SMART PORTS MANUAL

STRATEGY AND ROADMAP

IDB

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ACRONYMS

3D	Three-dimensional technology
4G	Fourth generation of mobile technology
5G	Fifth generation of mobile technology
ADSL	Asymmetrical digital subscriber line
AGS	Automated gate system
AI	Artificial intelligence
AIS	Automatic identification system
AM	Additive manufacturing
B2G	Business-to-government
BI	Business intelligence
BSC	Balanced scorecard
CCTV	Closed-circuit television
CMS	Content management system
CO2	Carbon dioxide
DLT	Distributed ledger technologies
EAI	Enterprise application interface
ECA	Emission control area
ECLAC	Economic Commission for Latin America and the Caribbean
ERP	Enterprise resource planning
FTSW	Foreign trade single window
G2G	Government-to-government
GIS	Geographic information system
HPA	Hamburg Port Authority
HRMS	Human resource management system
ICT	Information and communications technology
IIoT	Industrial Internet of Things
IoT	Internet of Things
IPCSA	International Port Community System Association
IT	Information technology
ITS	Intelligent transportation system
KPI	Key performance indicator
LTE	Long-Term Evolution
LTE-M	Long-Term Evolution, Category M1

ML	*Machine learning*
MPA	*Maritime and Port Authority of Singapore*
MPOS	*Multi-purpose operating system*
NB-IoT	*Narrowband IoT*
NFC	*Near-field communication*
NVOCC	*Non-vessel owning common carrier*
OECD	*Organization for Economic Co-operation and Development*
PCS	*Port community system*
PDA	*Personal digital assistant*
PDS	*Positioning detection system*
PMIS	*Port management information system*
PSA	*Presence sensor aggregator*
SCADA	*Supervisory control and data acquisition*
SMI	*Singapore Maritime Institute*
SOA	*Service-oriented architecture*
SW	*Single window*
TETRA	*Terrestrial Trunked Radio*
TOS	*Terminal operating system*
VAR	*Virtual and augmented reality*
VTS	*Vessel traffic service*
WAN	*Wide area network*

1 • INTRODUCTION

The Smart Port Manual is a tool designed to help port authorities and terminal operators monitor and evaluate the process of transforming ports into smart ports. The manual's content is based on international best practice for implementing smart ports. It describes different smart port initiatives and includes a list of quantitative and qualitative indicators that can be measured to track and score the progress made. This manual gives a comprehensive overview of the technological and legal ecosystem needed in order to create smart ports.

It consists of five white papers: four that introduce and expand on specific topics, and one that provides guidance on implementing the proposed solutions at ports:

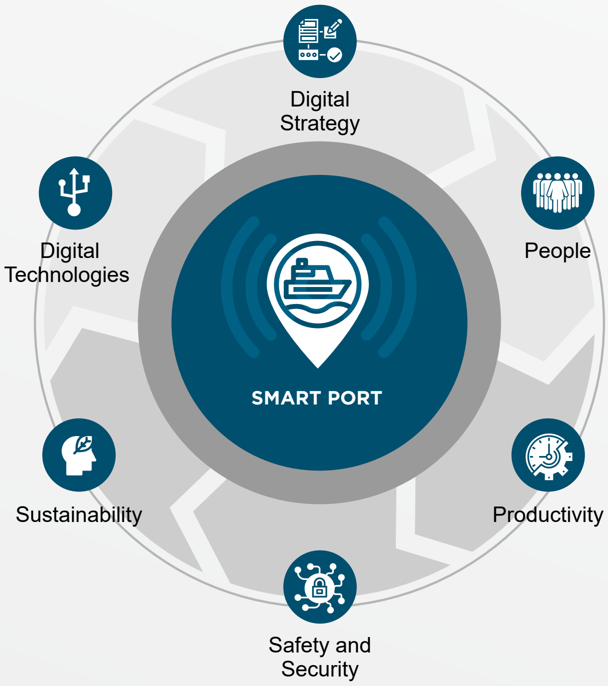
- ***White Paper 1***, *Conceptual Framework*, introduces and provides the theory behind smart ports.
- ***White Paper 2***, *Strategy for Smart Ports*, defines the strategy for developing smart ports.
- ***White Paper 3***, *Broad Trends and Technological Innovation lays out the innovations* and technological solutions to be implemented at smart ports.
- ***White Paper 4***, *Government and Private-Sector Challenges for Developing Smart Ports* addresses the challenges and difficulties that governments and port companies may face when applying the concept of smart ports.
- ***White Paper 5***, *Roadmap*, describes the process ports need to follow to become smart ports.

This executive summary was also added to provide a condensed overview of the content of the five papers and give a multi-modal perspective on the process of transforming ports into smart ports.

2 • CONCEPTUAL FRAMEWORK: SMART PORTS

A smart port transforms all aspects of a port's value chain into an open and interconnected ecosystem (Figure 1).

FIGURE 1 • COMPONENTS OF SMART PORTS



The digital transformation needed to turn a port into a smart port requires the use of digital technologies, but it also depends on a proper digital strategy and a cultural transformation. There can be no smart ports without smart people. Any transition process will need a strong component of training, change management, transformation, and skill-building in order to properly meet the new challenges of smart ports.

Becoming "smart" means becoming more attractive and competitive for customers and users, as well as for a port's broader community. Artificial intelligence, the Internet of Things, big data, and other technologies allow ports to make their workflow, conditions, or customer management smarter, which leads to better decision-making and processes for more efficient, clean, and respectful operations. However, all these transformations are still in their infancy.

On the other hand, a smart port should not be thought of as a mere application of digital technology. How smart a port is also depends on its ability to cultivate an atmosphere of cooperation between shipping lines, logistics facilities and port terminals, carriers, and logistics operators. It is also contingent on its relationship with the city and local communities where the port operates. The port authority or port infrastructure manager must take a cross-cutting approach to technical and technological issues. The challenge is to create ecosystems, communities of interest, and practices that make the system as a whole smarter.

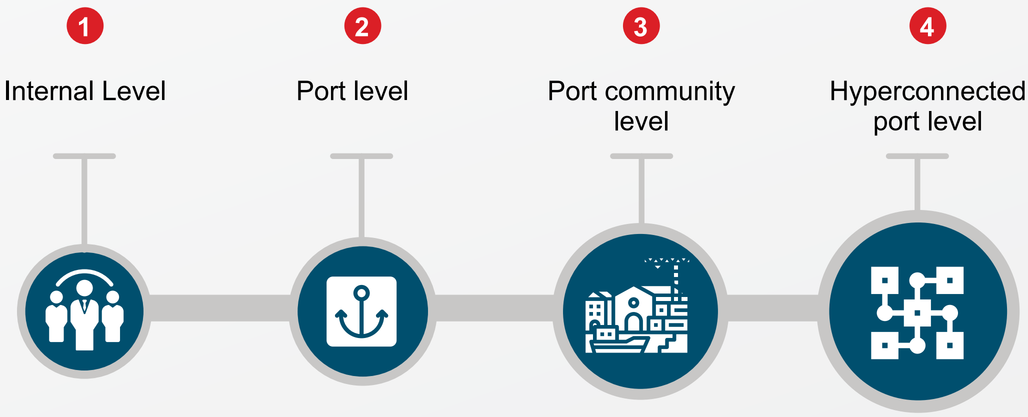
Likewise, the operational improvements brought about by Industry 4.0 in other sectors can also provide immediate benefits to ports, increasing their productivity, security, safety, and sustainability while reducing operating costs and increasing profits.

Based on these needs, a digital and innovation strategy, a roadmap, an investment plan, substantial organization, and change management will all be needed in order to implement a smart port.

2.1 LEVELS OF TRANSFORMATION INTO A SMART PORT

To achieve a smart port, there are four levels of concrete actions within the process of digital transformation (Figure 2). A port is a complex system, and transforming one of its components does not make the entire port smart. Rather, a holistic digital transformation on these four levels needs to take place in order to achieve this goal.

FIGURE 2 • LEVELS OF DIGITAL TRANSFORMATION INTO A SMART PORT



Level 1: Internal digital transformation.

At this level, the companies and organizations involved in port activities work to improve their processes and to each achieve internal digital transformation. Within a port, the degree of modernization may vary from organization to organization. Certain entities may be well advanced in their digital transformation process, while others may lag far behind. At this level, the objective is to ensure that each individual player's internal systems maximize the value of the business and make it more competitive through digital transformation, prioritizing investments in technology, information systems, standardized procedures, and internal quality systems to make operations more efficient and reduce costs. However, even with these internal improvements, many manual processes still exist, as well as a heavy reliance on paper or other inefficient mechanisms for communicating with third parties in businesses' value chains or those involved in port logistics activities. For example, the activities of provisioning, logistics, sales, providing different services and customer service for the different regulatory security and safety functions, managing the public domain and infrastructures, and coordinating and performing port logistics operations all continue to be highly inefficient.

Level 2: Connect port.

At this level, the port's digitization begins to extend beyond each organization's internal boundaries and centers on the port facility. The aim is to increase efficiency and reduce costs by replacing manual processes between third parties with automated electronic ones. This level chiefly affects the administrations (port authority, customs, border inspection services, maritime authority) and port terminals, which open up their internal systems to provide a set of online services for processing declarations and completing administrative steps electronically, scheduling and setting up appointments, and electronically managing documentation or reports. Users can communicate data by entering it in applications provided by single windows and terminals, or the data needed can be logged through a digital exchange between the different information systems. At this level, administrative single windows are key to facilitating the movements of ships and freight.

“The port infrastructure is made up of physical assets, while its infostructure is composed of digital assets"

Francesc Sánchez. General Director.
Valencia Port Authority

Level 3: Connect port community.

Here the previous level expands to achieve a partnership where the entire port community works together to create a connected and coordinated logistics hub. The aim is to establish synergies and benefits that extend beyond individual companies so that the port community as a whole and the public services run by the State can benefit. A connected port community also needs port-level standard operating procedures and quality systems. At this level, the challenge is to break down data silos, which are a significant hindrance to efficient port logistics activities. At this level, ports work to set up and use digital platforms like port community systems (PCS) and transportation procurement and management platforms (for example, platforms for booking, procuring, managing and tracing maritime, road, or rail transportation; freight exchanges; etc.). PCS links together different systems within the port and, in some cases, outside of the actual port community. These systems would otherwise be isolated, leading to silos, duplications, inefficiencies, inconsistencies, and errors in the data logged and reported for the different operations and in the formal procedures performed by regulatory authorities to audit and control those operations.

“To achieve transformation, the port industry should shift its strategy from simply controlling resources to managing resources, from optimizing internal processes to external interactivity, and from maximizing value for customers to maximizing value for the entire ecosystem.”

Yan Jun. CEO.
Shanghai International Port (Group) Co., Ltd.

Level 4: Hyperconnected port.

