Smart and future-ready ports: Building India's next-generation maritime gateways

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Message from FICCI



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India's maritime sector stands at a defining moment. Expanding trade, changing supply chains, and the transition to cleaner operations create an opportunity to build ports that are smarter, more resilient, and globally competitive. India's ports must now move beyond capacity creation to deliver predictable services, integrated operations, sustainability, and resilience across the port ecosystem.

The country enters this next phase with a strong foundation built through expanded capacity, improved connectivity, and modernised maritime infrastructure. **Maritime India Vision 2030 and Maritime Amrit Kaal Vision 2047** provide the long-term direction, while **Sagarmala 2.0, the Maritime Single Window (MSW) under Sagar Setu, the One Nation One Port Process (ONOP), and the Sagar Aankalan** guidelines are translating that ambition into investment, standardised digital processes, and stronger port performance.

This transition requires coordinated progress in digital technology, automation, clean energy, cybersecurity, and workforce capability. Artificial intelligence and digital twins can improve decisions, automation can strengthen operational consistency and safety, and electrification and shore power can reduce emissions. Their greatest value will come when data, systems, and skills develop together.

This **FICCI–PwC knowledge paper, 'Smart and future-ready ports: Building India's next-generation maritime gateways',** makes a clear case for moving from isolated technology projects to coordinated transformation. It positions predictive intelligence, autonomous operations, clean energy, trusted digital infrastructure, and workforce skills as interconnected priorities. It also offers a practical approach for ports to assess their starting point, prioritise investments, test solutions, and scale what works.

The report is timely because it connects long-term ambition with practical choices for port authorities, terminal operators, policymakers, and industry. Its emphasis on measurable outcomes, phased implementation, and coordinated investment can help ports pursue transformation paths suited to their operating context.

I am confident that the report will help align priorities, mobilise investment, and forge practical partnerships. Together, these efforts can advance India's vision for efficient, sustainable, secure, and globally trusted maritime gateways.

We welcome your valuable feedback and suggestions.

Message from PwC



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India's ports have expanded steadily over the past decade. Major ports handled a record 915 million tonnes of cargo in 2025–26.[1] This growth has come from investment in capacity, mechanisation, and port connectivity. Reforms such as the MSW and the ONOP have also simplified the port call.

At the same time, more is expected of ports. Shipping lines and cargo owners want predictable turnaround, real-time visibility, cleaner operations, and reliable service even when supply chains are disrupted. Meeting these expectations depends on how well a port uses its data and coordinates with the many organisations involved in each vessel call. It also depends on preparing people and systems for new ways of working.

Technology can support this shift. Artificial intelligence and digital twins can help ports anticipate congestion and equipment failures. Automation can make terminal operations faster and more consistent, and shore power and electrified equipment can reduce emissions at the quayside. All of these factors depends on reliable data, secure digital systems, and a skilled workforce, so the value is greatest when they are planned together.

India's policy direction already supports this transition through Maritime Amrit Kaal Vision 2047, the Harit Sagar Green Port Guidelines, and national initiatives on maritime security and skilling. The task ahead is to turn this direction into plans and results at each port.

This paper looks at what a smart, future-ready port involves. We also propose a framework to help port authorities and operators plan and prioritise this transition. We hope that this report encourages discussion among policymakers, port authorities, terminal operators, and industry on building India's next-generation maritime gateways.

1 PIB, Major Ports Record 915 Million Tonnes Cargo in FY 2025–26, Surpass Target with 7.06% Growth, 5 April 2026 (accessed as of 21 October 2026)

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01

Why ports must become future ready

India's ports: Gateways for national trade and growth

Ports are essential to India's trade, industrial growth and energy security. India has a coastline of about 11,099 km, nearly 14,500 km of potentially navigable waterways, 12 major ports, and more than 200 notified non-major ports. Maritime transport carries about 95% of the country's trade by volume and around 70% by value.[2] Ports therefore influence not only the movement of cargo but also the cost and reliability of imports, exports, and domestic supply chains.

Demand on this network has grown substantially. Cargo handled at India's major ports rose from ~607 million tonnes in 2015–16 (against a capacity of ~965 million tonnes) to ~915 million tonnes in 2025–26 (against a capacity of more than 1,700 million tonnes in 2025–26).[3] Investment in capacity, mechanisation, terminals, roads, and rail links made this growth possible. Capacity alone, however, will not decide how India's ports perform in the decade ahead as the conditions in which they operate are changing.



2 PIB, Sagarmala: Transforming India's Maritime Landscape (accessed as of 21 October 2026)

3 PIB, Sagarmala: Transforming India's Maritime Landscape and MoPSW, Annual report 2025-26 (accessed as of 21 October 2026)

A changing operating landscape: What ports must respond to

Ports today must respond to five main shifts in their operating environment:

- **Larger vessels:** Bigger ships can lower transport costs per container, but they also bring more cargo into each call. Ports must plan berths, pilots, tugs, cranes, yards, and onward transport as one operation, as a delay at any point erodes the benefit of faster ship-to-shore transfer.
- **Supply-chain disruption:** Geopolitical events, extreme weather, and congestion can change sailing schedules at short notice. Ports need reliable forecasts and contingency plans to adjust resources before queues build up.
- **Decarbonisation:** The International Maritime Organization's (IMO) 2023 Greenhouse Gas (GHG) Strategy sets an ambition for international shipping to reach net-zero greenhouse-gas emissions by or around 2050, and encourages port developments such as onshore power supply and infrastructure for zero or near zero emission fuels.
- **Competition for cargo and transshipment:** Shipping lines assess ports based on vessel turnaround, schedule reliability, connectivity, customs processes, and the efficiency of onward movement. About 75% of India's transshipped cargo[4] is handled at ports outside India, with Colombo, Singapore, and Klang handling more than 85% of this cargo.
- **Rising customer expectations:** Cargo owners expect shipment visibility and dependable delivery windows. They gain the full benefit of digital transactions when information flows across the port community and supports coordinated action.

From capacity to intelligence: The next stage for India's ports

Port operations have moved over time from largely manual work to greater use of equipment and technology. The next stage is for ports to become smart. A smart port uses shared data to plan operations across the port community, so that a change in a vessel's arrival time, for example, can be reflected at once in berth allocation, labour, yard preparation, and truck appointments. It also moves to cleaner energy, so that emissions can fall even as cargo volumes grow.

