

Practices and Insights from the Automation Upgrade of Yangshan Deep-Water Port Phase IV

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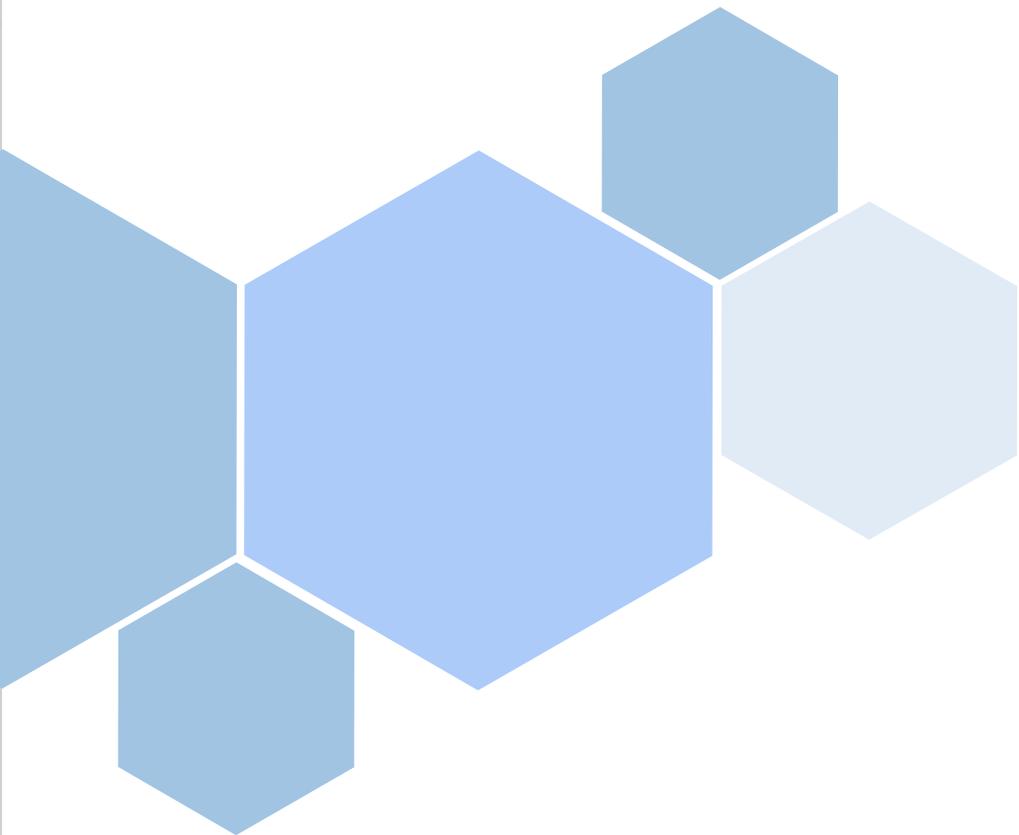
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Introduction The Yangshan Practice

Strategic Position as a Global Shipping Hub – A Model of Automated Ports



01

World's Largest Single Fully Automated Container Terminal

Yangshan Phase IV is the world's largest single fully automated container terminal, leading globally in both scale and technology. It exemplifies the highest level of automation in modern port operations.



02

The Strategic Anchoring of Shanghai Port in Global Resource Allocation

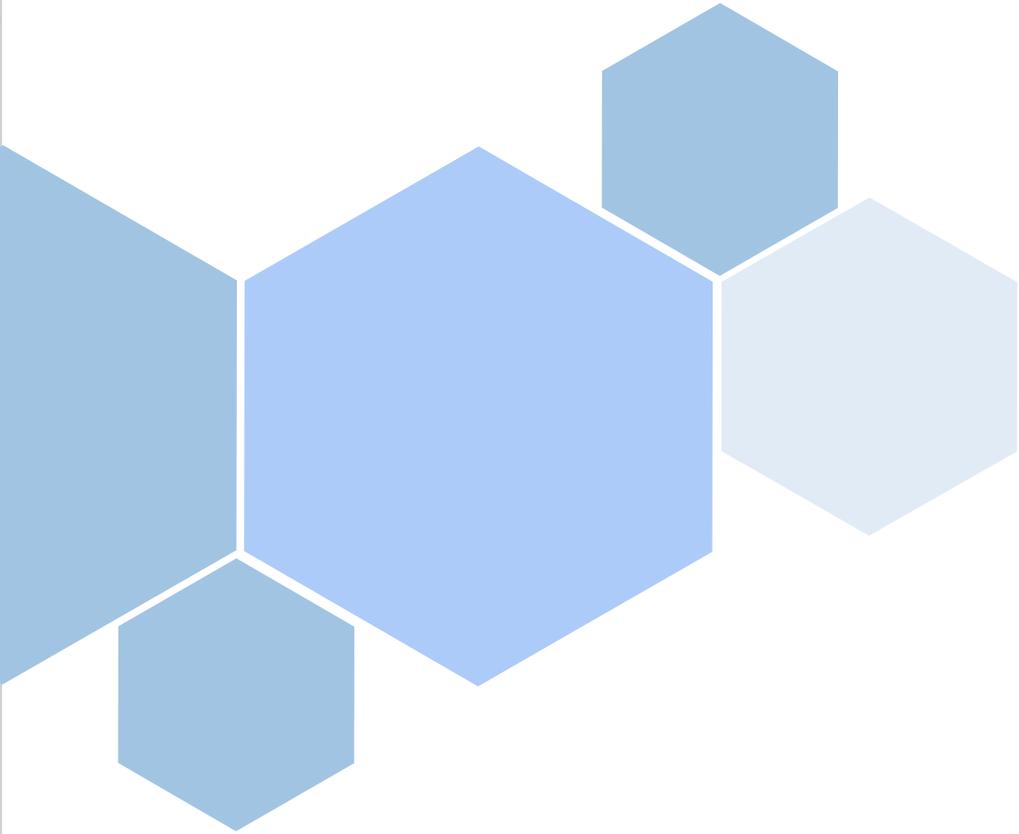
As the strategic anchor of Shanghai Port, Yangshan Phase IV enhances global resource allocation through intelligent upgrades. It strengthens Shanghai's role as an international shipping hub and consolidates its position in the global logistics network.