This is the highest level of digital transformation of a port. People, organizations, and objects (infrastructures, vehicles, devices, sensors, etc.) are interconnected and tap into the advantages of emerging digital information and communication technologies. Beyond digitizing information, these actions effectively virtualize the entire environment, bringing intelligence, immediacy, interactivity, mobility, and automation to all port activities and aligning the transformation with each organization’s business objectives. By adopting disruptive technologies like the Internet of Things, cloud computing, mobile apps, the Internet of Value (blockchain and distributed ledgers), big data, digital twins, or machine learning and artificial intelligence, ports can catalyze the smart port transformation in their functional areas: regulatory, operational, public domain management, and port community. A smart port’s aims are not limited to operational efficiency and cutting individual costs. They also include improved measures to promote safety, control, and security; protect the environment; use energy efficiently; generate and use clean energy; integrate well into the surroundings and cities; and connect the port with land and sea corridors and with global logistics chains.

Even if individual organizations operating within a port are very technologically advanced, the port may not necessarily be considered a smart port because the term refers to how the port’s ecosystem functions.

Ports must set objectives for each level of digitization in order to achieve digital transformation. Each member of a given port community will lay out their own digitization strategy, and the combination of these strategies should pave the way for achieving a smart port. During this process, port community members, clients and users of port facilities, and the cities and communities around the port should coordinate with each other as much as possible in order to make progress on the port's four levels of digital transformation, setting specific individual and collective objectives and projects. The division of ports' digital transformation process into four levels will help establish individual and collective objectives that each party will work towards. It will also help define the steps and projects needed at each level in order to achieve those objectives.

2.2 THE PORT DIGITIZATION AGENDA

Digitization is the shift of traditional information and communications technologies toward a connected world where the physical and digital merge. Digital technologies are associated with transforming our surroundings into a smart environment. For example, digitization is achieved by building sensors and electronic devices into physical elements, making them smart devices or cyber-physical systems, which in turn form part of a broader concept: The Internet of Things.

Digitization is a key part of the process of automating the transportation and port handling process. It enables the creation of terminals that are smarter and more automated, as well as port surveillance operations, autonomous reception and delivery, driverless freight transportation, automated ship loading and unloading services, and unmanned and automated vessels, all of which will make ports smarter and require less human resources. In the future, ports will make broad use of sensor technologies, wireless technologies, drones, blockchain, alternative energy sources, smart networks, and other emerging technologies.

There is currently an extensive gamut of technologies and applications for digitization, so ports should narrow down the options to those most important to their operations and context. Based on these priorities, the digitization strategy of the body in charge of managing the port (whether a port authority, company, or corporation) should address the challenges and opportunities of the port and the body itself in order to use the digital environment to strengthen its value chain, with the intensity and timeline appropriate to each case. Port customers and users should always remain at the center of these processes.

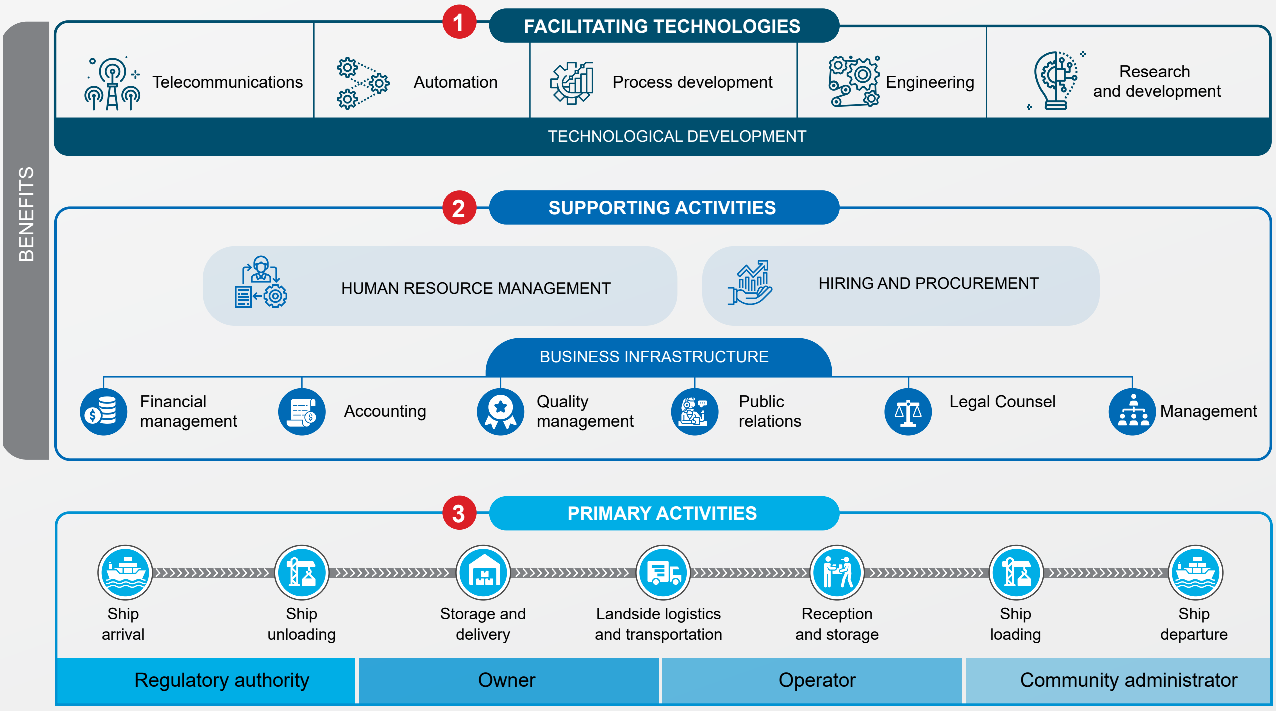
In each case, this strategy is the foundation for achieving commitment and coordination within the organization, at the port facility, and in the community. The goal is a port that is hyperconnected via the interconnection of multiple systems and devices at the smart port.

2.2.1 • DEFINING THE SMART PORT'S VISION

The port, as part of a global logistics chain, needs to be aware of all current initiatives and trends emerging in the port sector or other industries and draw on them as inspiration for its vision for its digital strategy. A smart port's vision should be based on a realistic understanding of what will be required in order to implement that vision, given existing constraints, resources, and timelines. At the same time, a smart port's vision should incorporate the port's productivity, sustainability, security, and safety.

To set a smart port's vision, the managing body (port authority, company, or corporation) should start by identifying how digital technologies could help meet the port's needs in its value chain. However, a port does not consist of a single entity, but rather of a group of entities that should operate in a coordinated and interconnected way as a single virtual enterprise with a value chain that is distributed among all its entities (Figure 3). A port is thus a complex system where it is not enough to understand how each individual entity works. It is essential to also understand the relationships between all these entities in order to understand the system.

FIGURE 3 • THE PORT VALUE CHAIN



To make that vision a reality, the body in charge of the port must survey the port's current situation: its problems, points where it loses value, and the challenges and opportunities for its primary and secondary activities. It should also identify the facilitating technologies that would allow the needs it finds to be met.

2.2.2 • CREATING VALUE THROUGH SMART PORTS

Smart ports provide solutions to ports' different challenges, such as those described by the Economic Commission for Latin America and the Caribbean during the "First Regional Latin American and Caribbean Meeting of Port and Logistics Communities:"

- **Sustainable expansion and growth of port capacity**, providing technological solutions that improve the productivity, efficiency, and connectivity of the infrastructures.
- **Improving port logistics** by implementing collaborative models on different digital platforms that are connected both to each other and to the means of transportation, infrastructures, and people.
- **Integration with the hinterland**, creating interconnected ports to provide networked services within multimodal and global logistics chains.
- **Digitization and innovation**, fostering an attractive environment that encourages innovation and the adoption of new technologies, where researchers, companies, startups, and public entities develop a culture of innovation and technological change to create the ports of the future.
- **City-port integration**, interconnecting smart ports' digital platforms with the digital platforms of smart cities (smart city-ports) to facilitate a mutual relationship and joint actions to improve problems associated with traffic, mobility, and pollution; sustainability; the economy; promoting sustainable tourism; ongoing dialog between the port community and the city; and the port's added value for the city and region.
- **Quality of service and economic regulation**, creating a transparent environment that allows ports to establish indicators that track the quality of their services and enable a more dynamic market, and that also promotes competition, protects users, and ensures that efficiency gains are passed on to the entire logistics chain.
- **Social sustainability**, leading to better-trained human capital and a port and logistics space that attracts talent; new labor relations within a framework of collaboration; improved standards for industrial safety, physical security, and cyber security; and lower risk of work-related accidents.
- **Environmental performance**, through mechanisms for monitoring the environmental impact of port activities, as well as measures to make ports more environmentally friendly, improve facilities' energy efficiency, use and generate renewable energy, and progressively move away from a reliance on hydrocarbons for operations.

2.3 GOVERNANCE AND DIGITAL TRANSFORMATION

The enterprise model, or business model, for each action is key to the successful implementation of smart port systems and solutions. Decisions about investment, ownership, operations models, revenue streams, expenditures, profits, and the orientation of services need to be made considering all the different stakeholders.

Each port has its own legal and institutional particularities that can shape the design of the business model resulting from the application of Industry 4.0 technologies or from different business opportunities ushered in by the digital transformation. Table 1 shows a list of the most common factors that can lead to different business models.

TABLE 1 • FACTORS INFLUENCING THE BUSINESS MODEL FOR SMART PORT INITIATIVES

PARTIES THAT COULD BE INVOLVED IN SMART PORT INITIATIVES	OWNERSHIP MODEL	OPERATIONS MODEL	TYPES OF REVENUE OR PROFIT STREAMS
• Port authority	• Private	• Private	• Per-unit charge
• Maritime authority			
• Customs	• Public-Private	• Public-Private	• Per-transaction charge
• Immigration			
• Inspections	• Public	• Public	
• Port operators			• Per-user charge
• Port terminals			
• Shipping lines			• Per-use charge
• Consolidators/NVOCC			
• Freight forwarders			• Subscription fee
• Customs brokers			
• Empty depots			• Monthly fee
• Inland carriers			

Ownership structures and operations models are shaped by their shareholders or participants, users, and services offered. A technology can have a private or public-private ownership and operations model, or it can be an exclusively public service managed by a port authority, a local/state authority, or a national authority. Regarding the types of revenue streams within the smart port business model, the cost of implementing a technological solution at a port can be covered by charges per cargo unit moved, per transaction, per user, or per use of the solution. Alternatively, it could be paid for via dues for implementing and operating the technological solution. In some cases, especially when the technology or digital solution itself is offered as a service, the cost of its use can be covered by specific fee or rate to be paid by the users, while in other cases it can form part of the structure of costs that make up the port service fees or rates charged to customers in the value chain.