India's several national initiatives already point ports in this direction:

- Long-term vision: Maritime India Vision 2030 and Maritime Amrit Kaal Vision 2047, which outlines more than 300 actionable initiatives.[5]
- Integrated planning: Sagarmala promotes port-led development,[6] and PM Gati Shakti supports integrated infrastructure planning.[7]
- Greener operations: The Harit Sagar Green Port Guidelines set targets for greener operations at major ports.[8]
- Digital processes: The Maritime Single Window (MSW) and the One Nation One Port Process (ONOP) are standardising and digitising port processes.[9]

4 PIB, EoI to be invited for the International Transshipment Port at Great Nicobar Island (accessed as of 21 October 2026)

5 MoPSW, "Maritime India Vision 2030" and "Maritime Amrit Kaal Vision 2047" (accessed as of 21 October 2026)

6 PIB, Sagarmala: Transforming India's Maritime Landscape (accessed as of 21 October 2026)

7 PIB, Five Years of PM GatiShakti: Transforming India's Infrastructure Planning (accessed as of 21 October 2026)

8 MoPSW, 'Harit Sagar' Green Port Guidelines (issued May 2023) (accessed as of 21 October 2026)

9 PIB, 21st Meeting of Maritime State Development Council Concludes Successfully at Mumbai (accessed as of 21 October 2026)

02

What a smart, future-ready port looks like

For some, a smart port means paperless processes; for others, automated terminals or a port powered by clean energy. Each view captures part of the picture, but none is complete on its own. Policy and investment need a common view of what a future-ready port is, what it is built on, and how its parts fit together, so that gains in one area are not lost to gaps in another.

Beyond digitalisation: Defining the future-ready port

Digital transformation of India’s ports is progressing through initiatives such as the MSW and ONOP. These initiatives are standardising and digitising port processes, removing redundant and duplicate requirements and repeated data entry, and moving the port ecosystem towards a single digital interface. A future-ready port builds on this base. It uses connected data to move from reacting to congestion and breakdowns to predicting them and acting ahead by rescheduling berths, cranes, gates, and energy loads before operations are affected. Such a port is:

- Connected: Assets, vessels, cargo and stakeholders share data in real time.
- Predictive: Planning and operations draw on analytics, AI and simulation, alongside operational experience.
- Automated where it adds value: Repetitive, hazardous or precision tasks are automated or remotely operated.
- Low-carbon: Operations run increasingly on clean electricity, and the port supports cleaner shipping.
- Secure and resilient: Operations continue through disruption or recover quickly.
- People-centred: The workforce is skilled, safe, and engaged in the transition.





Technology foundation: The five layers of a future-ready port

A future-ready port rests on five interconnected layers of technology. Each layer builds on the one below it, and value grows as data moves up the stack—from raw signals to informed action. Two capabilities run across every layer: cybersecurity and resilience; and governance, skills, and change management. Weakness in either can undermine well-designed investments.

Figure 1: Five technology layers of a future-ready port

5	**Applications and control**	**Turn insight into action** Berth planning • gate automation • energy management • integrated command centre	**Cybersecurity and resilience**	**Governance, skills, and change**
4	**Intelligence**	**Turn data into insight** AI/ML models • predictive analytics • digital twin • optimisation engines		
3	**Data platforms**	**Make data usable across organisations** Port community system • data lake • APIs • common data standards		
2	**Connectivity**	**Carry data reliably, in real time** 5G / private LTE • IoT networks • edge computing • fibre backbone		
1	**Physical assets and sensors**	**Generate the data** Cranes • vehicles • berths • gates • CCTV • AIS • LiDAR • energy meters		

Value grows as data moves up the stack—from raw signals to informed action

Cross-cutting capabilities

03

Bringing it together: Our framework

The attributes and technology layers describe what a future-ready port is and what it is built on. Turning them into results calls for a structured approach to plan, prioritise, and measure the transition. Ports often adopt technologies one at a time, such as an AI tool for berth planning, an automated gate, or a solar installation. Each may be justified on its own. However, unless these technologies are planned together, data stays in separate systems, investments overlap, and the combined benefit falls short of its potential.

We propose our framework for smart ports to enable this. It groups the capabilities of a future-ready port into five pillars, each of which poses a specific question for the port operator.

Figure 2: Our framework

P	O	R	T	S
Predictive intelligence	**Optimised and autonomous operations**	**Renewable and electrified energy**	**Trusted digital infrastructure**	**Skilled workforce**
How does the port think and plan ahead?	**How does the port act faster and more reliably?**	**How does the port power itself sustainably?**	**How does the port protect its systems and keep running?**	**Who runs the port of the future?**
AI-enabled operations and digital twins that forecast arrivals, congestion, and equipment health, and recommend the best plan.	Smart terminal technologies, automation, and autonomous cargo handling that convert better plans into shorter turnaround, less idle time, and higher productivity.	Shore power, electrification of equipment and vehicles, and smart energy management that cut emissions and energy costs.	Cybersecurity and resilient digital infrastructure that safeguard increasingly connected operations.	Skilling, reskilling, and inclusive workforce transition for digitally transformed operations.

Foundation: Shared data, common standards, and sound governance enable all five pillars to work as one system.



3.1 Pillar P: Predictive intelligence (AI-enabled port operations and digital twins)

Ports already collect data on vessels, berths, cranes, yards, equipment, and trucks, mostly in separate systems and to record what has happened. Predictive intelligence uses this data to anticipate what will happen next, giving port authorities and operators time to act before problems reach the quay, the yard, or the gate.

AI across the port call: From vessel arrival to cargo evacuation

A port call is a chain of connected steps, and a delay at one step results in delays in the subsequent steps. AI models forecast conditions at each step and recommend how berths, equipment, and people should be allocated. The largest gains come when these forecasts are linked: A better arrival forecast improves berth and crane planning, which makes yard and gate activity more predictable.

Figure 3: AI use cases across the port call

Before arrival	Anchorage and pilotage	Berth and quay	Yard	Gate and evacuation
What AI does Combines AIS data, weather, and voyage history to forecast arrival time	**What AI does** Forecasts demand for pilots, tugs, and channel slots	**What AI does** Allocates berths and cranes by vessel size, draft, cargo, tides, and equipment availability	**What AI does** Decides container stacking positions to reduce re-handling and travel	**What AI does** Forecasts truck arrivals and rail rake availability
Outcome More accurate ETAs; supports JIT arrival	**Outcome** Lower pre-berthing waiting time	**Outcome** Better berth and crane use	**Outcome** Fewer crane moves; lower dwell time	**Outcome** Smoother gate flow; less yard build-up

Across all stages—predictive maintenance: Sensor data on load, temperature, and vibration flags likely failures in cranes, conveyors, and vehicles before they occur.