03

Global Contributions of the "China's Solution" for Smart Ports

Yangshan Phase IV offers a replicable "China Solution" for smart port development worldwide. Its automation innovations and operational practices provide valuable experiences and insights for technological transformation and upgrade of ports in other countries and regions.



02

Development Course Evolution from Traditional to Automated Port

Yangshan Port: Construction Review and Outlook

Phase I (2002–2005): Laying the Foundation for the Deep-Water Port

- China's first island-type deep-water port;
- With 5 berths of 100,000 DWT and an annual throughput capacity of 2.2 million TEUs;
- Supported by the synchronous completion of the 32.5-km Donghai Bridge, one of the world's longest cross-sea bridges at the time.

Phase IV (2014–2017): Concentrated Application of Automation Technology

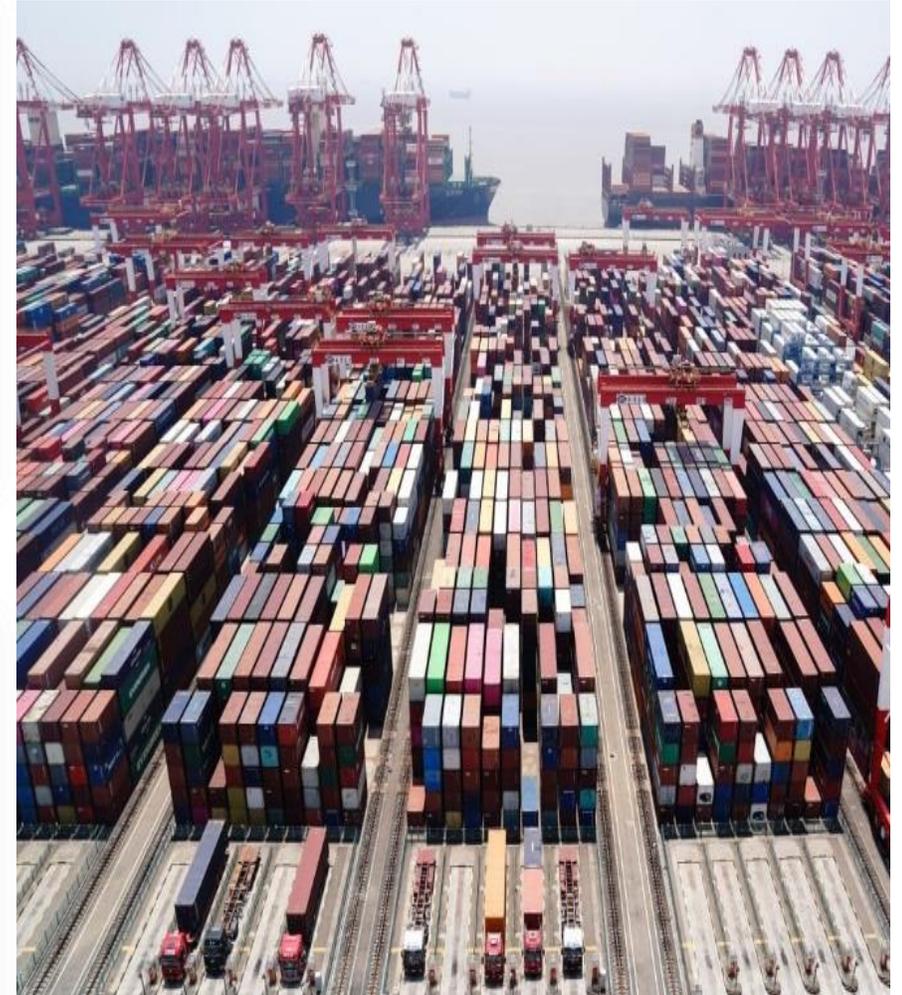
- World's largest single fully automated container terminal, featuring 7 berths of 200,000 DWT and an annual throughput capacity of 6.3 million TEUs;
- Strengthened Shanghai Port's global role, supporting it exceed 40 million TEUs—about 1/10 of global container throughput.