Table 2 lays out the details of the possible models

TABLE 2 • TYPES OF BUSINESS MODELS FOR SMART PORT INITIATIVES

OWNERSHIP MODEL FOR THE INITIATIVE	OPERATIONS MODEL FOR THE INITIATIVE	CHARACTERISTICS
• Public	• Public	• The public sector funds and provides the capital for the solution, equipment, and infrastructure and is also in charge of operating and maintaining them. • Positive aspects: The active participation of the public sector would be expected to boost integration and interoperability with existing B2G and G2G information service platforms. • Negative aspects of this model: government agencies' lack of agility and efficiency when incorporating technological advances and new services demanded by stakeholders. It requires financial and governance support to ensure a sustainable and attractive public business model that does not favor any one company.
• Public	• Private	• The public sector invests in and funds the solution, equipment, and infrastructure, but it outsources their operation and maintenance to a private company through a service agreement, concession, or authorization. • Positive aspects: Government agencies take an active role in ensuring that the services are provided neutrally and fairly to all parties involved, while a private company manages the technology based on commercial standards. • Negative aspects: There have to be convincing arguments that the services are public in nature and that they therefore must be regulated to cover risks that the private sector is not willing to assume or protect port users from potentially monopolistic practices related to setting prices, access to information, neutrality, inappropriate use of data, and equity.
• Public-Private	• Private or Public-private	• The public sector and the private sector jointly invest in and underwrite the solution, equipment, and infrastructure, while the solution may be operated by the same partnership or by the private party only. • Positive and negative aspects: This scenario requires a contractual agreement between one or more parties from the private and public sectors. Both assume the project's financial, technical, and operational risks.
• Private	• Private	• The private sector funds and invests in the solution, equipment, and infrastructure and also takes care of its operation and maintenance. One risk of this model is that the solutions or digital services provided could be fragmented or disconnected. • Negative aspects: This model could fail to incentivize the development of services that are not profitable for the owner of the initiative but that are valuable for the port. It could also lead some logistics players to think that the most dominant participants receive preferential treatment, thus hindering the creation of a neutral and fair solution for all and generating unfair advantage, to the detriment of the value chain.

2.4 ECONOMIC AND SOCIAL DRIVERS OF SMART PORT SOLUTIONS

Outside of the digitization process, ports face other major transformation a challenges such as the energy transition, pressure from local cities and communities, the shift to a circular and environmentally sustainable economy, and the transition to Industry 4.0 for production activities.

The main challenge for ports is ensuring that its clusters continue to be vital to the economy in a competitive context that is increasingly based on innovation. Successfully applying new technologies is essential for this transition. The main economic and social drivers of smart port solutions are presented below.

2.4.1 • CLIMATE CHANGE

Ports are important centers of economic activity given their crucial role in international trade, but their negative environmental consequences should not be overlooked. Ports are often located near urban areas, and their activities are responsible for a significant portion of those cities' adverse environmental impacts. According to the OECD[1], the environmental cost of port activities (such as air, water, and noise pollution, or waste generation) tend to be localized, chiefly affecting nearby communities. Activities within the port area are not the only cause of environmental damage, which can also be caused by transportation between the port and its hinterland[2].

The detrimental environmental impact of seaports and maritime logistics originates from various sources, including ships, freight handling operations, road transportation, port infrastructure, and development initiatives. These negative impacts may vary from port to port depending its size, its type of operations, the ships that call on it, and its volume of traffic.

The Paris Agreement and its bottom-up architecture mean that every signatory should strive not just to meet its emissions reduction targets, but also to set ambitious goals that have an even greater positive impact. The report on green ports and maritime logistics[3] authored by the Inter-American Development Bank provides important data on the sector's role in climate change and the impacts in Latin America and the Caribbean. It also provides an analysis of mitigation alternatives (Table 3).

Sustainability takes social, economic, and environmental considerations into account so that better economic and social results can be attained by reducing environmental impacts. The growing focus on protecting the environment makes it crucial for maritime logistics and maritime ports to mitigate their negative environmental externalities. This means developing or continuing efforts to transform the port and its associated operations. It means making ports more environmentally friendly and sustainable by reconciling economic, social, and environmental objectives with local cities and communities. Ports must constantly evolve to meet growing demands, but now environmental efficiency joins profitability as the core of this evolution. Port operations and maritime logistics should be run with a holistic focus on sustainability.

A green port is one that factors the environment into its routine activities, using environmental development projects and policies while considering and striking a balance with its economic interests. These ports focus on reducing their carbon footprint and pollution, conserving natural resources, and wasting as little energy as possible. Some green ports also work to develop ties with their communities and reduce noise and visual impacts.

1. Merk, Olaf "The Competitiveness of Global Port-Cities: Synthesis Report," OECD Regional Development Working Papers (OECD, September 6, 2013), https://doi.org/10.1787/5k40hdhp6t8s-en.

2. Gonzalez, Marta, Bergovist Rickard, and Monios, Jason, "A Global Review of the Hinterland Dimension of Green Port Strategies," Transportation Research Part D: Transport and Environment 59 (March 2018): 23– 34, https://doi-org.proxy-um.researchport.umd.edu/10.1016/j.trd.2017.12.013.

3. Greening Ports and Logistics in Latin America and the Caribbean. Inter-American Development Bank (IDB)

TABLE 3 • ANALYSIS OF ENVIRONMENTAL MITIGATION ALTERNATIVES

	SOURCE	ENVIRONMENTAL IMPACT	ALTERNATIVE
AIR POLLUTION	• Ships	• CO2 → Climate Change • SO2, NO2 and PM → Health problems	• Onshore Power Supply • Reducing Speeds • Optimizing Ports • Alternative Fuels
	• Loading Machinery • Trucks		• Alternative Fuels • Electrical equipment/cleaner trucks • Not accelerating and speed limits • Rails in container yards • Shorter distances between terminals and land transportation
WATER POLLUTION	• Excess water	• Invasive species → Damage to the marine ecosystem	• Systems and regulations for managing excess water
	• Oil spills (operational and accidental)	• Crude oil in sediments → Damage to the marine ecosystem	• Safer oil tanks • Follow the MARPOL rules • Download management systems
	• Wastewater (blackwater and graywater)	• Spills → Water Pollution	
	• Spills via runoff water	• Accumulation of pollutants in the water → water pollution	• Stormwater management systems
	• Dredging	• Release of pollutants → dirtied water and damaged marine ecosystems	• Systems for managing waste from dredging
NOISE POLLUTION	• Ships • Loading and Unloading Containers • Landside Traffic • Machinery for civil engineering works	• Harmful health effects for nearby communities • Harm to marine species	• Noise management systems
WASTE	• Blackwater and sewage	• Degradation of natural environments • Air pollution	• Waste management plan for minimizing, eliminating, treating, and mitigating waste
LANDSIDE DEVE-LOPMENT	• Land Consumption • Increased activity	• Damage to ecosystems and biodiversity	• Increasing the productivity of the land domain • Relocating ports • Aligning the land-use plans of ports and cities

Source: Greening Ports and Logistics in Latin America and the Caribbean for the Inter-American Development Bank (IDB)

The relevance of green ports ensures the highest level of efficiency, security, social inclusion, resource conservation, and environmental protection. Ports should integrate environmental concerns into their operations and into their interactions with other stakeholders, including terminal operators, shipping lines, and nearby communities.

While the main driver of environmental policies is, in reality, the gradual entry into force of new environmental regulations, it is important to point out that these measures can also provide opportunities to improve ports' efficiency and competitiveness. Many companies have specific targets for reducing their products' carbon footprint. Export and import companies increasingly require that their suppliers guarantee a more efficient, sustainable, and environmentally responsible logistics chain. These demands justify the search for and development of port solutions and policies that make zero-emissions operations models possible in the medium term.

Admittedly, shipping lines do not currently choose a port based on its environmental excellence. However, the market trend described above and the approval of increasingly strict environmental regulations mean that the commitment to sustainability could be a differentiating factor that adds value to ports that follow this model, especially when regulations get stricter and carriers and shipping lines look to load and unload at "green" ports.

2.4.2 • ENERGY-RELATED CHANGES

Energy efficiency is a discipline that encompasses different sets of actions. It is key to maintaining or increasing ports' competitiveness as they strive to use resources more efficiently.

As different environmental regulations have taken effect, the environmental consciousness of the port space has increased significantly. Examples of these regulations include the Admission Control Areas (ECAs) or initiatives like the World Ports Climate Initiative, where 55 ports from all over the world signed a joint commitment to reduce their greenhouse gas emissions.

This has fueled research into and development of solutions for reducing ship and port emissions, as well as the implementation of technologies—like alternative fuels, renewable energy, or smart energy management systems—to enhance the energy efficiency of these key infrastructures.

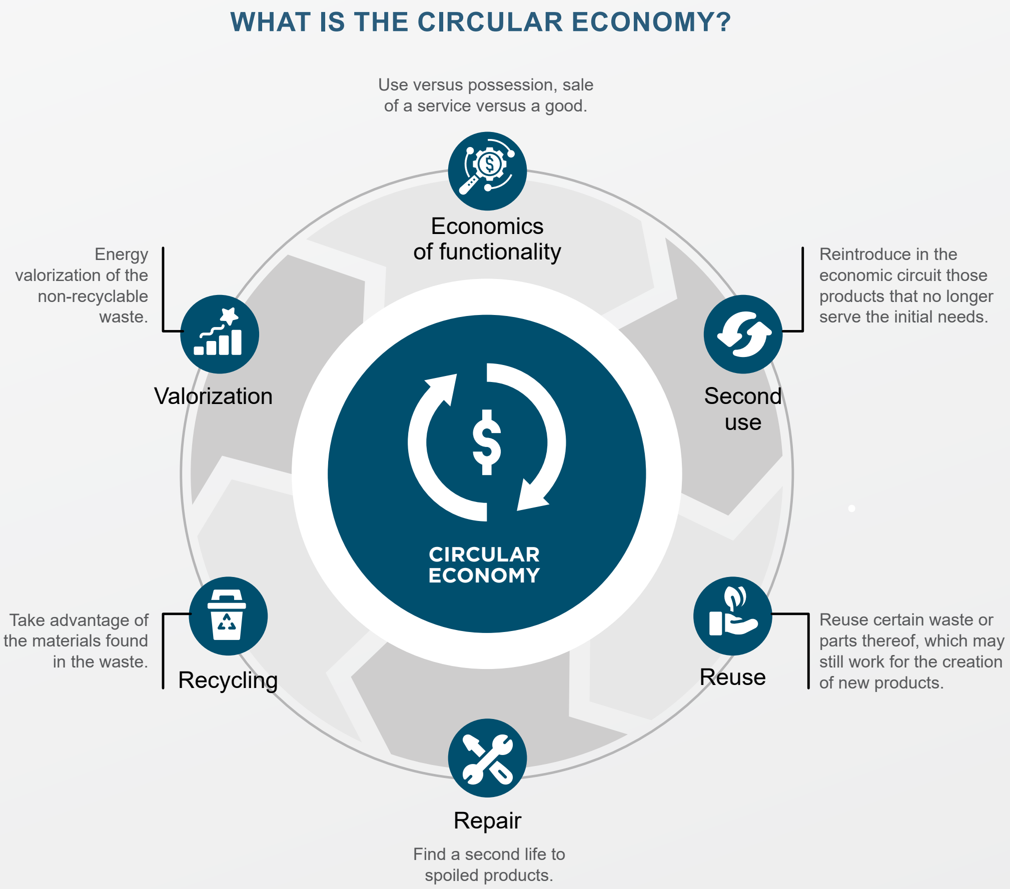
Essentially, energy efficiency is considered an opportunity to cut costs and boost the productivity of port cluster companies, whether carriers, logistics operators, terminal operators, port authorities, or shipping lines. This aspect will thus hold significant weight in these players' business models in upcoming years. An example of this is the sensorizing of machinery and equipment in ports and terminals, which allows players to measure, evaluate and improve their operational and energy performance.