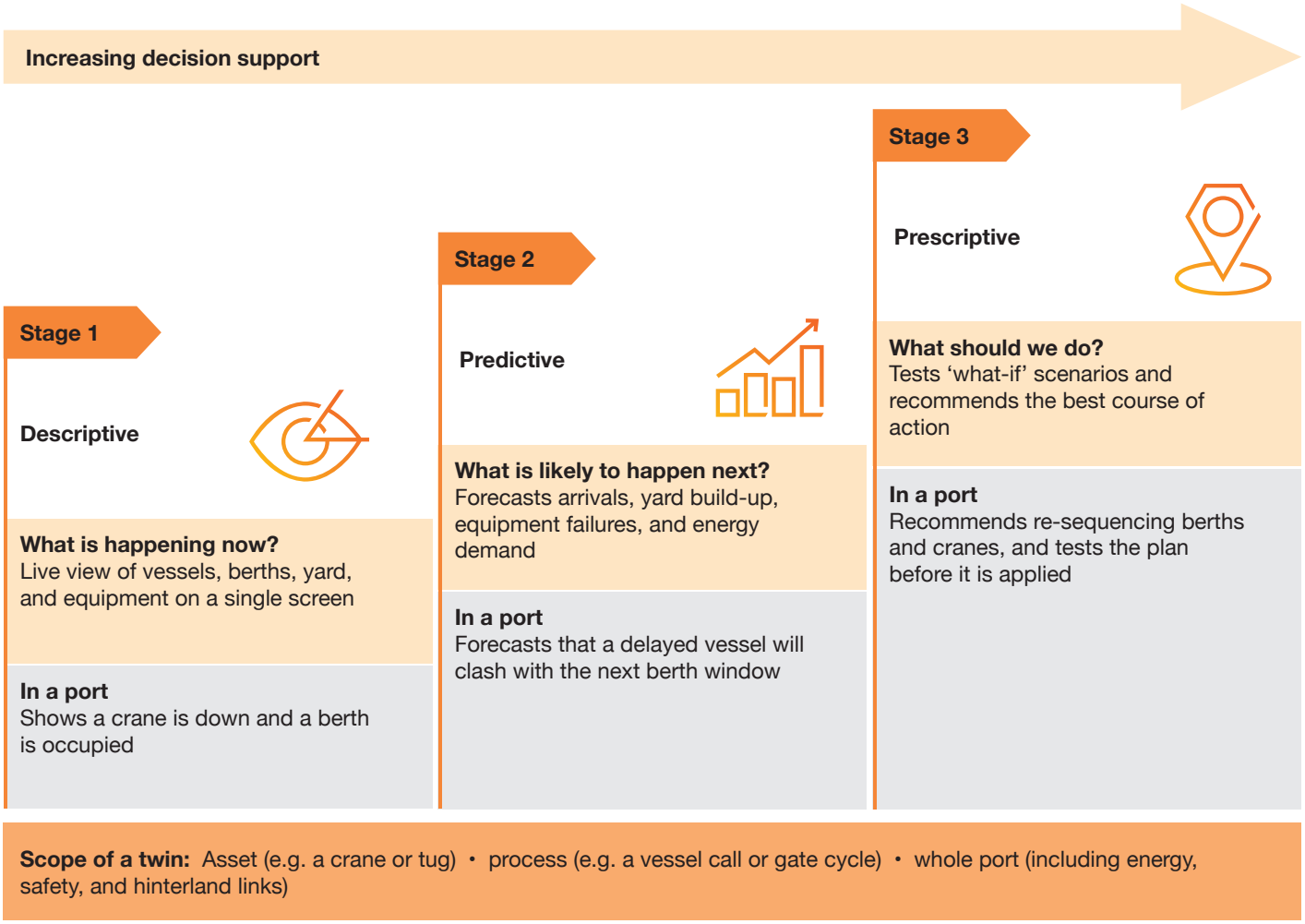
Accurate forecasts also enable just-in-time (JIT) arrival, under which a ship adjusts its speed to arrive when its berth, fairway, and nautical services are available. The Just In Time Arrival Guide, published under the IMO-led Global Maritime Energy Efficiency Partnerships Project (GloMEEP), notes that ships may spend 5–10% of their time waiting to get into port, and that JIT arrival reduces fuel consumption and emissions.[10]

10 GEF-UNDP-IMO GloMEEP Project and the Global Industry Alliance, Just In Time Arrival Guide – Barriers and Potential Solutions (2020) (accessed as of 21 October 2026)

Digital twins: From real-time visibility to decision support

A digital twin is a virtual replica of an asset, process, or the whole port, kept up to date with real-world data. It matures from showing current conditions to forecasting them and recommending action. Its value lies in testing decisions before they are applied, for example by simulating a delayed vessel or an equipment breakdown and choosing the response with least disruption.

Figure 4: Stages of digital twin maturity



V.O. Chidambaranar Port: India's first major port digital twin

In February 2026, V.O. Chidambaranar Port Authority became the first major Indian port to launch a digital twin. Using IoT sensors, GPS, LiDAR, drones, and CCTV, it mirrors berth occupancy, vessel movements, crane utilisation, and yard capacity in real time, and supports predictive maintenance, berth optimisation, emissions tracking, and 'what-if' simulation. It is designed to reduce vessel turnaround time by up to 25% and is being implemented in phases.[11]

11 PIB, V.O. Chidambaranar Port becomes First Indian Major Port to Implement Digital Twin, 12 March 2026 (accessed as of 21 October 2026)

Data foundations: Shared, standardised, and well-governed data

Predictive tools are only as reliable as their data, which is held by many parties in different formats for a single port call. Ports need common platforms, data standards, and clear rules on who owns, shares, and uses each data set. Since 1 January 2024, the IMO's Convention on Facilitation of International Maritime Traffic (FAL Convention) has required public authorities to enable electronic submission of information to a single window and to ensure that data on a ship's arrival, stay, and departure is provided only once and re used to the maximum extent possible.[12] The IMO Compendium on Facilitation and Electronic Business supports this by harmonising the data elements required during a port call and standardising electronic messages. These regulations were made in alignment with the World Customs Organization (WCO), United Nations Economic Commission for Europe (UNECE), and International Organization for Standardization (ISO).[13]



12 IMO, Resolution FAL.14(46), Amendments to the Annex to the Convention on Facilitation of International Maritime Traffic, 1965 (adopted on 13 May 2022) (accessed as of 21 October 2026)

13 GEF-UNDP-IMO GloMEEP Project and the Global Industry Alliance, Just In Time Arrival Guide – Barriers and Potential Solutions (2020) (accessed as of 21 October 2026)

3.2 Pillar O: Optimised and autonomous operations (smart terminal technologies and autonomous cargo handling)

Predictive intelligence plans what should happen at the port. Optimised and autonomous operations make it happen at the quay, in the yard, and at the gate. This is where shipping lines and cargo owners see the gains: shorter vessel turnaround, higher crane productivity, lower container dwell time, and faster truck movement.

