in real time. The PCS/ERP for KPT is expected during 2025, however, there is a time gap till they are in operation.
- **Traffic Management:** The current Vessel and Berth Scheduling process at KPT is mostly manual, with traffic management. A local VTS for pilotage exists but KPT does not have any

<sup>80</sup> "PND\_2708250003\_k\_e529.Pdf."

<sup>81</sup> Breccorder, "KPT Handles All-Time High Cargo in FY25."

<sup>82</sup> Ghoshal, "Largest Automated Port Will Handle 65 Million Containers per Year."

<sup>83</sup> Xinhua, "Shanghai Port Sees Annual Container Throughput Exceed 50 Million TEUs."

<sup>84</sup> *Oman's Ports in 2025*, August 5, 2025.

<sup>85</sup> Marit. Port Auth. Singap. MPA, "Port of the Future."

<sup>86</sup> Abbasi, "Govt Launches Comprehensive Ports' Digitisation Plan," February 6, 2025.

advanced Digital traffic control such as Singapore's VTS NextGen and Shanghai's port-wide monitoring.<sup>87</sup> KPT does have automated identification system (AIS) trackers but lacks predictive navigational software. Full deployment of VTS has been ordered by the government of Pakistan but till now only VTS with an old technology (RADAR) was being used in Karachi.<sup>88</sup> To summarize, ports around the world are leveraging AI-powered traffic management systems, while KPT is in the process of enhancing their existing VTS capabilities.

- **Infrastructure and Environment:** KPT's infrastructure has not kept pace with smart standards. Berth depths remain relatively shallow (12–14 m, restricting Ultra Large Crude Carriers) and much of the equipment is diesel-powered. The case ports prioritize electrification from day one. For example, any new berth at Tuas or Salalah is immediately equipped with electric cranes. KPT's older equipment – thousands of manual yard trucks and rubber-tyred gantries – are still diesel. APMT's upgrades at Salalah have shown the gains: KPT currently cannot claim similar emissions reductions. Recognizing this, Pakistan's national policy is now encouraging shore power (for Karachi and Gwadar) and cleaner fuels<sup>89</sup>, but these are future projects.
- **Regulatory and Operational Processes:** The efficiency of KPT is hampered by procedural bottlenecks. Container dwell times at KPT historically averaged ~7 days (compared to 2–3 days at world-class ports).<sup>90</sup> A high-level committee in 2025 aims to cut this drastically.<sup>91</sup> In contrast, Singapore and China have streamlined customs and port procedures, resulting in much shorter dwell. Saudi and Omani ports (part of the same MSCI index as Salalah) also enjoy single-window clearing, 24/7 operations, and minimal free time. KPT is moving toward this through reforms (e.g. 24/7 shifts, electronic gate handling, risk-based customs checks). Early outcomes are positive – Business Recorder reported cargo handling up 23% as of mid-2025 – but efficiency is still below peers.<sup>92</sup>

**Table 2:** *Summarizes Key Metrics and Features*

<sup>87</sup> Marit. Port Auth. Singap. MPA, "Port of the Future," September 24, 2025.

<sup>88</sup> Abbasi, "Govt Launches Comprehensive Ports' Digitisation Plan," February 6, 2025.

<sup>89</sup> Deputy PM Calls for Modernizing Port Infrastructure to Boost Pakistan Trade Competitiveness | Arab News.

<sup>90</sup> Dilawar, "Pakistan Plans to Slash Container Dwell Time at Ports by 70% to Boost Trade Efficiency," July 8, 2025.

<sup>91</sup> Ali, "Govt Forms Body to Slash Container Dwell Time," 05:56:25+05:00.