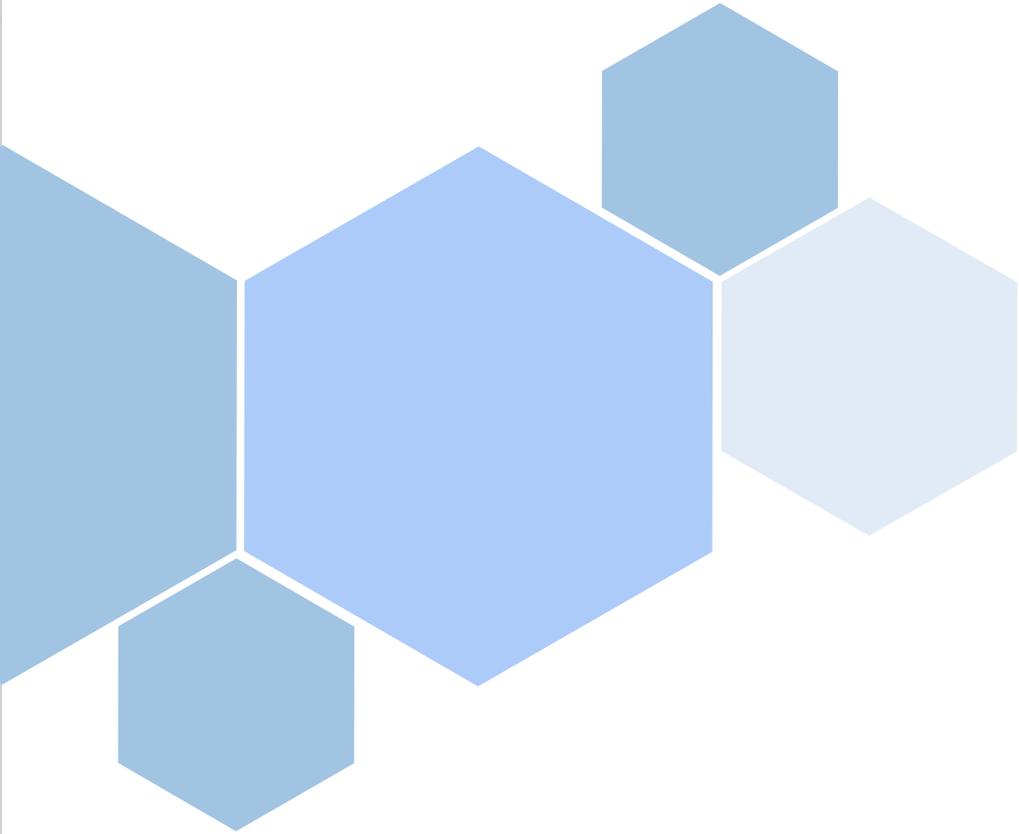
Phases II & III (2005–2012): Rapid Expansion of Throughput

- Added 11 deep-water berths, raising total capacity to over 9.3 million TEUs annually;
- Land area expanded to nearly 10 km² (up from the original 1.76km²) through reclamation, facilitating large-scale container handling.

Technological Breakthroughs and Engineering Innovations Achieved

- From Phase I to Phase IV, advances included deep-water construction, long-span sea-crossing bridges, and integrated automation systems—showcasing China's capability in designing and executing world-class port projects.