Smart terminal technologies: Faster, more predictable operations

Most smart terminal technologies can be added to existing terminals without rebuilding them, and each removes a specific source of delay. They work best together: The terminal operating system (TOS) uses live data from gates, sensors, and cameras to assign each move to the right equipment. The same approach applies to bulk and liquid terminals. In Maharashtra, for example, a supervisory control and data acquisition (SCADA) and programmable logic controller (PLC) automation system has been taken up at the marine oil terminal.[14]

Figure 5: Smart terminal technologies and the efficiency measures they improve

Technology	Vessel turnaround	Crane productivity	Container dwell	Truck turnaround	Equipment uptime	Safety
Automated gates OCR, RFID, and ANPR identify trucks and containers without manual checks			▪	■		▪
Smart TOS Coordinates berth, yard, and gate operations in real time	■	■	■	▪		
Computer vision Detects container damage, reads seals, and monitors safety zones		▪		▪		■
Drones Inspect infrastructure and assets that are hard to reach					▪	■
Connected equipment (IoT) Cranes and vehicles report location, load, and condition live	▪	▪			■	▪

■ Primary effect ▪ Supporting effect

Combined effect: The TOS uses live data from gates, cameras, and connected equipment to assign each move to the right equipment.

14 PIB, Development and Modernisation of Ports in Maharashtra, 4 August 2026 (accessed on 21 October 2026)

Automation and autonomous cargo handling: A progressive path

Terminals usually automate step by step. Gate processing and container stacking in the yard are often automated first, as these tasks are repetitive and take place in controlled areas. The transfer of containers between quay and yard can follow, using automated vehicles. Work at the quayside is harder to automate, as tasks such as lashing still need people on site. Some terminals operate quay cranes remotely from a control room instead. The right level of automation therefore differs from one terminal to another.

The International Transport Forum's (ITF's) review of container port automation finds that automation suits terminals with steady cargo flows better than those with volatile volumes, such as transshipment terminals.[15]

Tuas Port, Singapore: Automation built into new capacity

Tuas Port opened in September 2022 and is being developed in four phases. When completed in the 2040s, it will be the world's largest fully automated terminal, with a handling capacity of 65 million TEUs. Beyond the terminal, Singapore is adding maritime 5G coverage of its anchorages and fairways and an AI-enabled vessel traffic management system that predicts potential collisions.[16]

Planning automation: Aligning investment with outcomes

The ITF also recommends better assessment of costs and benefits before committing to automation, more flexible labour arrangements, social dialogue between employers and workers, and attention to the social costs of automation.[17] Greenfield ports such as Vadhavan (Maharashtra), approved in June 2024 with a planned capacity of 298 million tonnes a year,[18] can design automation into their layout from the outset; existing terminals usually gain more from phased upgrades. In both cases, the business case should be tested against turnaround, crane productivity, dwell time, energy use per move, and safety.



15 International Transport Forum, Container Port Automation: Impacts and Implications, Case-Specific Policy Analysis, OECD Publishing (2021) (accessed as of 21 October 2026)

16 Maritime and Port Authority of Singapore, Media Factsheet: Strengthening Singapore's Competitiveness as a Hub Port and International Maritime Centre, 3 March 2023 (accessed on 21 October 2026)

17 International Transport Forum, Container Port Automation: Impacts and Implications, Case-Specific Policy Analysis, OECD Publishing (2021) (accessed as of 21 October 2026)

18 PIB, Development and Modernisation of Ports in Maharashtra, 4 August 2026 (accessed as of 21 October 2026)

3.3 Pillar R: Renewable and electrified energy (shore power, electrification, and smart energy management)

At berth, ships usually run auxiliary engines to power on-board systems, while cranes, yard equipment, tugs, and trucks use diesel and electricity. As this demand is concentrated in one area, ports are well placed to shift it to clean electricity through shore power, electrification, and smart energy management.

Energy transition: A shared global and national direction

The shift to cleaner port energy is guided by clear direction at both the global and national level. The 2023 IMO GHG Strategy sets ambitions for carbon intensity, uptake of zero or near-zero emission fuels, and net-zero emissions for international shipping by or around 2050, with checkpoints for 2030 and 2040.[19] In India, the Harit Sagar Green Port Guidelines set targets for major ports for 2030 and 2047.[20]

Figure 6: Global and national decarbonisation targets

Framework	Indicator	2030	2035	2040	2047	2050
IMO 2023 GHG Strategy International shipping; reductions vs 2008	Reduce total annual GHG emissions from international shipping (indicative checkpoints)	At least 20%, striving 30%	–	At least 70%, striving 80%	–	–
	Reduce CO_2 emissions per transport work, as an average across international shipping	At least 40%	–	–	–	–
	Uptake of zero/near-zero GHG emission technologies, fuels and/or energy sources (share of energy used)	At least 5%, striving 10%	–	–	–	–
	Net-zero GHG emissions from international shipping	–	–	–	–	By or around 2050
Harit Sagar Green Port Guidelines Major ports, India; reductions vs FY 2022–23 baseline	% share of renewable energy consumption at ports (self-generated + procurement from grid)	>60%	–	–	>90%	–
	% port equipment/vehicles electrified	>50%	–	–	>90%	–
	% reduction in energy consumption/tonne of cargo	>20%	–	–	–	–
	% reduction in CO_2 emission/tonne of cargo	>30%	–	–	>70%	–
	% GHG emission reduction in all coastal/ EXIM vessels	>10%		–	>50%	–
	LNG bunkering station	At least one	–	–	–	–
	Green hydrogen/ammonia bunkers and refuelling facilities	–	By 2035	–	–	–

19 IMO, Resolution MEPC.377(80), 2023 IMO Strategy on Reduction of GHG Emissions from Ships (adopted on 7 July 2023) (accessed as of 21 October 2026)