Ports will increasingly shift their focus to establishing active innovation policies for energy efficiency, progressively implementing renewable energy at their facilities, using new alternative fuels like hydrogen, and combining these innovations with information technology. These types of policies not only make ports more competitive, they also improve citizens' perception of them, transforming the traditional image of a polluting port into a sustainable and innovative enclave that is technologically advanced and has a minimal environmental impact.

2.4.3 • CIRCULAR ECONOMY

The economic activity required for today's society to access goods and services in most cases takes a negative toll on the environment. Different production processes convert raw materials into finished products that provide food, energy, infrastructures, etc. to society. The scarcity of these resources has always been one of the key issues to be solved by the economy. Burgeoning international trade, the growing trend towards e-commerce, and reliance on resource-intensive production models pose countless environmental, social, and economic problems.

FIGURE 4 • THE CIRCULAR ECONOMY



Source: RAEE Andalucía

The concept of a circular economy offers part of the solution to these problems. This sustainable model centers on benefiting society by redefining growth based on strategies that prolong the value of products, materials, and resources for as long as possible, thus cutting down on waste. Broadly speaking, the concept posits a structure of collaboration between sectors to minimize the impact of their economic activity and the waste it generates. This structure is based on sharing assets, using lease arrangements, performing repairs, valorization, secondhand markets, industrial symbiosis patterns, etc. (Figure 4). In contrast, the traditional economic model is based chiefly on the concept of disposable products and requires large volumes of cheap and easily accessible materials and energy.

One of the reasons to move towards a circular economy is the increased demand for commodities and the scarcity of resources. Various crucial raw materials are finite, and as the world population grows, so does demand. Another reason is other countries' dependence on certain commodities. Climate impacts are another factor. The extraction and use of raw materials have substantial environmental consequences and drive up energy consumption and CO2 emissions, while smarter use of raw materials can help cutpolluting emissions.

The port and maritime sector will play an important role in launching circular economy initiatives since ports will serve as “intermediaries” and transit points for different types of waste and industrial flows, acting as logistics centers for importing and exporting waste materials. For this reason, port clusters are ideal places to assess and incorporate circular economy strategies. Furthermore, ports have numerous industries that collect, transport, and process the waste generated by the port’s own activities and by the ships that call at the port. This situation stimulates the rise of circles of innovation associated with these activities. Ports can also use technology and smart processes to help achieve these objectives.

Understanding the circular economy as a system; correctly evaluating waste streams; cooperative arrangements for material consumption, machinery, etc.; creating smart waste management systems, and other measures form part of the strategy that all ports should develop to add value and be technologically competitive on the market.

2.5 BARRIERS TO DEVELOPING SMART PORTS

Despite the theoretical advantages of the concept of smart ports, there are several barriers and challenges that need to be addressed.

Governance and funding models

This aspect is one of the main difficulties in implementing smart port technologies. In many cases, implementing these technologies requires a significant economic investment (in infrastructure, equipment, software, people, training, etc.). Therefore, decision-makers need to thoroughly analyze the feasibility of the measures and the participation of the public and private sector. Lack of funding limits development in this field. There is a wide gap between large companies and ports with more access to economic resources for implementing the systems and small and medium-sized companies and smaller ports that face difficulties when doing so. This initial barrier can be overcome by prioritizing initiatives; taking advantage of incentives, funds, or aid for innovation; creating open innovation mechanisms; or using innovative public procurement mechanisms.

Managing change and innovation

The transition to smart ports involves changes related to technological innovation, increases in efficiency, and greater cooperation between companies, as well as changes in processes, economic approaches, and corporate culture. To make these shifts, organizations must be able to learn and manage changes in human resources. The adoption of new technologies forces port stakeholders to shift their conception and attitude. Digitization is moving forward a staggering pace, and those who fall behind risk becoming obsolete and excluded from the market.

Thus, people who do not understand the implications of a very advanced technology like AI may distrust it. Likewise, business models based on the transparency of information and the shift towards open information can spark fears that data could be leaked and used in ways contrary to the interests of the party that supplied it. These fears or distrust can lead certain parties or companies to reject the changes.

Given this panorama, the digital transformation needs to be gradual at first. Port innovation ecosystems can facilitate a shift in company and employee culture by introducing new values and attitudes towards the port's digital transformation. These ecosystems can also partner to tackle larger-scale projects.

Societal rejection

Societal rejection is another barrier to the digital transformation of ports. This barrier is associated with using new technologies to replace people, and the fear is that automating operations and using robots will eliminate jobs. Though this barrier is controversial, new trends can be presented in a better light by showing data on the number of tech jobs that can be created. This type of information can be found in a report published by the International Labour Organization, [4]among others.

The digitization of industry brings with it new kinds of psychological, social, organizational, security, and ergonomic risks. Organizations should promote strategies and actions to prevent these risks. These steps include mentoring techniques, training, codes of ethics that promote remote work and the right to disconnect, psychosocial risk evaluations, cobots and wearables, together with smart safety systems that improve ergonomic conditions, prevent accidents, and protect workers from occupational hazards and health risks.

The challenge of technology

Technology often seems to evolve at a speed that organizations and workers cannot keep pace with, but at the same time technology does not seem mature and consolidated enough to be adopted and replace current technologies. In order to master technology and apply it to priority areas, organizations or ports can develop prototypes, test concepts, and pilot programs to verify a technology's validity and complete the process of learning it.

The problem of cybersecurity

Introducing new technologies or lack of familiarity with them can lead to fear of possible vulnerabilities that could jeopardize digital assets and data. This situation may make people and companies reluctant to adopt these new technologies because

4 https://www.ilo.org/global/research/publications/working-papers/WCMS_544189/lang--es/index.htm

of the insecurity they create. The trust needed to speed up the adoption of new technologies can be built by creating and applying standards and measures for protection against cyberattacks and by correctly configuring systems, so they are protected.

The need to work together

An essential part of the smart port concept is cooperation both within and between companies. When this collaboration is weak or nonexistent, the results achieved by implementing technologies will fall short of expectations. In some cases, institutions or governments will need to provide greater support to encourage actions such as using vehicles powered by alternative fuels. To ensure the efficiency of the measures to be taken, all stakeholders must be willing to cooperate to achieve the expected benefits. Stakeholders must be convinced that the best way to enhance the efficiency of a port's operations is by working together, seeking a win-win relationship for all.

Lack of qualified personnel

The rise of Industry 4.0 and the Internet of Things has brought with it a demand for qualified personnel with new professional profiles and skills in areas like data analysis, predictive maintenance, cybersecurity, or blockchain. There are not currently enough formal training opportunities to meet this demand, and professionals are forced to teach themselves. Smart ports also require not only good training on new technologies, but also knowledge of the industry and the port and maritime sector. Individuals with this additional specific training are a rarity on the job market.

Digital transformation also gives rise to new professional profiles and requires people to learn crosscutting human skills that are beyond the capabilities of machines. In the future, professionals with design and programming expertise will be in highest demand, as well as those with human analytical, problem-solving, leadership, and social influencing skills. Sales and marketing professionals, managers, innovators, and customer service personnel will also be highly sought after.

2.6 THE RISE OF PORT INNOVATION ECOSYSTEMS

Innovation is one of the keys to overcoming the barriers that smart ports face, which were described in the previous section. In an ecosystem as competitive as that of ports, the key to boosting productivity and overcoming social and economic barriers lies in being able to orchestrate the port ecosystem, learning how to combine financial capital with human capital and add value to the port community and its city.

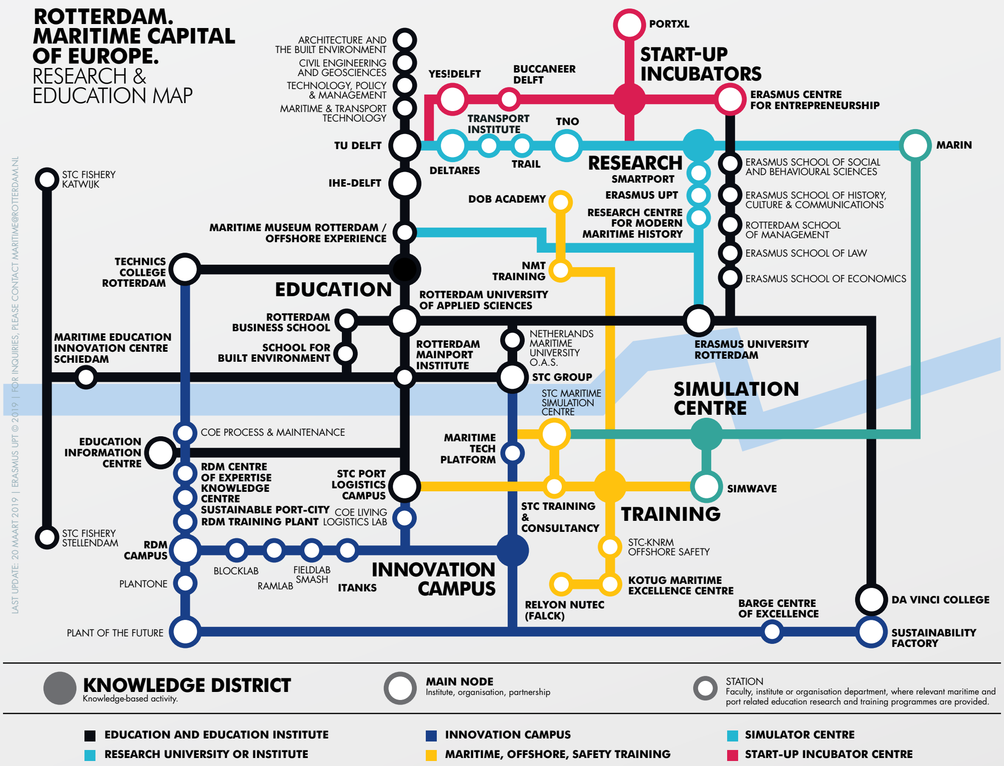
The term "innovation ecosystem" has gained widespread use among those involved in innovation systems. Its central idea is that thriving innovation cannot be achieved through isolated actions by individual companies. Rather, innovation depends on a wide range of interrelated actors. An innovation ecosystem has different components, including a strong business culture, the availability of venture capital, educational institutions, research and development hubs, startup incubators and accelerators, and appropriate regulations that encourage innovation.