<sup>92</sup> Ali, "Govt Forms Body to Slash Container Dwell Time," 05:56:25+05:00.

| Metric/Feature                           | Karachi Port (KPT)                          | Tuas Port (SG)                                       | Shanghai Port (CN)                                            | Salalah Port (OM)                               |
|------------------------------------------|---------------------------------------------|------------------------------------------------------|---------------------------------------------------------------|-------------------------------------------------|
| <b>Annual Throughput (TEU)</b>           | ~2.65 million (FY2024–25) <sup>93</sup>     | ~41 million (2024) <sup>94</sup>                     | ~50+ million (2024) <sup>95</sup>                             | ~3.3 million (2024) <sup>96</sup>               |
| <b>Automation Level</b>                  | Mostly manual; some RTGs & shuttles         | Fully automated cranes & AGVs <sup>97</sup>          | Fully automated cranes/AGVs <sup>98</sup>                     | Mixed; new hybrid/electric cranes <sup>99</sup> |
| <b>Port Community System</b>             | Under development <sup>100</sup>            | Fully implemented (digitalPORT)                      | Advanced (NEO-TOS integrates all stakeholders) <sup>101</sup> | ERP systems (APMT network)                      |
| <b>Average Dwell Time</b>                | ~7 days (target 2 days) <sup>102</sup>      | ~1–2 days (global benchmark)                         | ~2 days (efficient global ports)                              | ~0.5 days (90% within 1 hour) <sup>103</sup>    |
| <b>Carbon Emissions (CO<sub>2</sub>)</b> | High (diesel equipment)                     | 50% reduction via electrification                    | Zero on-site emissions (100% electric) <sup>104</sup>         | ~50% reduction with hybrid cranes               |
| <b>Technology Maturity</b>               | Implementing PCS, AI pilots                 | Mature smart port (5G, AI, digital twin)             | Mature smart port (AI TOS, IoT sensors)                       | Emerging smart port (upgrading ICT)             |
| <b>Port Efficiency Rank</b>              | 61 <sup>st</sup> in CPPI report (Improving) | 17 <sup>th</sup> in CPPI report (Efficient handling) | 1 <sup>st</sup> in CPPI report (High productivity)            | 2nd in CPPI report (very high) <sup>105</sup>   |

This comparison highlights the fact that KPT is behind with regard to automation, digital integration, and green features. It is still not fully addressed how to overcome its operational challenges (dredging bottlenecks, congested access, coordination challenges). In the meantime,

<sup>93</sup> Breccorder, “KPT Handles All-Time High Cargo in FY25.”

<sup>94</sup> Ghoshal, “Largest Automated Port Will Handle 65 Million Containers per Year.”

<sup>95</sup> Xinhua, “Shanghai Port Sees Annual Container Throughput Exceed 50 Million TEUs.”

<sup>96</sup> *Oman’s Ports in 2025*, August 5, 2025.

<sup>97</sup> Marit. Port Auth. Singap. MPA, “Port of the Future.”

<sup>98</sup> “sipgEn.”

<sup>99</sup> “Port of Salalah Celebrates Milestone Expansion of 2 Million TEU.”

<sup>100</sup> Abbasi, “Govt Launches Comprehensive Ports’ Digitisation Plan,” February 6, 2025.

<sup>101</sup> “sipgEn.”

<sup>102</sup> Dilawar, “Pakistan Plans to Slash Container Dwell Time at Ports by 70% to Boost Trade Efficiency,” July 8, 2025.

<sup>103</sup> *Oman’s Ports in 2025*, August 5, 2025.

<sup>104</sup> “sipgEn.”

<sup>105</sup> *Oman’s Ports in 2025*, August 5, 2025.

Tuas, Shanghai and Salalah exemplify state of the art. These ports are examples of the benefits of technology investment for high throughput and sustainability.