20 MoPSW, 'Harit Sagar' Green Port Guidelines (issued May 2023) (accessed as of 21 October 2026)

Shore power: Cleaner ships at berth

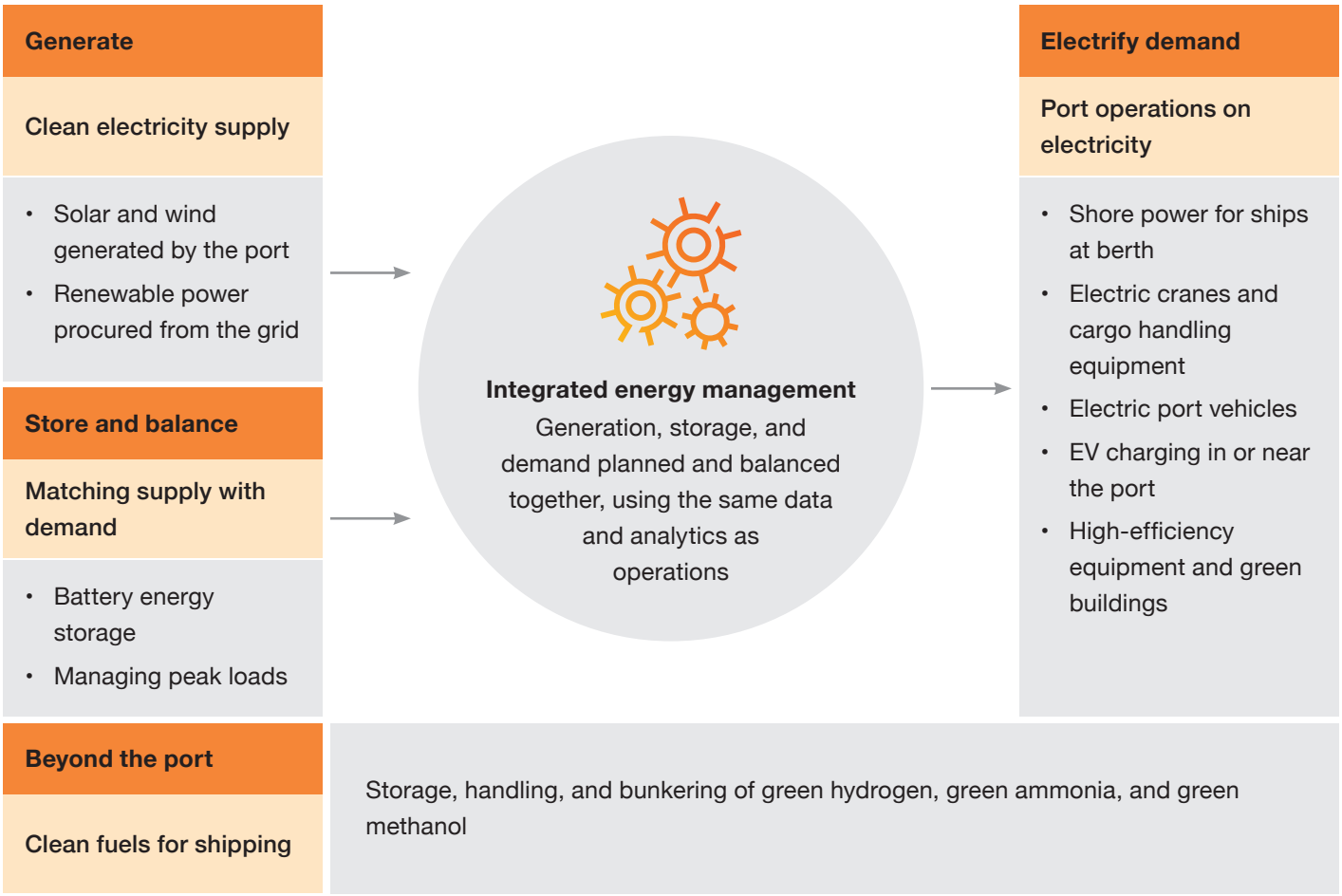
Onshore power supply (OPS) supplies electricity from the shore to meet a ship's power needs at berth. With it, the ship can switch off its auxiliary engines for the duration of its stay. In June 2023, the IMO issued interim guidelines on the safe operation of OPS for ships on international voyages, covering both the ship side and the shore side.[21]

In India, the Harit Sagar Guidelines require ports to develop shore-to-ship power in a phased manner and allow incentives such as queue priority or a rebate in berth dues for vessels able to take their full running load from shore.[22] Ports build the infrastructure, and incentives encourage ships to use it.

Electrification and smart energy management: The port as an integrated energy system

The Harit Sagar Guidelines require ports to convert cranes, forklifts, vehicles, and other equipment to electric power in a phased manner, and require future procurement to be electric or compatible with low-carbon fuels such as CNG, methanol, ammonia, or hydrogen fuel cells. As electrified equipment, shore power, and renewable generation grow, the port's energy has to be managed as one system. Generation, storage, and demand can be planned together, much as berths and cranes are scheduled today, using the same data and analytics as predictive intelligence.

Figure 7: Integrated port energy system



21 IMO, MSC.1/Circ.1675, Interim Guidelines on Safe Operation of Onshore Power Supply (OPS) Service in Port for Ships Engaged on International Voyages (27 June 2023) (accessed as of 21 October 2026)

22 MoPSW, 'Harit Sagar' Green Port Guidelines (issued May 2023) (accessed as of 21 October 2026)

The port's energy role also extends beyond its own operations. The Harit Sagar Guidelines require ports to prepare action plans for the targets set for them under the National Green Hydrogen Mission. These plans include infrastructure at select ports for storing, bunkering, and refuelling green hydrogen and its derivatives.

Green ammonia bunkering and refuelling facilities are to be set up at all major ports by 2035. Deendayal, Paradip, and V.O. Chidambaranar ports have been recognised as green hydrogen hubs.[23] Ports are becoming suppliers of clean energy to shipping as well as users of it.

V.O. Chidambaranar Port, Tuticorin: Building a green energy hub on the southern coast

In September 2025, V.O. Chidambaranar Port commissioned a 10 Nm^3/hr green hydrogen pilot facility. It powers streetlights and an EV charging station in the port colony. A new 400-kW rooftop solar plant raised the port's rooftop solar capacity to 1.04 MW, the highest among Indian ports. The port also laid the foundation for a 6-MW wind farm and for a 750-m^3 pilot green methanol bunkering and refuelling facility, aligned with the proposed Kandla–Tuticorin Coastal Green Shipping Corridor.[24]

Deendayal Port, Kandla: Advancing clean fuels and electrification on the western coast

In July 2025, the Deendayal Port Authority (DPA) commissioned a 1-MW green hydrogen plant at Kandla. The plant can produce about 140 tonnes of green hydrogen a year and is the first module of a 10-MW project.[25] DPA also plans to expand into green ammonia production.[26] In December 2025, steel cutting began on India's first all-electric green tug,[27] built for DPA with a 60-tonne bollard pull. DPA was the first port to formally start construction under the Green Tug Transition Programme.