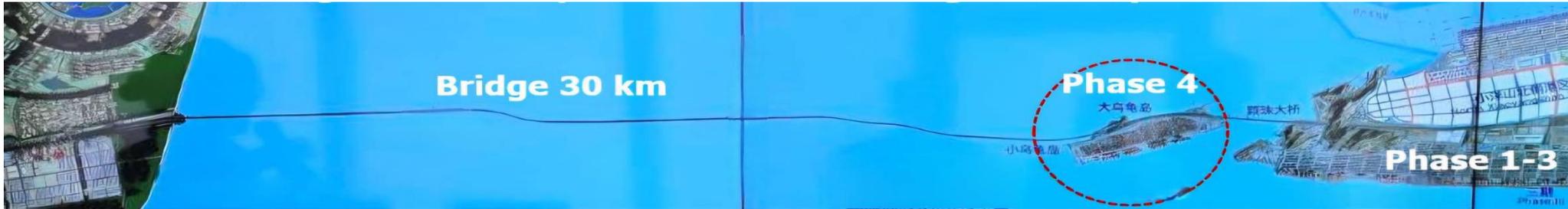




03

Technical Highlights **Core Technologies of Fully** **Automated Port**

Overview of Yangshan Port Phase IV



Specifications	Yangshan Port – Phase 4
COD	Dec 2017
Operator	Shanghai International Port Group
Designed capacity (MTEU)	6.3 MTEU
CAPEX	61.2 B THB
Berth length (meter)	2,350
Layout	Perpendicular
Gross crane rates (moves /hr)	28 moves/hr (max 47 moves)
Truck turnaround time (mins)	20
AGV	145
ARMG	122
Twin lift STS	2 TEU / 2 x 40' MT container
STS	28 STS Crane (ZPMC mostly)



- ✓ Maximum single-quay-crane operation efficiency: **57.4 TEUs per hour**.
- ✓ **Over 7 million TEUs handled in 2024**, far exceeding its initial design capacity of 4 million TEUs.
- ✓ **Labor productivity per capita is 213%** of that of traditional terminals.
- ✓ **The number of personnel reduced by 70%** compared with terminals of the same scale.