At the international level, the ports of Rotterdam and Singapore stand out as leaders of innovation ecosystems.

The Port of Rotterdam has set the bar by establishing a strong agenda of innovation along with its port community, creating and investing in different structures. The aim of the Port of Rotterdam Authority is to be not only to be the world's largest port, but also the European capital of maritime innovation. The diagrammatic map published by the port (Figure 5) clearly shows its effort to develop its ecosystem. The map gives an overview of the centers for training, research, innovation, and development in Rotterdam.

Programs created in the port of Rotterdam to stimulate the ecosystem include: **PortXL**, which serves as an ideas accelerator; **SmartPort**, which runs research and development programs; and **RDM**, which functions as a startups incubator and coordinates testing.

FIGURE 5 • STRUCTURE OF ROTTERDAM'S INNOVATION ECOSYSTEM



Source: Port of Rotterdam

The Maritime and Port Authority of Singapore (MPA[5]), in turn, along with port operator PSA International and the local port community, have created a maritime innovation ecosystem that has set the standard not only for Asia, but for the whole world. This Asian ecosystem has recently developed initiatives that include: **PIERT71[6]** , which brings together the concepts of incubator, startup accelerator, and maritime port innovation marketplace; **PSA Unboxed**[7] the branch of PSA International that accelerates and invests in startups, **and Singapore Maritime Institute - SMI[8] (R&D Institute)**, which does research and development work.

In addition to these two examples, other ports like the Port of New York (New York Maritime Innovation Center), Hamburg (Rainmaking Trade & Transport Impact Program), or London (StartupWharfis) have begun to implement different innovation initiatives.

The institutions that lead these clusters should have the objective of aligning stakeholders and setting a shared agenda for developing human capital, research, and innovation. Using this approach, ports like Rotterdam and Singapore are solving very specific problems related to operational efficiency, equipment use, energy consumption, or use of labor. In this way, they contribute to the economic and social development of the port community, city, and region.

5 https://www.mpa.gov.sg/
6 https://www.pier71.sg/
7 https://unboxed.globalpsa.com/
8 https://www.maritimeinstitute.sg/default.aspx

3 • STRATEGIC PLANNING

Setting a strategy and vision for a smart port is the springboard for achieving commitment and coordination within each organization, within the port facility, and within the community in order to reach the highest level of connectivity (hyperconnected port), where multiple systems and devices can be used to create a constant connection between the different sources of information found at a smart port.

Strategic planning is the process of defining and fleshing out the business strategy. It is a method for defining, developing, and implementing the steps toward achieving the objectives set by the company's management.

Strategic planning is important because it is directly linked to an organization's performance, economic or otherwise. Strategic planning also impacts both internal processes and the company's relations with external agents. In any of these processes, strategic planning governs actions and should guide decisions towards achieving the organization's objectives.

It is common knowledge that a company's strategy is based on its mission, vision, and values. The mission defines what the company does, the intended market for its products and services, and the business's corporate image. The vision describes the status and position the organization aspires to achieve over the medium- and long-term; in other words, where it wants to be in the future. The values are the philosophy, principles, beliefs, regulations, and general rules for how the business runs. The strategy is usually divided into core strategy areas that are the fundamental pillars for carrying out a business' mission and achieving its vision.

Organizations can also use the strategic planning process to create a digital strategy. The organization's mission remains the same, but its vision is expanded to include details about incorporating new technologies to increase productivity, security, safety, and sustainability at the individual, port, port community, and hyperconnected port levels.

3.1 THE STRATEGIC PLANNING PROCESS

Strategic planning requires constant monitoring of the company strategy and consists of different stages As shown in Figure 6, the strategic planning process starts with an analysis of the current state of the company and its relationship to the context in which it operates. This analysis should identify its strengths, weaknesses, opportunities and threats. The organization should define its mission, vision, and values based on the results of this analysis. After completing these two stages, the company should articulate a clear and succinct strategy, which in turn is divided into core strategy areas.

In the next stages of strategic planning, companies establish strategic objectives, indicators, and initiatives, which will be monitored and tracked using the balanced scorecard as a strategy management tool.

FIGURE 6 • STAGES OF STRATEGIC PLANNING

A well-designed smart port strategy must enable the proposed objectives to be achieved over time and should consider ongoing interaction with the port's environment. It is also essential for the strategy to be dynamic so the company or organization can adapt to constant changes in the market. It should also serve as the basis for setting goals and establishing initiatives for achieving the plan's objectives.

Based on the strategic planning process, a smart port's strategy is subdivided into core strategy areas. These core strategies are the key and priority guidelines for developing a smart port. Each encompasses one or more objectives that fall into the same group. A smart port's core strategy areas generally reflect the main areas of action, such as productivity, including operational excellence; development and modernization; industrial and physical security (or safety); sustainability, including environmental protection; energy efficiency and the use of renewable energy sources; growth; and user and customer satisfaction.

3.2 TOOLS TO SUPPORT STRATEGIC PLANNING

Strategic planning tools can be a major support when systematizing the process of measuring, compiling, monitoring, and tracking progress towards achieving strategic objectives. The most common tools are balanced scorecards, strategy maps, indicator systems, and monitoring and control tools.

The **balanced scorecard** (BSC) is a management tool that helps businesses implement their strategy. It provides the proper framework, structure, and language for converting the mission, vision, and values into objectives and indicators. The first step toward creating a balanced scorecard is identifying the main purposes, that is, the strategic objectives. The indicator or indicators that best reflect and express the intention of those objectives are then selected. It is important to make these objectives real and measurable so they can be properly quantified by choosing the correct indicators.

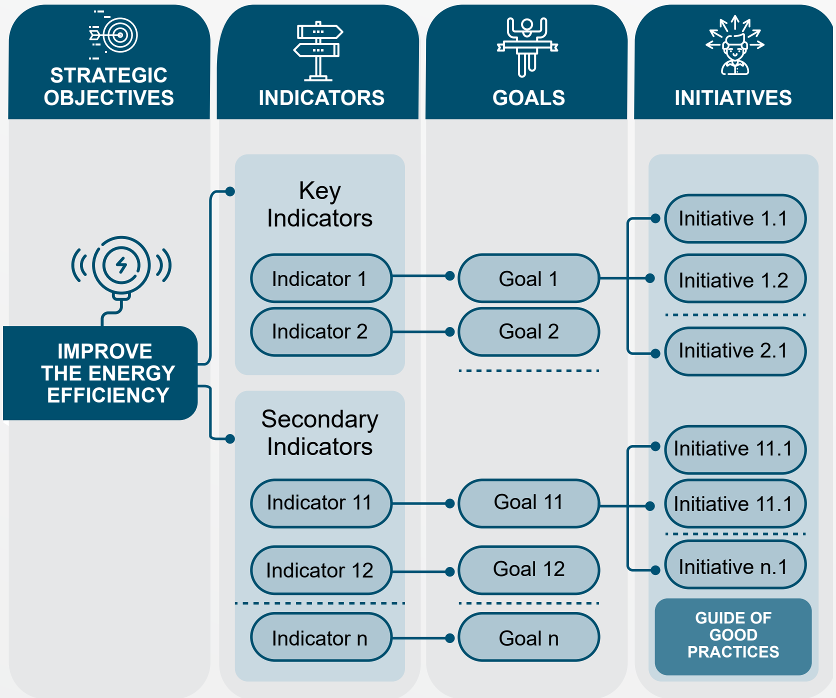
The internal perspective is associated with smart port actions taken internally, while the customer perspective contains actions tackled at the port facility, port community, or hyperconnected port level.

Among other advantages, this tool expands the set of **strategic objectives** beyond the financial realm, making it the ideal management system for incorporating objectives in other categories, like the smart port objectives not solely focused on boosting productivity. To incorporate these other categories, the BSC addresses actions from different interrelated perspectives from across the organization's core strategy areas. Generally, four perspectives are developed, although each company can add as many as it deems necessary. The most common are:

- The financial perspective, which covers the objectives of company shareholders and balances short-term and long-term interests.
- The customer perspective, which contains a unique value proposition at the port facility, port community, or hyperconnected port level.
- The internal perspective, which covers the internal value creation processes. These processes can generally be divided into four groups: operations management processes, customer management processes, innovation processes, and regulatory and social processes.
- The learning and development perspective, which aligns strategy with resources, especially intangible ones: people, digital technologies, and organizational culture.

A set of **indicators** tied to those objectives are then created and classified as primary indicators or secondary indicators, depending on their importance. Specific target values for those indicators are also set based on the strategy. These are called **goals** (one per indicator and timeframe), and specific strategic **initiatives** are designed in order to achieve them. Strategic objectives, indicators, goals, and strategic initiatives make up the balanced scorecard, which is organized into a set of tables (Figure 7).

FIGURE 7 • BALANCED SCORECARD



To make good decisions, company management often needs more than the scores obtained by applying the BSC, even though they are divided into perspectives and strategic objectives. The missing link between designing the strategy and implementing it can be supplied by another tool, the **Strategy Map**. This map gives an overview that links the different strategic objectives to each other. As shown in Figure 8, this tool is a visual representation of the strategy. It shows, on a single page, how the strategic objectives of the different perspectives connect and combine with each other.

These interactions reveal the relationships between the values of the different indicators created to track the strategic objectives. They also make it easier to logically interpret the results. To successfully incorporate the smart port strategic objectives into the strategy of the business or organization, these strategic objectives need to be linked to the rest of the objectives on the strategy map.

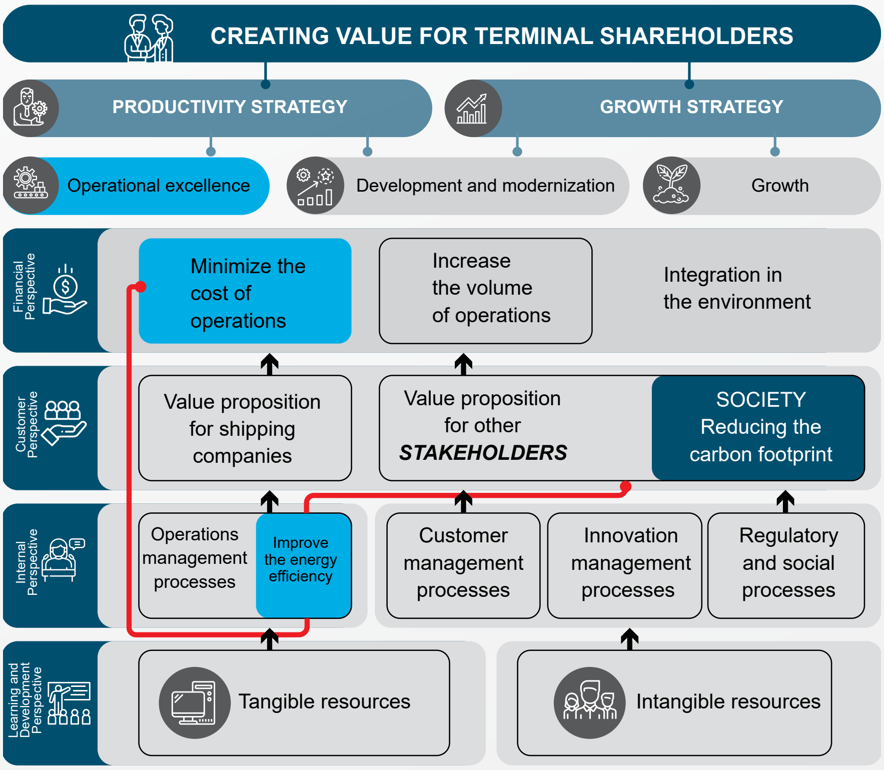
One of the most obvious links is cutting operational costs. This strategic objective is included in the financial perspective and is directly related to the strategy of productivity. Another clear connection is the one between the value propositions in the customer perspective and the objectives included in the core strategy area of integration with the port's environment.