3.4 Pillar T: Trusted digital infrastructure (cybersecurity and resilient digital maritime infrastructure)

Each pillar adds digital systems, and a disruption of these systems can stop the physical movement of cargo. Trusted digital infrastructure keeps systems protected, detects incidents early, and lets operations continue or recover quickly.

Expanding digital footprint: Where ports are exposed

The IMO Guidelines on Maritime Cyber Risk Management call on stakeholders to safeguard shipping from threats related to digitalisation, integration, and automation. For ports, exposure grows as IT and operational systems converge, more devices are connected, and more external organisations link to port systems. In August 2026, the Union Minister for Ports, Shipping and Waterways said that India's transition to smart ports must be accompanied by equally robust cybersecurity and risk management.[28]

23 PIB, Development of Green Ports and Maritime Infrastructure, 28 March 2026 (accessed as of 21 October 2026)

24 PIB, Shri Sarbananda Sonowal Unveils Green Hydrogen Pilot Project at VOC Port in Tamil Nadu (accessed as of 21 October 2026)

25 PIB, Indigenously-Built 1 MW Green Hydrogen Plant Commissioned at Kandla Port by Shri Sarbananda Sonowal (accessed as of 21 October 2026)

26 PIB, Shri Sarbananda Sonowal Virtually Flags Off Electrolysers for Green Hydrogen Plant in Kandla (accessed as of 21 October 2026)

27 PIB, India Takes Major Green-Tech Leap as Sarbananda Sonowal Flags off Nation's First All-Electric Tug Project (accessed as of 21 October 2026)

28 PIB, Union Minister Sarbananda Sonowal Pitches Technology-Led Maritime Security Framework as India's Port Network Expands, 6 August 2026 (accessed as of 21 October 2026)

Figure 8: Cyber risk exposure in a connected port

IT–OT convergence	More connected devices	More external links
Operational systems now connect to enterprise networks	**Every new device must be secured and monitored**	**Port systems connect to many outside organisations**
• Terminal operating systems • Crane and gate controls • Energy and shore power controls	• IoT sensors and cameras • Automated vehicles and drones • Smart meters and edge devices	• Port community systems • Single-window platforms • Shipping line portals and vendor remote access
Why it matters An incident starting in an office system can reach systems that move cargo	**Why it matters** Each added device widens the area to be protected	**Why it matters** Each connection is a potential entry point

Result: A disruption to digital systems can now halt the physical movement of cargo, not just administrative work.

Policy direction: Global and national cyber frameworks

IMO Resolution MSC.428(98) encourages administrations to ensure that cyber risks are addressed in ship safety management systems no later than the first annual verification of the company's Document of Compliance after 1 January 2021.[29] International Association of Classification Societies (IACS) cyber resilience requirements E26 and E27 apply to new ships contracted for construction on or after 1 July 2024.[30]

In India, CERT-In Directions require organisations to report specified cyber incidents within six hours.[31] The Bureau of Port Security, being constituted under the Merchant Shipping Act, 2025, will have a dedicated division to protect port IT infrastructure,[32] and the Ministry of Ports, Shipping and Waterways (MoPSW) has advocated 'security by design' at every stage of port development.[33]



29 IMO, Resolution MSC.428(98), Maritime Cyber Risk Management in Safety Management Systems (adopted on 16 June 2017) (accessed as of 21 October 2026)

30 IACS, IACS UR E26, and E27 Press Release (accessed as of 21 October 2026)

31 CERT-In, MeitY, Directions under sub-section (6) of section 70B of the Information Technology Act, 2000, No. 20(3)/2022-CERT-In (28 April 2022) (accessed as of 21 October 2026)

32 PIB, Union Home Minister and Minister of Cooperation Shri Amit Shah convenes a meeting for the constitution of a dedicated body, the Bureau of Port Security (BoPS), for the security of vessels and port facilities, 19 December 2025 (accessed as of 21 October 2026)

33 PIB, Union Minister Sarbananda Sonowal Pitches Technology-Led Maritime Security Framework as India's Port Network Expands, 6 August 2026 (accessed as of 21 October 2026)

Building cyber resilience: From protection to recovery

The IMO Guidelines set out six functional elements that work concurrently and continuously: govern, identify, protect, detect, respond and recover.[34] For a port, the aim is to keep operations running or restore them quickly when an incident occurs.

Figure 9: Six functional elements of cyber resilience



Govern
Leadership accountability, risk ownership, and policies that span IT and operational systems



Identify

Map all systems, including operational technology and their critical dependencies



Protect

Separate critical operational systems from office networks; build security into new systems by design



Detect

Monitor IT and operational networks continuously; staff who recognise and report threats



Respond

Act decisively to contain incidents; rehearse response through regular drills



Recover

Tested backups and manual fall-back procedures to keep cargo moving while systems are restored

DP World: Rapid containment and recovery

On 10 November 2023, DP World in Australia detected unauthorised access to its corporate network and disconnected it from the internet, which affected land-side operations but contained the incident. Operations restarted on 13 November, and by 20 November the backlog of some 30,137 containers was cleared.[35]

3.5 Pillar S: Skilled workforce (maritime skilling for digitally transformed port operations)

Every capability in the earlier pillars depends on people who can act on predictive outputs, operate and maintain automated and electrified equipment, and keep operations running when systems fail. A future-ready port plans for workforce change as carefully as it does for its technology.