Overview of Yangshan Port Phase IV



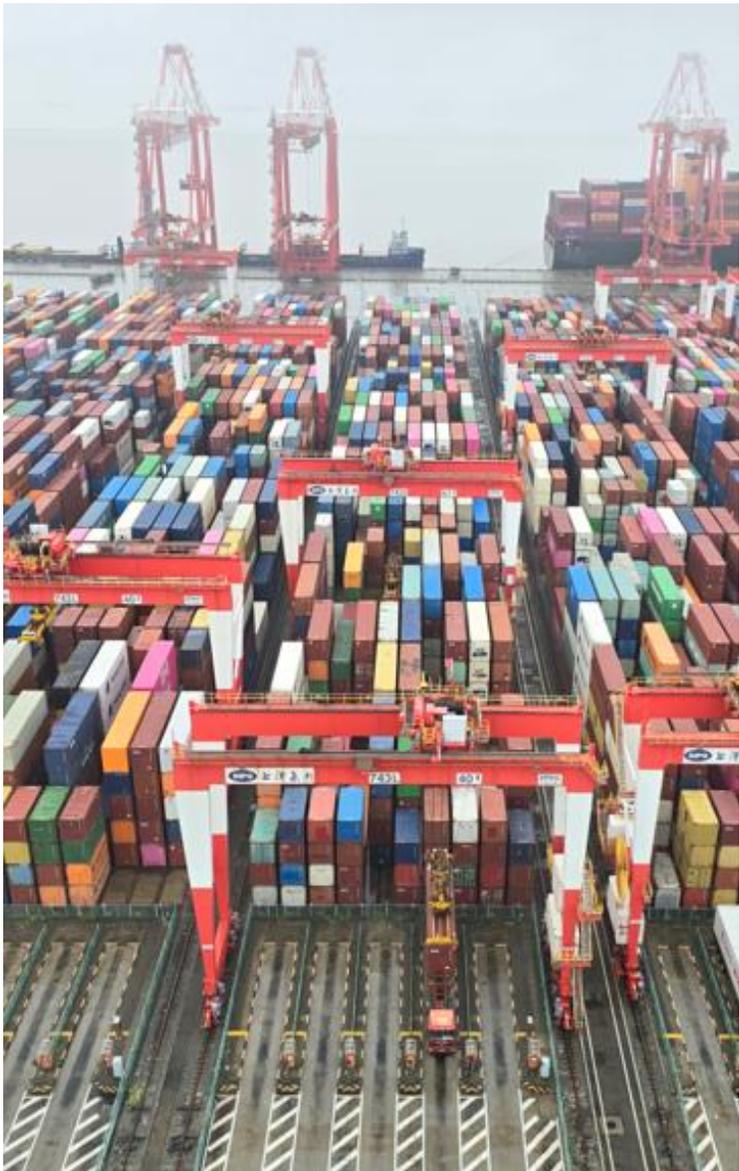
Office Tower



OCR Gate

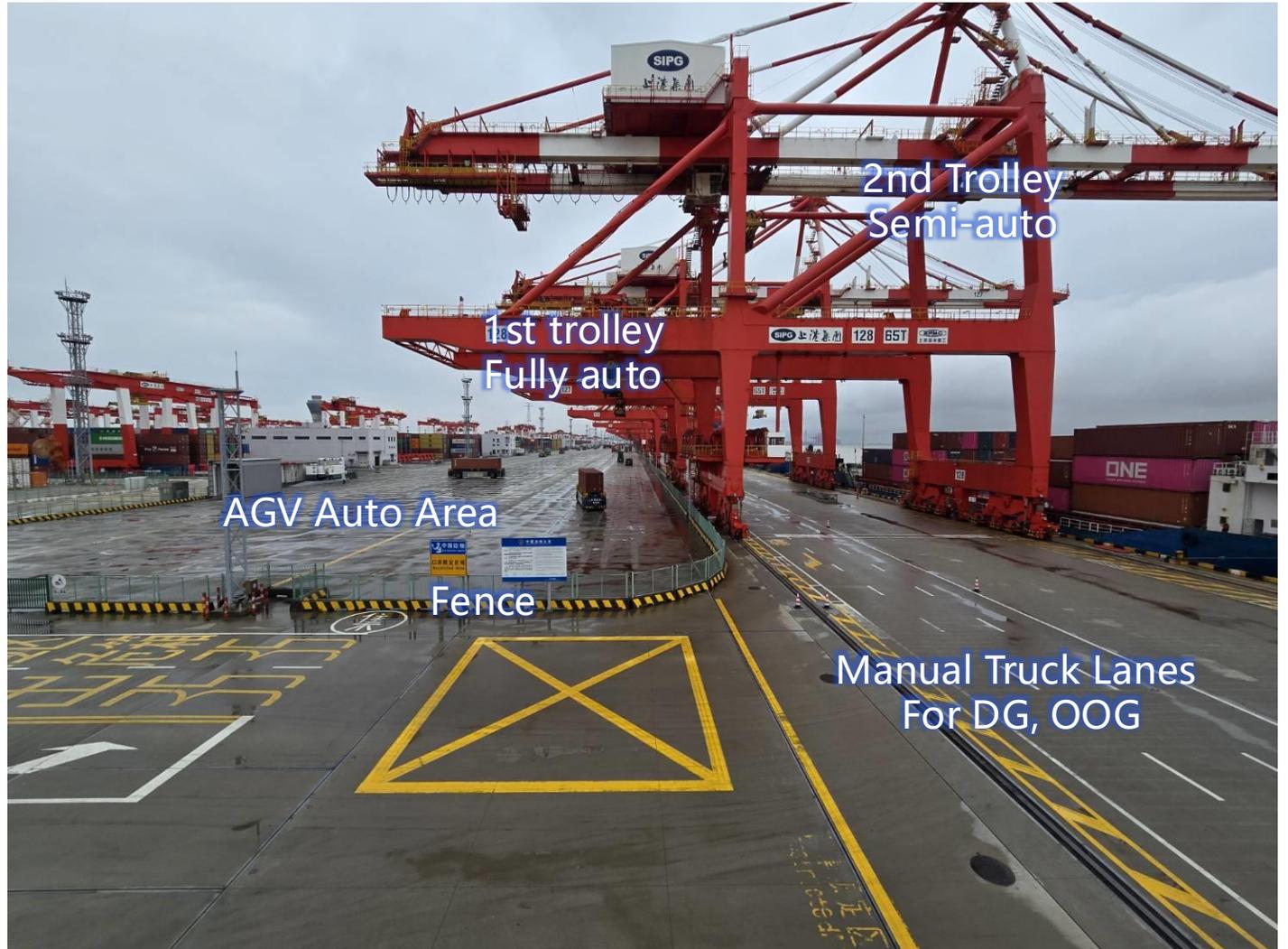


Yard Area, cranes



10 Row wide, 6 row height
With 5 truck entrance

Overview of Yangshan Port Phase IV



- Double Trolley Quay crane
- Completely separate Autonomous area

Technical Highlights: AGV Automated Guided Vehicle System

1. Autonomous Horizontal Transportation: 24/7 uninterrupted high-efficiency operation

- AGVs (Automated Guided Vehicles) enable fully autonomous, continuous container movement, significantly boosting operational efficiency and reducing labor dependency.
- Driverless operation enhances safety, lowers costs, and aligns with future port intelligence trends.

1

2. Large-scale Deployment: Fulfilling growing throughput demands

- Phase I deployed 50 AGVs, gradually expanded to 140+ units to handle rising cargo volumes.
- Large-scale AGV integration supports economies of scale and ensures stable port performance under increasing demand.

2

3. Precise Positioning: Magnetic Nail Navigation with centimeter-level precision

- A network of approximately 61,500 embedded magnetic nails provides centimeter-level positioning, ensuring accurate and safe AGV navigation in complex environments.
- This high-precision minimizes errors, optimizes routes, and upholds operational safety.

3

4. Reliable Power Supply: Fast-charging Lithium Batteries for Uninterrupted Operation

- AGVs use lithium batteries supporting 8-hour operation and 6-minute battery swapping, enabling near-uninterrupted workflow.
- Rapid energy replenishment maximizes asset utilization and sustains consistent transportation efficiency.

4

Technical Highlights: Remote-Controlled Container Quay Cranes

01

Fully Autonomous Control Architecture

- ◆ Core control relies on the independently developed TOS + ECS system, enabling full localized control from command generation to equipment response.
- ◆ Achieves command delay ≤ 50 ms (40% lower than imported systems) and supports >1,200 hours of continuous fault-free operation per quay crane (QC), reaching world-leading reliability.