Once the smart port objectives have been integrated into the organization's strategic objectives, the next step is to **define the strategic indicators** that can best measure progress toward those objectives and that can serve as monitoring and decision-making tools when making investments or modifying operations.

A single indicator may not be enough to show how much progress has been made toward an objective and thus could be misleading. For this reason, there needs to be a set of secondary indicators that confirm or explain the results yielded by the primary indicators.

Monitoring and control is the process of measuring the results of the proposed initiatives and evaluating how much they contributed to achieving the established objectives. This evaluation should allow a company to stop at some point and compare its objective with the reality reflected in the actual results.

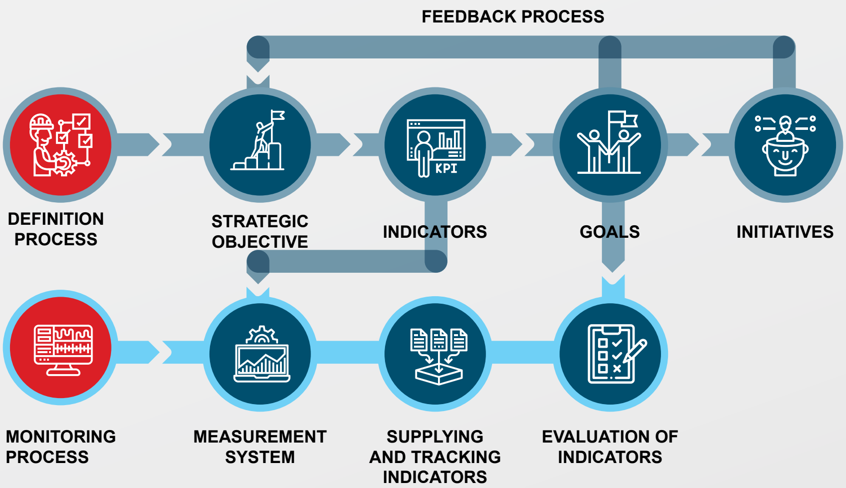
FIGURE 8 • STRATEGY MAP



In order to complete this process, there first have to be digital systems and technologies in place to systematically collect, record, process, and analyze the data and evaluate progress toward the strategic objective in a way that is reliable, real, and useful to the organization. Most of the data feeding the indicators can be collected using sensors and devices installed in physical elements or taken from existing records in information systems.

The BSC is an important synthesis and control tool that informs a business of the status of each indicator and allows it to compare it with the goal to measure the impact that its initiatives are having in terms of achieving the strategic objective. It also allows businesses to identify deficiencies and fix them. As shown in Figure 9, this feedback can be considered ongoing process that encompasses the highest levels of strategic planning based on on-the-ground results.

FIGURE 9 • BALANCED SCORECARD FEEDBACK PROCESS



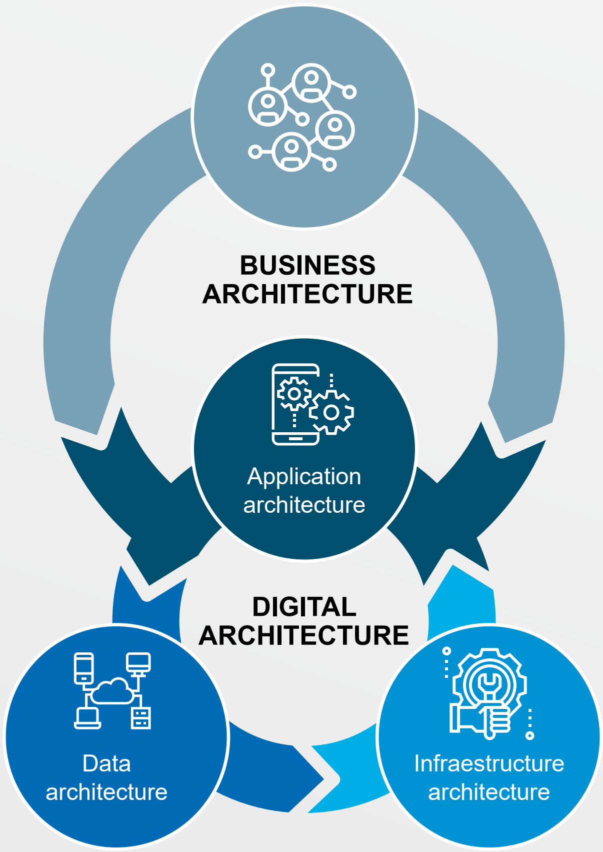
3.3 ENTERPRISE ARCHITECTURE

Enterprise architecture is the design, planning, and implementation actions that aim to integrate an organization's business processes and IT infrastructure. As shown in Figure 10, enterprise architecture aligns the organization's business processes, information, and business performance with the digital architecture, which comprises the applications, technology, and data architecture.

The **data architecture** defines the organization's physical and logical data assets, as well as the data management resources (databases, entities, information flows). The **infrastructure architecture** specifies the logical software, hardware, and digital capabilities needed to support business services, data, and applications. It includes data centers and cloud services, middleware, networks, communications, devices, sensors, cyber-physical systems, personal computers, PDAs, tablets, or any other digital resources. Lastly, the **applications architecture** describes the applications run by the organization and their relationships with basic business processes. In most cases, organizations have a set of applications rather than a single integrated one, and these applications need to be integrated in order to carry out the business processes. Applications can be integrated by using service-oriented architecture (SOA) and enterprise application interface (EAI) strategies.

The implementation of the **digital strategy** will be underpinned by the **enterprise architecture**, supported by a **service-oriented architecture** to ensure the interoperability of its components.

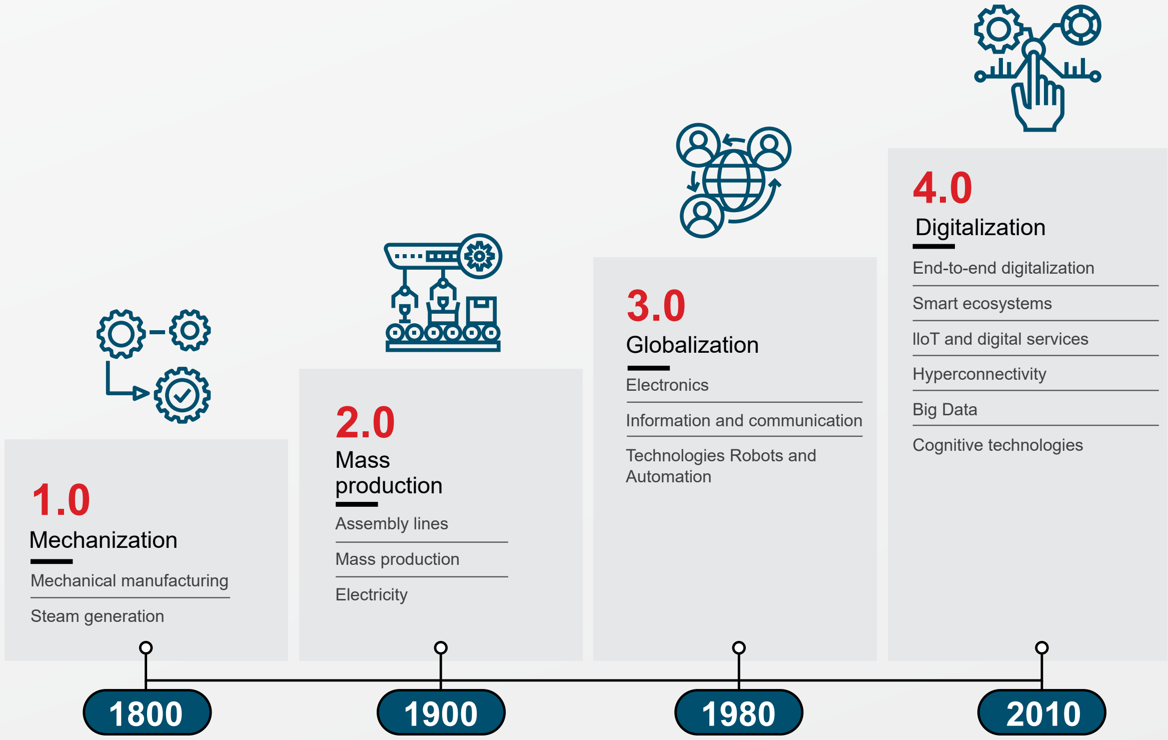
FIGURE 10 • COMPONENTS OF THE ENTERPRISE ARCHITECTURE



4 • TECHNOLOGICAL INNOVATION

Industry has evolved alongside technology, giving rise to the fourth industrial revolution. The first three industrial revolutions (manufacturing, mass production, and globalization) spanned almost two centuries, but starting in the 1980s, electronics, information technologies, and automation have sped up the process to such a degree that in less than 40 years, we are already experiencing the fourth industrial revolution, or Industry 4.0 (Figure 11).

FIGURE 11 • THE EVOLUTION OF INDUSTRY



The fourth industrial revolution is considered the next major disruptive step forward in productivity and people's lifestyles, a disruption that was also seen in previous industrial revolutions. This step drives the digital transformation of industry by introducing technologies that merge the physical world (devices, materials, products, equipment, and facilities) with the digital world. Using these technological solutions, industry 4.0 facilitates the interconnection and digitization of production activities by technically integrating cyber-physical systems[9] into manufacturing and logistics spaces, and through use of the internet's full potential in industrial processes. This connection allows devices and industrial systems, along with other systems, to function and create smart industry.

In this context, smart factories and ports have a key role to play in the digital transformation of industry 4.0 and in connected supply chains. As part of the digitization process, these facilities will create and use new smart products and services, new technological solutions, and sophisticated digital applications.

9 Cyber-physical systems are a new generation of systems where computing, communications, and control technologies are closely linked to each other, thus merging the physical and digital world.