### Challenges Affecting KPT's Operational Efficiency

While modernization plans are underway, KPT faces significant operational challenges that constrain its efficiency:

- **Port Congestion and Hinterland Constraints:** Limited draft and siltation issues at KPT cause congestion at the berth. Maintenance dredging in Karachi has been problematic; recent tenders were cancelled and reissued to ensure compliance.<sup>106</sup> Until KGTL's deepening project is complete, many large vessels still call at Gwadar or divert to other ports. Overland connectivity is another bottleneck. Karachi's trucking corridors to Sindh and Baluchistan suffer from highway congestion and security checks. A study mentions that logistics and hinterland infrastructure elasticity and predictability "compromise the performance of KPT" by delaying movements and increasing empty container movements.<sup>107</sup> Choking points exist for land and maritime access to the port.
- **Inefficient Customs and Administration:** Cargo release is delayed due to the complexity and fragmentation of administration. The container dwelling time at KPT is on average one week,<sup>108</sup> against the global best practice of 2–3 days. This increases the cost of the supply chain. Wishing to address the issue, the Pakistani authorities have initiated reforms: Starting from the middle of 2025, a committee, which includes both KPT and customs officials, has been charged with the reengineering of clearance processes. It is envisioned that they will integrate data flows via PCS and PSW, use artificial intelligence (AI) for risk assessments, and run 24/7 terminals. The implementation of single window filings will also be complemented with a vertical reduction of time (free period reduced from 5 days to 3) in order to reach global best practices.
- **Aging Equipment and Manual Operations:** A lot of KPT's cargo handling equipment is getting old and is still operated manually. Approximately 50% of the cargo containers require a manual straddle carrier and/or crane for transfer, which is a time-consuming process. Because most of the automated terminals close for a day once a week at most, KPT has few options for automated night time operations. Like most terminals, KPT does not have automated transport vehicles, real time tracking for cargo in the yard, or transport vehicles in the yard. All of these things contribute to increased turnaround times for KPT's customers. KPT has started to deal with these challenges by planning for the gradual replacement and upgrades of their handling equipment. For example, KPT is in the process of obtaining new quay cranes and rubber tyre gantries (RTGs) through the KGTL concession, which will provide modern cranes. KPT does not have full automation planned for the near future.
- **Regulatory Overlap and Coordination:** There are a number of regulatory agencies involved in the operations of a port (customs, marine, transport) and the KPT is no exception. Even when there are digital copies of plans, dealing with these agencies can be cumbersome. For example, weighbridges for trucks and customs checks may still happen outside of the terminal gates.<sup>109</sup>

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<sup>106</sup> "Four Karachi Port Trust High-Ups Named in Probe over Dredging Contract Violations - DredgeWire : DredgeWire."

<sup>107</sup> Zohaib et al., "EXPLORING THE IMPACT OF LOGISTICS NETWORK DYNAMICS ON PORT EFFICIENCY."

<sup>108</sup> Dilawar, "Pakistan Plans to Slash Container Dwell Time at Ports by 70% to Boost Trade Efficiency," July 8, 2025.

<sup>109</sup> Abbasi, "Govt Launches Comprehensive Ports' Digitisation Plan," February 6, 2025.

Legacy issues of coordination still remain. The Dawn news reports new, innovative ways of working for KPT, which include the use of AI, drones, and CCTVs to centralize and monitor all activities of the port.<sup>110</sup> There are similar systems in Tuas and Shanghai, which will provide KPT with a new operational perspective.

- **Resilience to External Shocks:** KPT is exposed to a range of external risks, including monsoon flooding, strikes, and other geopolitical concerns. Outbreaks and other forms of regional unrest can influence the stability and predictability of international trade. In this regard, a smart port can predict and plan for these external shocks through Predictive Analytics and Resilience Planning (the MDPI study refers to this as Supply Chain Resilience).<sup>111</sup> KPT has only just identified and begun to employ these advanced and integrated risk management frameworks.

KPT struggles with a combination of infrastructural issues (i.e. dredging, expansion of berths, and connectivity), as well as issues of a procedural nature (i.e. clearance delays and manual systems). This has resulted in slow and infrequent services. Pakistani authorities have included these challenges in the 2024–2025 reforms, however, to overcome these challenges and operate at the efficiency of a smart port will require a sustained and considerable effort. To achieve a smart port transformation success, these challenges will, at the minimum, need to be addressed.