02

Cooperative Sensing and Remote Operation

- ◆ Powered by the world's first 5G private network for ports (10 ms latency, 10 Gbps bandwidth), integrated with digital twin and panoramic monitoring for real-time, dead-angle-free oversight.
- ◆ Enables unmanned coordination among AGVs and automated rail-mounted gantry cranes (RMGs), allowing 1 operator to manage 2–3 QCs. Boosts collaborative efficiency by 50% and reduces labor costs by over 60%.

03

Millimeter-level Precision Operation Technology

- ◆ Uses multi-sensor fusion (LiDAR+Beidou Satellite+inertial measurement) for accurate 6-DOF spreader positioning, with container stacking error ≤ 2 cm.
- ◆ An adaptive anti-sway algorithm reduces spreader swing to ≤ 5 cm (vs. 30 cm in manual operations), increasing loading/unloading efficiency by >30% even in complex island conditions.

04

Intelligent Operation and Maintenance Enhancing Reliability

- ◆ Employs multi-sensor intelligent diagnostic system, with 92% accuracy in detection and early warning of critical component malfunctions, cutting unplanned downtime by 70%.
- ◆ Features redundant “5G + fiber” dual links and dual power supplies, enabling fault switching in less than 2 seconds to maintain continuous operations under extreme weather conditions.
- ◆ Smart lubrication reduces oil use by 30%.

Technical Highlights: China-developed Core System Architecture – TOS+ ECS

01

TOS: Intelligent Brain Driving Holistic Optimization

- ❑ The **Intelligent Terminal Operating System (ITOS)** of Yangshan IV, developed by Shanghai International Port Group, serves as the port's "smart brain", integrating vessel planning, stowage, and scheduling for end-to-end optimization.
- ❑ Connects with big data platforms to enable real-time monitoring and intelligent decision-making, significantly boosting overall operational efficiency.

02

ECS: Precision Scheduling & Cluster Synergy

- ❑ The **Equipment Control System (ECS)** of Yangshan IV, developed by ZPMC, enables unified, millisecond-level collaborative control of AGVs, RMGs, and other key equipment.
- ❑ Delivers 25% higher efficiency than other comparable ECS systems, ensuring rapid and precise inter-device responses.

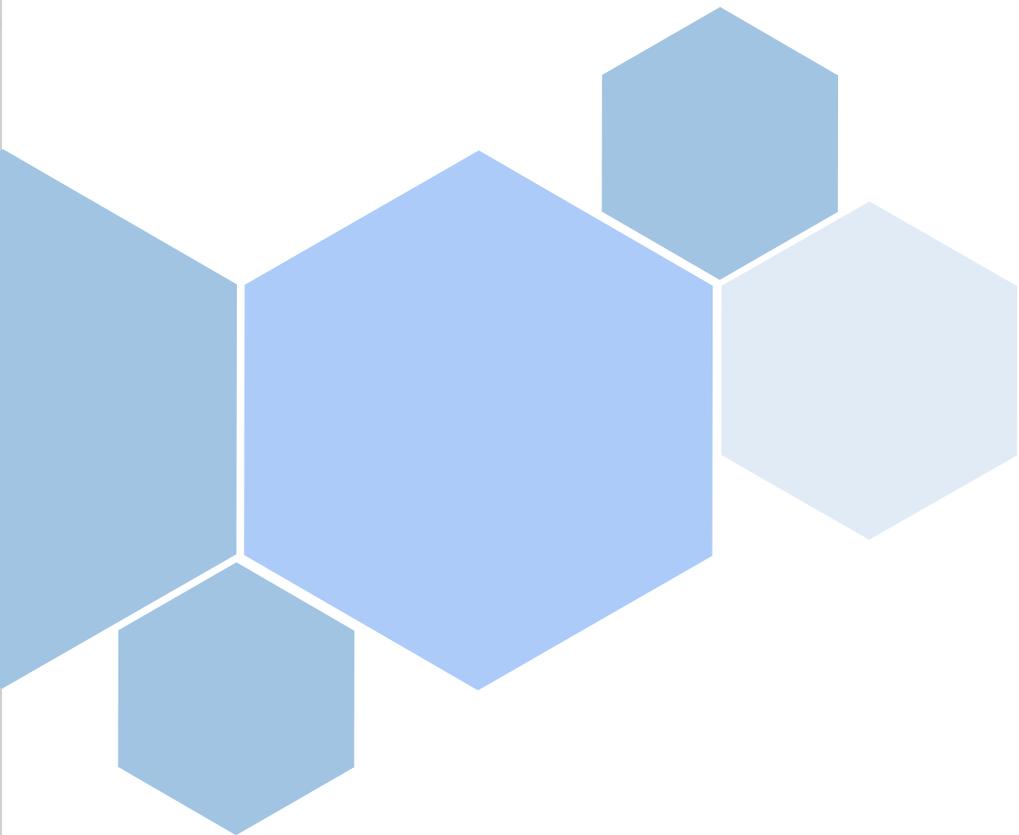
03

Digital Twin: Rapid Simulation and Optimization

- ❑ The self-developed **Digital Twin System** allows sub-second dynamic simulation of terminal status, supporting rapid optimization of operations.
- ❑ Enhances the port's agility, enabling quick adaptation to changing market demands and strengthening competitiveness.