34 IMO, MSC-FAL.1/Circ.3/Rev.4, Guidelines on Maritime Cyber Risk Management (28 May 2026) (accessed as of 21 October 2026)

35 DP World, Media Statement: Update on Cybersecurity Incident, 28 November 2023 (accessed as of 21 October 2026)

Changing roles: New skills for digital port operations

Manual data entry, on-site equipment operation, and paper documentation give way to supervision of automated systems, remote operation, data interpretation, and maintenance of electrical and digital assets. Internationally, the IMO is revising the Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW Convention and Code), the global framework for seafarer training and certification, to adapt it to new trends and developments in the maritime sector, including emerging technologies. In February 2026, it finalised interim guidelines on training for seafarers on ships using methyl/ethyl alcohols and ammonia as fuel.[36]

Figure 10: Evolving roles in port operations

Area	Traditional focus	Emerging focus	Key skills
Cargo handling	On-site equipment operation	Remote operation and supervision of automated equipment	Remote control, system supervision, exception handling
Planning and control	Experience-based planning; manual data entry	Interpreting real-time data and predictive outputs	Data literacy, analytics, decision support tools
Maintenance	Mechanical and diesel equipment	Electrical, electronic, and digital assets	Electrical systems, automation, predictive maintenance
Energy	Fuel supply and basic power distribution	Shore power, charging, and energy management	High-voltage safety, energy management systems
Digital and cyber	Paper-based documentation and records	Securing and running connected systems	Cyber awareness, incident response, fall-back operations

Common thread: Existing operational experience remains the base on which new skills are built.

36 IMO, Sub-Committee on Human Element, Training and Watchkeeping (HTW 12) – Closing remarks by the Secretary-General, 27 February 2026 (accessed as of 21 October 2026)

Building capability: Training, certification, and partnerships

The Directorate General of Maritime Administration (DGMA) has linked Industrial Training Institutes (ITIs) with Maritime Training Institutes (MTIs). This creates a pathway into maritime careers for students from trades such as electrician, fitter, and refrigeration technician. India now has 176 MTIs (81 pre-sea and 95 post-sea), with an approved annual intake of 23,717 candidates in pre-sea courses and 22,264 in post-sea courses. These institutes run 20 simulator-based courses and are conducted nationwide. Training facilities include full mission bridge simulators, full mission engine room simulators, radar/automatic radar plotting aid (ARPA), Electronic Chart Display Information System (ECDIS), Global Maritime Distress and Safety System (GMDSS), liquid cargo handling, LNG/LPG, and ship manoeuvring simulators. More than 1.15 lakh candidates underwent simulator-based training between 2020 and 2025. Separately, the e-Samudra platform provides a paperless e-governance system covering maritime training, certification, and examinations.[37]

At the port level, suppliers can train staff before new systems go live, and simulators provide safe settings to practice operations and emergencies. Ports also need to bring existing staff along by involving workers early in technology plans, reskilling them for new roles, and updating safety procedures for work alongside automated equipment, shore power, and new fuels.



Centre of Excellence in Maritime & Shipbuilding (CEMS)—industry-linked skilling for the maritime sector

CEMS was set up by the MoPSW under the Sagarmala Programme with industry partners, at a cost of ₹766 crore. Industry contributed technology, expertise, and 87% of the funding. The Ministry provided a one-time grant of ₹50.07 crore for machinery, classrooms, workshops, and labs.[38] CEMS has campuses at Mumbai and Visakhapatnam, with more than 20 labs, and has trained more than 21,000 students. It offers training programmes, including online courses, in areas such as product design, electrical systems, PLC and automation, mechatronics, CNC machining, and pneumatics and hydraulics. The model shows how public support and industry partnership can create industry-relevant training capacity.[39]

37 MoPSW, Lok Sabha Unstarred Question No. 3385 on Maritime Skill Development, answered on 7 August 2026 (accessed as of 21 October 2026)

38 PIB, World Class Center of Excellence in Maritime and Ship Building to come up in Mumbai and Vishakhapatnam, 21 November 2017 (accessed as of 21 October 2026)

39 CEMS, Centre of Excellence in Maritime & Shipbuilding (accessed as of 21 October 2026)

04

The way forward: Building India's future-ready ports

The previous chapters looked at each pillar in isolation. Considered together, they lead to three conclusions.

First, the pillars depend on each other:

- Predictive intelligence needs shared data.
- Automated equipment needs predictive plans to carry out.
- Electrified equipment and shore power add electricity demand that has to be managed with the same data.
- Every new system adds to what must be protected.
- Every new technology changes the skills the workforce needs.

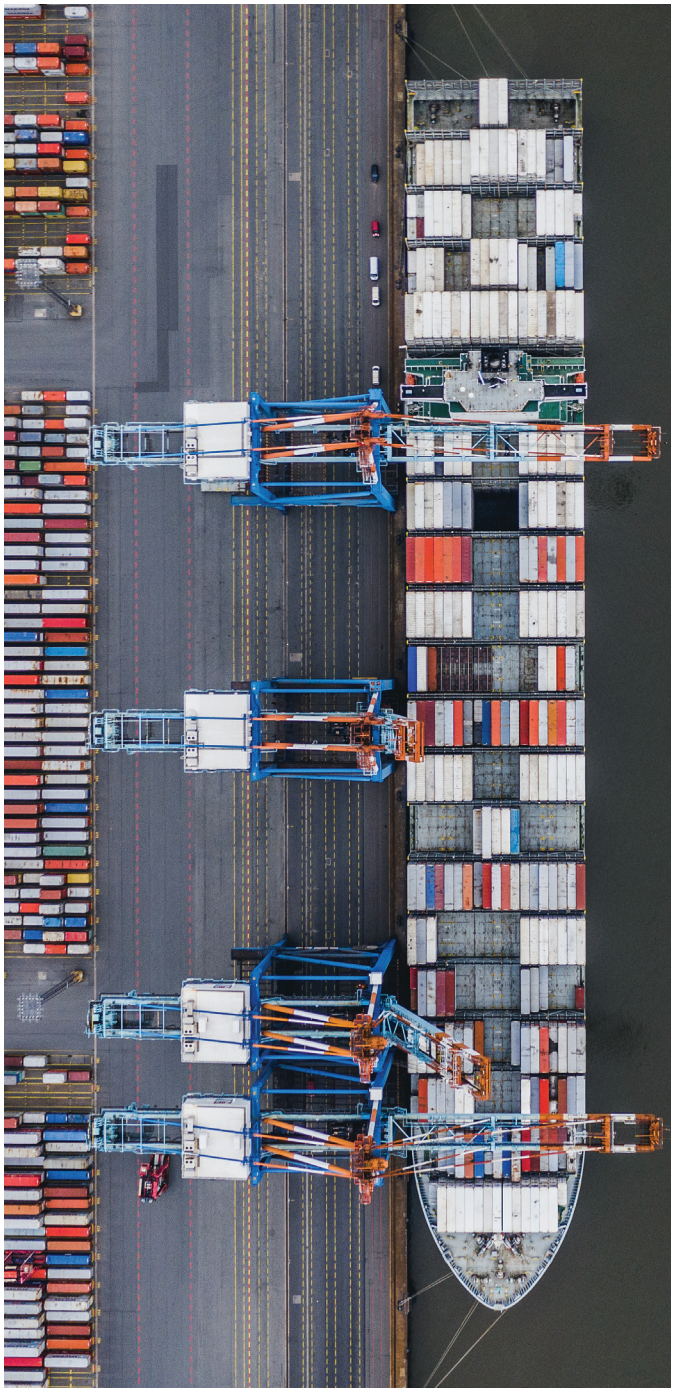
A port that invests in one pillar alone is likely to find the benefits limited by pillars it has not developed.