### **Recommendations**

Drawing on the international benchmarks and Pakistan's own strategic goals, this paper recommends the following evidence-based initiatives as the best roadmap transforming KPT into a well-defined smart port. For the practical implementation, all recommendations are divided into three phases. The Phase-1 (Now onwards to Mid-2026), Phase-2 (Mid-2026 to 2030), and Phase-3 (post-2030) are structured in such a way that the identified smart port features could be realistically applied to KPT. This transition of KPT into a smart port starts with low-cost technologies and then gradually scaling.

#### **1<sup>st</sup> Phase (Now onwards to Mid-2026)**

In the short term, KPT should complete critical fixes: implement the PCS phase 1, invest in high-speed connectivity (5G, IoT), install VTMS, and upgrade all customs/clearance to digital and strengthen human capacity and cyber security. This phase should also electrify any equipment nearing end-of-life and train staff on new systems.

#### **2<sup>nd</sup> Phase (Mid-2026 to 2030)**

Medium-term (3–5 years), KPT should deploy advanced automation at scale: commission remote and AI driven crane operations across all berths, roll out sensor networks (for cargo, equipment, environment), build an integrated operations center with analytics and most importantly improve Hinterland Connectivity. Concurrently, KPT must strengthen governance (clear KPIs, transparent reporting) to sustain momentum.

#### **3<sup>rd</sup> Phase (post 2030)**

In the long-term (7-15 years), the target should be to achieve full smart port integration with a fully automated, zero-emission, and digitally developed ports, including digital twins. Furthermore, KPT should integrate fully automated stacking systems in all of the port's terminals. KPT should,

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<sup>110</sup> Ali, "Govt Forms Body to Slash Container Dwell Time," 05:56:25+05:00.

<sup>111</sup> Alavi-Borazjani et al., "An Overview of Critical Success Factors for Digital Shipping Corridors."



by this time, be operating to a level of comparable industry peers, including the full 100% digital clearance, and regional peers for terminal throughputs.

All recommendations come from a strong evidence base. They are built from the many advanced technologies KPT has as an option to implement as part of its strategic rebuilding for Port Digitalization. As documented in its International Maritime Gateways, KPT has gaps experienced by other ports. To target resolution of the gaps seen in KPT, digital twin ports allow KPT to operate its Port and integrate other advanced technologies from the operations of the port, including the integration of fully automated systems within the port's terminal stacking to operating to its efficiency peers and environmental integration and climate depletion in favor of a net-zero port operations with full renewable and advanced technologies. These include AI for control and climate depletion to meet the sustainability goals of the port and its operations.

Integrating smart features is both an investment and political/will cost. World lenders (i.e. World Bank, ADB, etc.) and other partners could fund pilot projects, because of the significance of Karachi in regional trade. The recommendations above should be made in phases; immediate implementation of PCS integration is recommended, followed by terminal automation. Recent trading reforms (2024–2025) indicate a political will pushing for the modernization of KPT.

### **Conclusion**

The introduction of the smart port has brought a new dimension to maritime logistics. Ports like Tuas in Singapore, the Shanghai terminals in China, and Salalah in Oman are examples of the benefits of the total digital, automation, and green technology integration and innovations. All of them have built IoT gear, AI, integrated data, and sustainable operations as part of their facilities. The Karachi Port Trust is also on the verge of the same. While KPT has made recent advances (the record throughput of 2024-25 and policy changes to facilitate digitalization), KPT may need to quicken the pace of technological adoption to be on the same competitive level as the others. The data shows that adopting smart-port technologies, as per our recommendations, will lead to improved efficiency, cost optimization, and better environmental results. Pakistan's recent maritime policy changes and port digitalization plan have provided the groundwork. Their implementation will show commitment to the specific technologies used successfully in other nations. Through learning from other ports and looking at its own needs, KPT can enhance its trade facilitation and bring its operations in line with the latest maritime operations. KPT can become a digitally-empowered and green maritime hub and can help bring South Asia into the 21st Century.

### **Conflict of Interest**

The authors showed no conflict of interest.

### **Funding**

The authors did not mention any funding for this research.

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