Certificate of Shanghai Municipal Science and Technology Award





04

Green Development Building a Sustainable Port Ecosystem

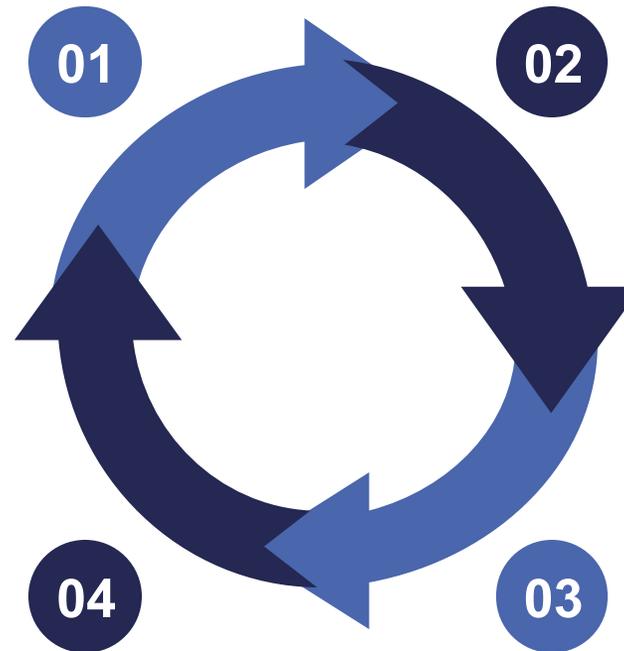
Diversified Supply of Green Energy

1. All-electric Powered: Drastic Carbon Emission Cuts

- ◆ 100% of operational equipment is powered by electricity, replacing fossil-fuel machinery to slash carbon emissions and reduce pollution at the source.
- ◆ Adopting all-electric equipment improves working conditions, curbs noise pollution, boosts energy efficiency, and delivers sustainable, eco-friendly development.

4. Future Energy: Diversified Deployment of Methanol, LNG & Beyond

- ◆ Pilot programs of green methanol and LNG bunkering are planned by 2025, alongside explorations of wind and tidal power.
- ◆ Aims to build an integrated "Source-Grid-Load-Storage-Control" energy system, reducing fossil fuel reliance and diversifying the energy mix.



2. 100% Shore Power Coverage: Cutting Vessel-related Pollution

- ◆ Every berth provides shore power facilities, enabling vessels to turn off onboard fuel generators during port stays.
- ◆ Cuts NOx (Nitrogen Oxides) by 80% and PM (Particulate Matter) by 90% per vessel call, with annual carbon reductions of ~21,000 metric tons.

3. Renewable Energy: Solar PV Power & Green Electricity

- ◆ A 5 MW PV system on yard canopies and roofs generates - 6 million kWh annually, maximizing clean energy use.
- ◆ Remaining power needs are met through 100% green electricity procurement, forming a low-carbon energy supply system.

Intelligent Energy Management & Emission Reduction



1. ITOS: Intelligent Energy Management & Control Platform

- ❑ The Intelligent Terminal Operating System (ITOS) **dynamically matches equipment load with energy supply** using AI algorithms, enabling precise control and optimization .
- ❑ Cuts unit energy consumption by **over 30%** compared to traditional terminals, significantly boosting energy efficiency.

2. Digitalized Emission Reduction: Fully Data-driven Process

- ❑ Integrates shore power usage, green electricity supply, and equipment energy consumption into a unified platform, making carbon reduction efforts **traceable, analyzable, and optimizable**.
- ❑ Data-driven strategies enhance the monitoring and evaluation of emission reductions, supporting continuous improvement in sustainability goals.

3. Carbon Neutrality Achieved: 100% Green Power Operation in 2025

- ❑ As of September 4, 2025, Yangshan Phase IV operates on **100% green electricity**, becoming the world's first carbon-neutral fully automated container terminal.
- ❑ This milestone highlights China's commitment to leading the global green transition in the port industry.

Ecological Protection and Restoration Practices



Launch Scene of Coastal Marine Ecological Protection and Restoration Work

01

Ecological Revetment Engineering and Construction of Fish Migration Channels

- ❑ **Ecological revetments** were constructed to replace traditional hard structures, stabilizing the coastline while creating habitats for marine life.
- ❑ Dedicated **fish migration channels** were integrated to maintain biodiversity and support aquatic species movement.