4.1 SMART PRODUCTS AND SERVICES

Smart products have self-management and communication capabilities that offer new value propositions and business models by significantly enhancing the user experience and interactivity with customers. Sensors, computing and control tools, and cyber-physical systems are built into these products, making them **conscious** of their environment and of the product itself. This allows them to be **smart, connected**, and sensitive to changes in their surroundings.

Connectivity and the constant exchange of data, coupled with powerful analytics and economic tools, form the basis of a new range of smart services that can optimize the operational models of existing services. **Smart services** will be a differentiating factor in the competitive environment of Industry 4.0.

Another essential component of Industry 4.0 is **connected supply chains**, which will allow companies to generate value through transparency and process automation. To manage the growing complexity of supply chains, physical flows will need to be linked to digital platforms. Virtual images of the supply chain's activities can be created to achieve this integration. These will allow players to monitor all flows of information and events in real time, and will offer visibility, collaboration, and learning capabilities to support decision-making and autonomous control. This operational phase is known as the supply chain control tower.

4.2 BROAD TRENDS AND TECHNOLOGIES FOR SMART PORTS

Following the emergence of the **Internet of Information** and the **Internet of Services**, technology is now undergoing an innovation process directly tied to the rise of the **Internet of Things** and the **Internet of Value**.

At smart ports, we find a set of **emerging digital technologies** driving innovation and the digital transformation of products, services, processes, marketing, sales, and businesses in five major areas or trends:

• Digitization:

With the aim of replacing manual or technologically rudimentary processes in landside and maritime operations, some of the world's biggest ports have begun to develop a more efficient strategy based on the principle of digitizing and managing information. Information is a very important asset that can lead to major efficiency gains if processed and managed properly. Its ability to boost efficiency is especially relevant to ports, which generate, and exchange large quantities of information related to processes like loading and unloading containers, monitoring sensors for measuring emissions, monitoring dock space, etc. Within this digitization process, hyperconnected ports need to use digital platforms, which allow them to orchestrate a large set of operations related to Industry 4.0. This lets customers and businesses connect and communicate with the different service providers using a digital communication channel. Additionally, the digitization strategy works by incorporating other technological solutions like big data, artificial intelligence, blockchain, or cloud computing.

• Automation and Robotization:

Within the context of Industry 4.0, correct automation of the industrial environment is set to revolutionize the goods and services production chain by generating more efficiency and better resource management. As key components of this process, the emergence of new technologies like 5G and the Industrial Internet of Things (IIoT) promises to play a key role in generating information and automating ports through the development of cyber-physical systems (CPS). These cyber-physical systems, along with the other machinery housed in terminals, will be powered by electricity and other renewable sources, allowing ports to cut back significantly on the amount of fuel they use and on machinery maintenance costs. When included in the digitization process, automation and robotization can directly contribute to efficiency gains in most logistics and port processes.

• New Business Models:

Correctly digitizing and automating ports will open the door to a wide range of new business models based on using technology to share information and resources. Specifically, the emergence of technologies like blockchain promises to be a key factor in decentralizing transportation and logistics information flows, preparing the ground for new models where port managers and customers create added value. Within the port model, blockchain can be used to leverage a vertical, horizontal, and geographical collaboration model by sharing logistics and transportation information. More specifically, blockchain can be applied to trace cargo and containers for importers and exporters to improve the real-time tracking and visibility of goods and predict their movements in logistics chains. This new model will boost performance and profits and reduce costs, greenhouse gas emissions, and workflow congestion.

•Security:

Smart ports face an increasingly higher risk of physical and digital attacks as commercial activity expands and the amount of data and information exchanged at ports rises. Additionally, transporting and handling dangerous goods increases the risk of accidents or negligence during loading and unloading operations. These facts underscore the need for optimal security and safety systems—both physical and virtual—for ports and vessels. Internet of Things technology can be used to establish total control over a port's physical assets under the paradigm of Industry 4.0. Furthermore, fixed access and wireless technologies like fiber-optic, TETRA, LTE, or 5G will be able to ensure large bandwidths, as well as full availability and reliability for the different physical surveillance devices like cameras, radars, and drones used to monitor the land, maritime, and air domains. In the virtual dimension, cybersecurity systems must guarantee quick and efficient protection for any type of data related to workers and systems. To achieve this, the systems will incorporate different complementary mechanisms like digital signatures and certificates, public and private keys, encryption and authentication systems, and virtual private networks. They will also need to include an early warning system to combat cyber threats.

• Energy and Environment:

One of the main aims of the port technology revolution is to reduce energy consumption and lessen environmental impacts in order to transform ports into efficient and sustainable economic and trade centers. Using new technologies like IoT, ports can manage transportation more efficiently and move towards a sustainable model as part of the objective of decarbonizing ports. The shift to an automated, electricity-based model will be followed by the introduction of alternative fuels like liquefied natural gas or the use of renewables like wind or wave power, which will allow a transition towards a model with low greenhouse gas emissions. The development of smart grids[10], for example, enables new options for storing surplus electricity and later converting it into hydrogen. At the same time, ports will implement different systems for monitoring, energy management, and the control of different air pollutants, as well as the traffic management system.

Within these areas, there are many technological solutions designed to cover different smart port functionalities. More specifically, these technologies are:

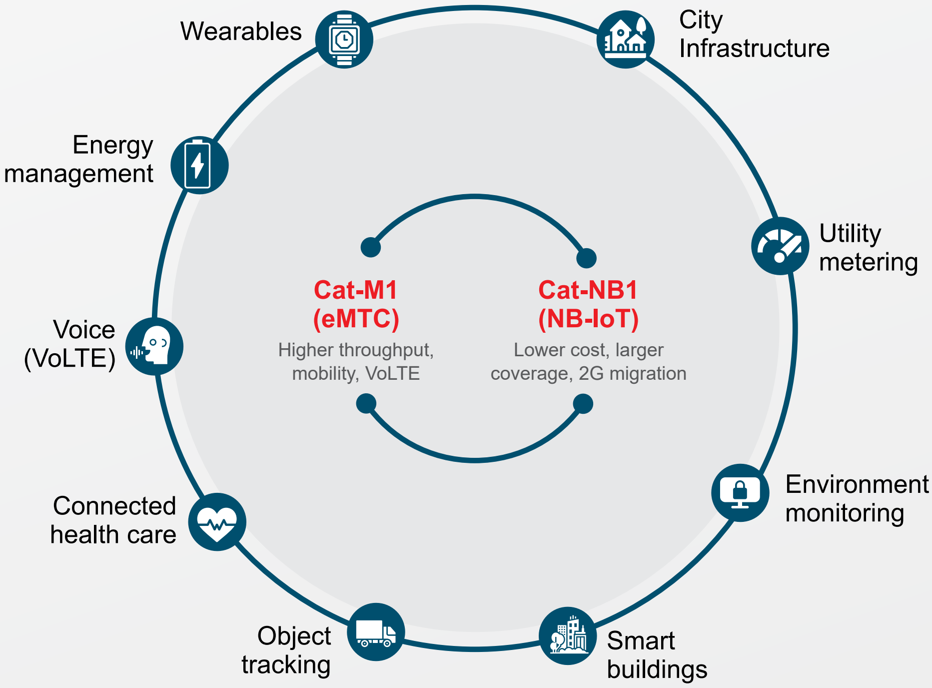
10 Electrical grid that links producers and consumers in a smart way to provide a secure and sustainable power supply.

4.2.1 • INDUSTRIAL INTERNET OF THINGS (IIOT)

The Internet of Things (IoT) is a term that encompasses the set of technologies and applications designed to provide secure communication and connections between all types of devices, objects, and machines using the IP communications protocol.

When applied to industry, IoT technology is known as Industrial IoT, or IIoT, and it can be used to connect a large number of devices like sensors, actuators, and machines, which record and collect information that is then processed and analyzed to be applied to different industrial tasks. Currently, the main IIoT solutions are LTE-M, NB-IoT, LoRa, Sigfox, Zigbee, and meshed networks. Because of their connectivity and interoperability, these IIoT solutions are set to play a key role in different industrial operations like manufacturing, power generation and distribution, transportation, logistics, communication between companies, and fleet and vehicle management and monitoring (Figure 12).

FIGURE 12 • LTE-M AND NB-IOT APPLICATIONS



Within ports, the integration of IIoT technology is poised to enhance the interconnection of all kinds of objects and sensors with the vehicles and equipment used at ports, facilitating smart loading, unloading, and transportation operations. Essentially, the Industrial Internet of Things is used to perform four basic operations within ports: sensitization, positioning, interconnection between devices, and monitoring. When these operations are performed correctly, IIoT technology can optimize different aspects of the processes of planning resources, managing technological assets, measuring and evaluating environmental impacts, and developing a security and safety system for the port and terminal.

In port systems, the SCADA system can also provide IIoT functions by monitoring and controlling the different industrial infrastructure processes, based on physical facilities.

4.2.2 • FIXED ACCESS AND WIRELESS TECHNOLOGIES

Fixed access and wireless technologies are used to send the information generated by all the devices, machines, and users in industries and ports.

Ports use fixed access solutions like ADSL or fiber-optic extensively to provide access to online services and implement local and wide area networks, which connect computer equipment to servers. These technologies provide computer equipment with the bandwidth and quality of service needed to send voice, data, video, and other types of information.

Ports also make broad use of wireless technologies to send information via radio frequency signals. This technology provides greater accessibility for connecting the different devices in sensorization, monitoring, and surveillance networks. This category of solutions includes wide and local area networks, wireless technologies for critical situations, and cellular technologies.

Wide and local area wireless technologies are very common solutions in many everyday and industrial contexts. Because it is low cost and easy to implement, Wi-Fi technology is the most common solution used to give large numbers of users access through local area networks. WiMax is a wireless technology for accessing wide area networks (WAN) that allows the configuration of different network topologies, like point-to-point, point-to-multipoint, and meshed networks. WiMax makes networks more reliable and energy-efficient by establishing shorter-range connections between different devices.

TETRA (Terrestrial Trunked Radio) is another wireless technology used, this time to provide service in critical situations. It is a digital radio standard used to securely transmit voice and small volumes of data and information with complete confidentiality and integrity. Because it is secure and robust and provides good coverage, TETRA is widely used for communication between different public security bodies like ambulances, firefighters, civil defense entities, civil and port authorities, etc.

Cellular technologies can be used to set up small and large networks within the port environment using the concepts of division into cells and frequency reuse. The most novel technologies within this type of solutions are LTE and 5G New Radio.

LTE (Long Term Evolution) is a point-to-point wireless communication standard part of the fourth generation of mobile communication systems (4G). The latest version of LTE, called LTE Advanced Pro, can offer high bandwidth over mobile technology, offering high transmission speeds under different mobility, coverage, latency, and device density conditions. LTE technology has been widely implemented in many industrial contexts, like factories and ports. It can also be combined with other technological solutions like TETRA to establish highly available and reliable communications for critical situations.