Second, the direction is already set. The IMO's GHG Strategy and the Harit Sagar Guidelines set time-bound energy targets, and the FAL Convention requires single-window data exchange. India is setting up the Bureau of Port Security, and MoPSW has advocated a security by design approach. National skilling platforms such as CEMS are in place. Ports can therefore act on existing policies to achieve plans, investments and results at their own sites.

Third, Indian ports already have working examples:

- a digital twin at V.O. Chidambaranar Port
- green hydrogen and an all-electric tug at Deendayal Port
- industry-linked skilling through CEMS

Each of these covers one pillar, or one part of a port's operations. The task ahead for each port is to move from such individual initiatives to a coordinated programme across all five pillars, so that its data, operations, energy, digital security, and workforce develop together.



Areas of improvement

Figure 11 sets out the priority actions for each pillar. Four principles would shape the order of these actions:

- **Start from outcomes and a baseline:** Link each investment to measures such as turnaround, waiting time, dwell time, energy use, and CO_2 per tonne.
- **Build the data foundation first:** Data inventories, standards, and sharing arrangements can lower the cost and risk of everything built on them.
- **Plan by dependency:** Shore power needs grid capacity, and automation needs a modern TOS, cyber protection, and trained staff before go-live.
- **Match the path to the port:** Greenfield ports can design automation and electrification into their layout from the outset, while existing ports usually gain more from phased upgrades.

Figure 11: Priority actions by pillar

Pillar	Foundations (near term)	Scale-up (medium term)	Integration (longer term)
P **Predictive intelligence**	Data inventory and common data standards; ETA prediction and berth planning using single-window data	Extend digital twins from pilot areas to the whole port; connect port community data	Prescriptive twin supporting an integrated command centre
O **Optimised and autonomous operations**	Automated gates, modern TOS, connected equipment at existing terminals	Remote crane operation where volumes justify it; automation designed into greenfield ports	Coordinated automated operations across quay, yard, and gate
R **Renewable and electrified energy**	Energy baseline; shore power for port crafts and selected berths; renewable procurement	Electrify yard equipment and tugs; port-wide energy management	Clean-fuel bunkering in line with Harit Sagar milestones
T **Trusted digital infrastructure**	Inventory of IT and OT systems; incident reporting; security by design in all new contracts	Monitoring of operational systems; tested recovery plans and drills	Participation in national threat information sharing
S **Skilled workforce**	Map roles affected by each project; involve workers early	Training ahead of go-live using suppliers, simulators, and national institutions	Career paths in data, automation, energy, and cyber roles

Reimagining the smart port journey: A practical approach

Two perspectives should shape how a port starts this journey. First, becoming a smart port is not only about implementing technology solutions; it is also about how technology supports decision-making. Technology adds value when it helps port authorities and operators take decisions more quickly and act together. Second, processes need to be reimagined before they are digitised. A process digitised as it stands carries its delays, redundancies, and duplicate steps into the new system. A piecemeal approach, with projects taken up one at a time, leaves data and benefits fragmented. A port gains most when it redesigns processes across the port community and then implements technology in a planned sequence.

We at PwC have worked across the port value chain with port authorities, terminal operators, shipping lines, customs, customs brokers, and freight forwarders, redesigning processes, building technology-enabled decision support systems, and delivering digital transformation programmes. Drawing on this experience, our approach to reimagining the smart port journey follows five steps:

1. **Establish the baseline.** Map the port call end to end, from pre-arrival to cargo evacuation, and measure current performance. Measures should include turnaround time, pre-berthing waiting time, berth and crane productivity, container dwell time, gate time, documents and approvals per call, and energy use per tonne. This shows where time and cost are lost, and sets the reference for judging every later investment.

2. **Reimagine and standardise processes.** Redesign processes using the baseline findings. Remove duplicate documents, approvals, and data entry. Agree on common definitions and service levels across stakeholders, and align with national platforms such as the MSW.

3. **Assess the port's maturity and build the business case.** Assess the port's current maturity across the five pillars of our framework and identify the gaps that would hold back the redesigned processes. Prioritise use cases by value and readiness. Give each a business case covering cost, expected benefits, KPIs, and dependencies on other pillars. The output would be a sequenced roadmap.

4. **Pilot and prove.** Test priority use cases on a defined scope, such as arrival prediction linked to berth planning, or gate automation. Measure results against the baseline. Involve the staff who will use the system, and refine the design before committing to wider investment.

5. **Scale and sustain.** Roll out proven use cases across the port through outcome-based procurement, with interoperability, cybersecurity, and training built into each contract. Track KPIs against the baseline, and update the roadmap as needs and technologies change.

India's ports begin this transition with a strong base. Initiatives such as the MSW and the ONOP are standardising and digitising port processes and laying the path for smart ports. Policy direction is clear, and working examples are emerging across several pillars. A structured approach that starts from a clear baseline, reimagines processes before digitising them, and considers the five pillars of our framework together could help ports progress towards becoming smart and future ready. The benefits for each port will depend on its context, priorities and implementation. In doing so, they could turn these investments into lasting gains in efficiency, sustainability, and resilience, and contribute to India's wider goals for trade, growth, and lower emissions.



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Established in 1927, FICCI is the largest and the oldest apex business Organisation in India. Its history is closely interwoven with India's struggle for independence, its industrialization, and its emergence as one of the most rapidly growing global economies.

A non-government, not-for-profit Organisation, FICCI is the voice of India's business and industry. From influencing policy to encouraging debate, engaging with policymakers and civil society, FICCI articulates the views and concerns of industry. The Organisation serves its members from the Indian private and public corporate sectors and multinational companies, drawing its strength from diverse regional chambers of commerce and industry across states, reaching out to more than 2,50,000 companies. FICCI provides a platform for networking and consensus building within and across sectors and is the first port of call for Indian industry, policymakers, and the international business community.

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We help you build trust so you can boldly reinvent

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