02

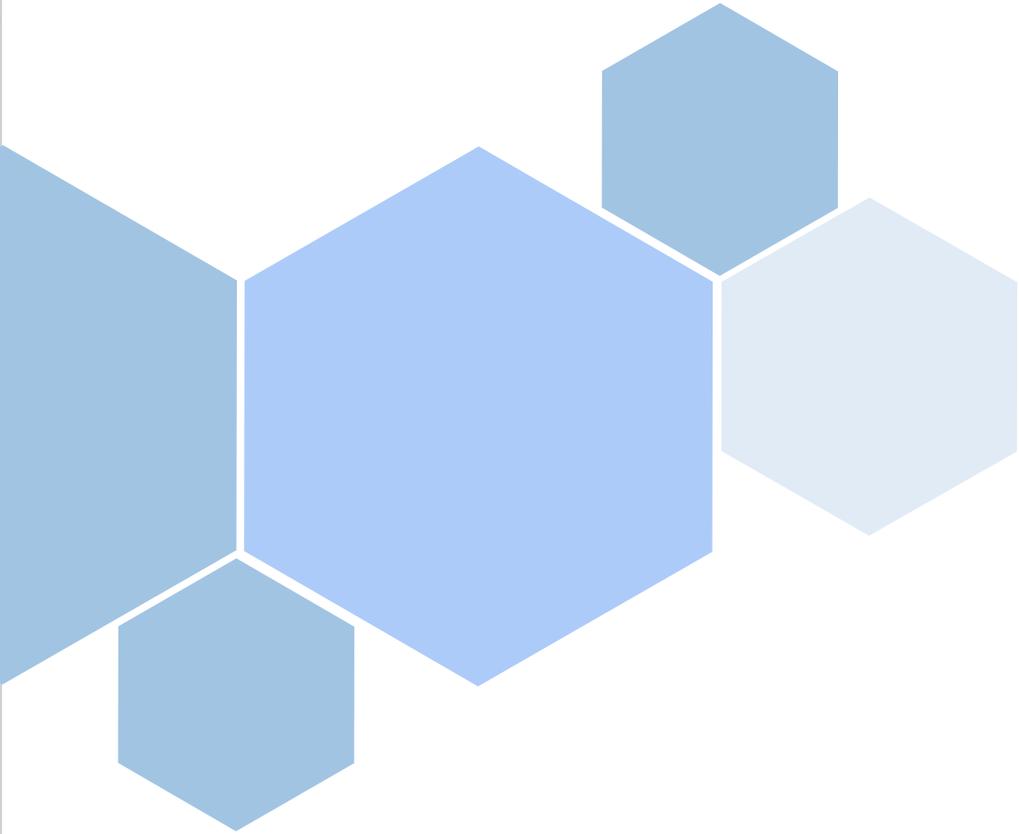
Recycling of Production Wastewater and Dust Control Measures

- ❑ **100% of production wastewater is recycled**, significantly reducing freshwater consumption.
- ❑ Dust emissions are controlled below **0.5 mg/m³** through sprinkling, enclosure systems, and real-time monitoring.

03

Regular Monitoring and Protection Mechanism for Marine Ecology

- ❑ A long-term **marine ecological monitoring system** tracks water quality and species diversity.
- ❑ Initiatives include deploying **artificial reefs** and restoring bird habitats to enhance local biodiversity.



05

Outlook Challenges & Future of Smart Ports

Core Challenges & Future Outlook: Smart Port Transformation

1. Current Core Challenges

- **Social & Employment Impact:** Automation may reduce 50%-60% of traditional port jobs, requiring careful workforce transition strategies.
- **Heavy Investment & Talent Gap:** Fully automated terminals require substantial upfront investment with long ROI cycles. Shortage of interdisciplinary skilled personnel in OT, IT, and DT maybe a crucial issue for operating and maintaining advanced systems.
- **System Integration & Security Risks:** Lack of global standards for core systems like TOS and ECS leads to interoperability issues. High reliance on networks increases vulnerability to cyber attacks, as seen in a 2021 incident where a major European port was suspended for over 48 hours due to cyber attack.

2. Future Outlook: From Automation to Smartization

- **Operation Smartization:** Leveraging digital twins and AI to shift from "experience-driven" to "model-driven" operations, achieving predictive decision-making and autonomous resource optimization.
- **Energy Greenization:** Transitioning from an "energy consumer" to a "green energy hub" by building flexible "Source-Grid-Load-Storage-Control" integrated power grids and utilizing new energies like hydrogen and green methanol.
- **Service & Ecosystem Integration:** Evolving from an "independent node" to a "supply chain brain" by providing high-value-added services and achieving seamless "Port-Shipping-Land" data interconnection for boosted synergy of the entire industrial chain.



Thank you!



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