5G New Radio (5G NR) is currently at the cutting edge of cellular technology for point-to-point connections. The flexibility, scalability, and efficiency of 5G solutions enable them to establish high-bandwidth communications on mobile technology, ultra-reliable communication with low latency for emergency and alert systems, or communication between many devices, vehicles, and objects. This solution enables the implementation of the Internet of Things, remote control over industrial machinery, and the beginnings of autonomous driving. In relation to ports, 5G is set to improve the capacity, connectivity and positioning conditions of routine logistics operations, providing reliable, real-time access and a high level of security between all port players.

4.2.3 • AUTOMATION

Industrial automation is the set of technological solutions that allow mechanical, hydraulic, pneumatic, electrical, electronic, or computerized systems or elements to be used to control machines and processes, thus reducing human intervention and heightening control over equipment and processes. Automation can be applied to terminals and maritime and aerial vehicles used across the spectrum of logistics and port operations.

Automated terminals are container port terminals that automate the process of moving containers within the yard and between the dock and the yard. At terminals, it is possible to automate access control systems at terminal gates, storage and distribution operations in freight yards, and quay cranes used to load and unload containers, among other components.

FIGURE 13 • REMOTE CONTROL OF VESSELS

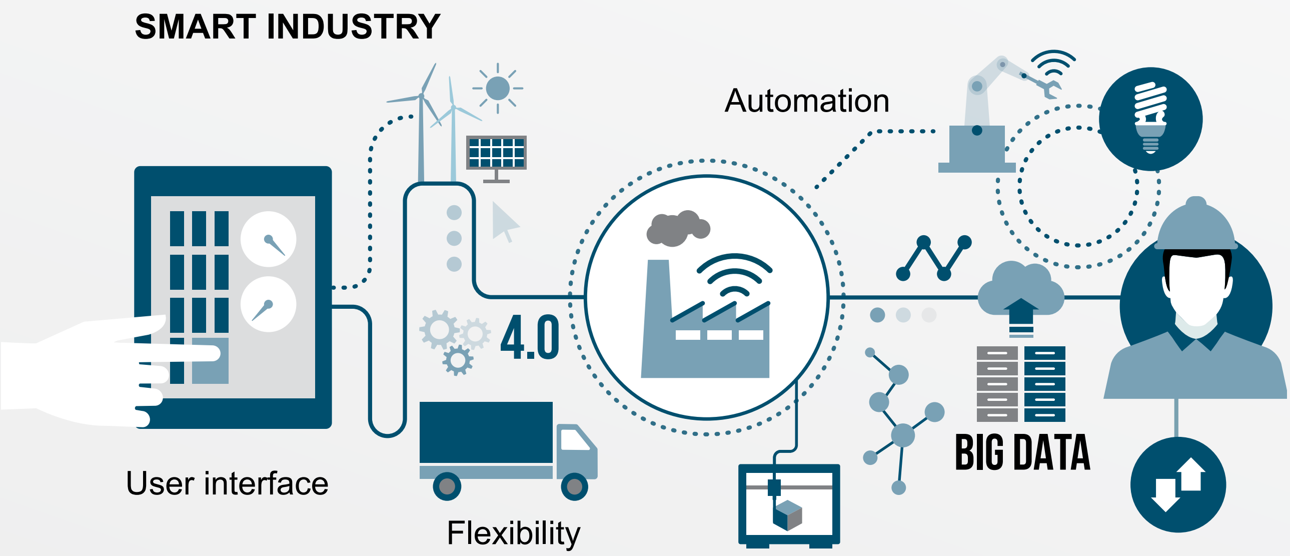
Maritime and aerial vehicle automation applies chiefly to vessels and drones. Remote-controlled or self-driving vessels are set to revolutionize maritime traffic by increasing the efficiency of operations and driving down costs and accident rates (Figure 13). Self-flying drones can be used to remotely streamline various logistical, surveillance, and monitoring tasks by increasing mobility and accessibility and bringing down human resource and logistical costs.

4.2.4 • BIG DATA

Big data is the branch of technology focused on designing and running the set of computer architectures and technologies used to store and process data and information in quantities that exceed conventional systems' processing capabilities.

In industry, the information recorded by sensors and devices can be processed in real time and on a massive scale using big data technology, allowing all kinds of data and statistics to be stored, shared and monitored (Figure 14). One industrial application of big data is the concept of digital twins, which are digital replicas or representations of a physical asset, typically composed of a set of variables that when combined and processed can describe and predict the behavior of the industrial assets to be monitored.

FIGURE 14 • TECHNOLOGICAL INTERACTION OF BIG DATA



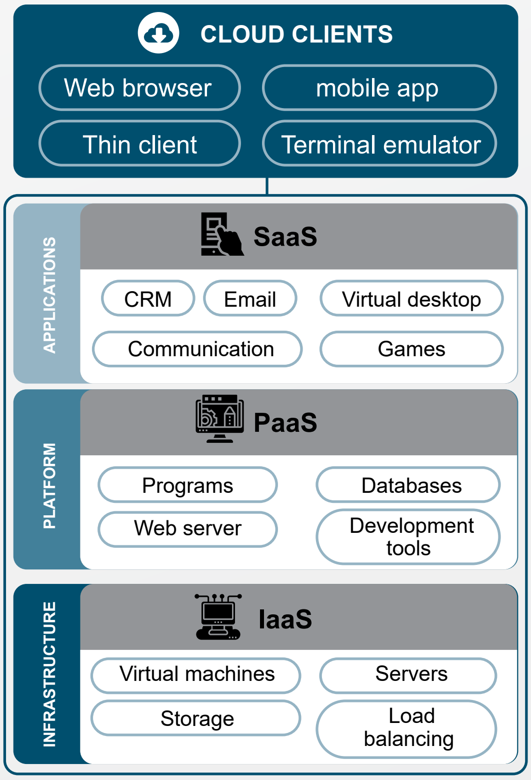
When applied to ports, big data and digital twin technology is poised to transform a wide range of operations. This technology can store different streams of information from logistics, sensorization, and positioning networks, and process that information in real time, which allows ports to create multi-dimensional models that then help optimize port supply chains, reducing delays and congestion and increasing the efficiency of the different players and facilities.

4.2.5 • VIRTUAL STORAGE

As the industrial and commercial segments have grown, most systems for managing, storing and processing digital information have migrated to a virtual storage model, which is designed to provide access to multiple services in a distributed and scalable way. This model includes technological solutions like digital containers, cloud computing, and edge computing.

Digital containers are the technological solution used to move or run software applications or services in an independent and isolated way, as if they were tiny virtual machines. Containers package software applications, allowing them to be migrated to any operating system in a portable and flexible manner. Within port systems, digital containers are especially useful for moving and running applications based on micro services as part of the Port Community Management System.

FIGURE 15 • CLOUD COMPUTING STACK



Cloud computing is the term used to describe the provision of computing services like infrastructures (servers and storage), platforms (databases and programs), and applications and other resources over the internet (Figure 15). Thanks to its flexibility and scalability, cloud computing has gained widespread use in port logistics, allowing companies and entities to use low-latency services and applications without investing in infrastructure.

Additionally, higher traffic in the core segments of the network has led most industrial and port entities to adopt an edge computing approach, which is based on computing and storing part of the data close to the end user. For ports, edge computing provides a distributed model that makes it easier to access and process the information generated in vessels in real time. This reduces congestion in central nodes, thus lowering latency in operations, bandwidth needs, and energy consumption.

Cloud computing and edge computing can be used simultaneously, giving both the core and local segment of the network flexibility and accessibility.

4.2.6 • BLOCKCHAIN

Blockchain is a kind of distributed ledger technology (DLT). It is used to perform digital transactions in real time and in a secure and distributed manner. Blockchain's concept of decentralized and digital value sharing (tangible and intangible assets) gives it multiple applications in different industrial and commercial sectors.

For ports, blockchain gives different entities in the supply and logistics chains reliable information on the rest of the players for making decisions, performing operations, or undertaking activities. The goal is boosting productivity, cutting costs, increasing reliability, and fostering agreement among customers and providers.

For ports, one of its most notable application is to container tracing and tracking services. It enables greater visibility of the flow of container import and export operations taking place all along the logistics chain.

4.2.7 • ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING (ML)

Artificial intelligence (AI) is the branch of computer science focused on developing and combining algorithms created in computers and programs in order to learn and make connections and observations normally done by human reasoning. A subset of AI is machine learning (ML), which is designed to develop algorithms that can automatically detect patterns in example data sets and information to then extrapolate these behaviors and make predictions and decisions about future situations.

In the port and logistics space, ML is set to greatly enhance the different systems for managing and mass processing information used in the land and maritime domains. For a port's land domain, ML can use the information gathered by sensors, actuators, and mobile technology to understand and coordinate traffic flows. ML can help predict traffic conditions and wait and delivery times for trucks at the entrance to the terminal. In the maritime domain, ML can be used both in the dock area and terminals to calculate how long containers remain in the terminal, predict the date and time of ships' arrival, or shed light on vessel loading and unloading patterns.

The use of ML in the port environment could significantly reduce the number of operations to be performed in the terminal, thus increasing efficiency and reducing emissions and costs.

4.2.8 • VIRTUAL AND AUGMENTED REALITY (VR AND AR)

Virtual reality and augmented reality are technologies that combine images in real time and in an interactive way. They provide a full or partial experience allowing users to receive more virtual information. Virtual reality fully immerses the user in virtual information, while augmented reality simply complements the real information the user perceives.

Since they increase and combine information in real time, virtual reality and augmented reality are considered highly useful tools in work contexts, as they support or complement the information that workers perceive in real time and can also warn them of potentially dangerous situations.

At ports, these technologies can be applied to the land and maritime domains to support or complement the information that workers perceive in real time, to visualize port facilities, or to warn of potential emergencies or dangerous situations.

Using all these technological solutions can make ports more profitable and productive, thus driving the development of entities and companies in the port and logistics space.

4.2.9 • 3D PRINTING AND ADDITIVE MANUFACTURING (AM)

3D printing is the digital process of creating three-dimensional objects by designing, modeling, and manufacturing them according to a specific size and shape, and with particular characteristics. In the industrial or work environment, the process of converting a digital product file into a physical object by adding layers of material with a 3D printer is known as additive manufacturing.

Additive manufacturing gives product developers unprecedented flexibility to make and implement personalized changes to new products. Because this technology is so efficient, it cuts down on the number of intermediaries and the time required to perform operations within a design and production chain, thus lowering costs.

Additive manufacturing can be used at ports as a quicker and less expensive way to develop and manufacture parts or other objects used in terminals and vessels.

4.2.10 • CONFIGURING AND MANAGING INFORMATION TECHNOLOGIES

Information technology configuration and management systems include all the physical and virtual networks, servers, equipment, routers, terminals, software tools (databases, files, etc.), and other devices needed to interconnect, access, store, and control all the flows of information generated and collected using the technologies described earlier in this section.

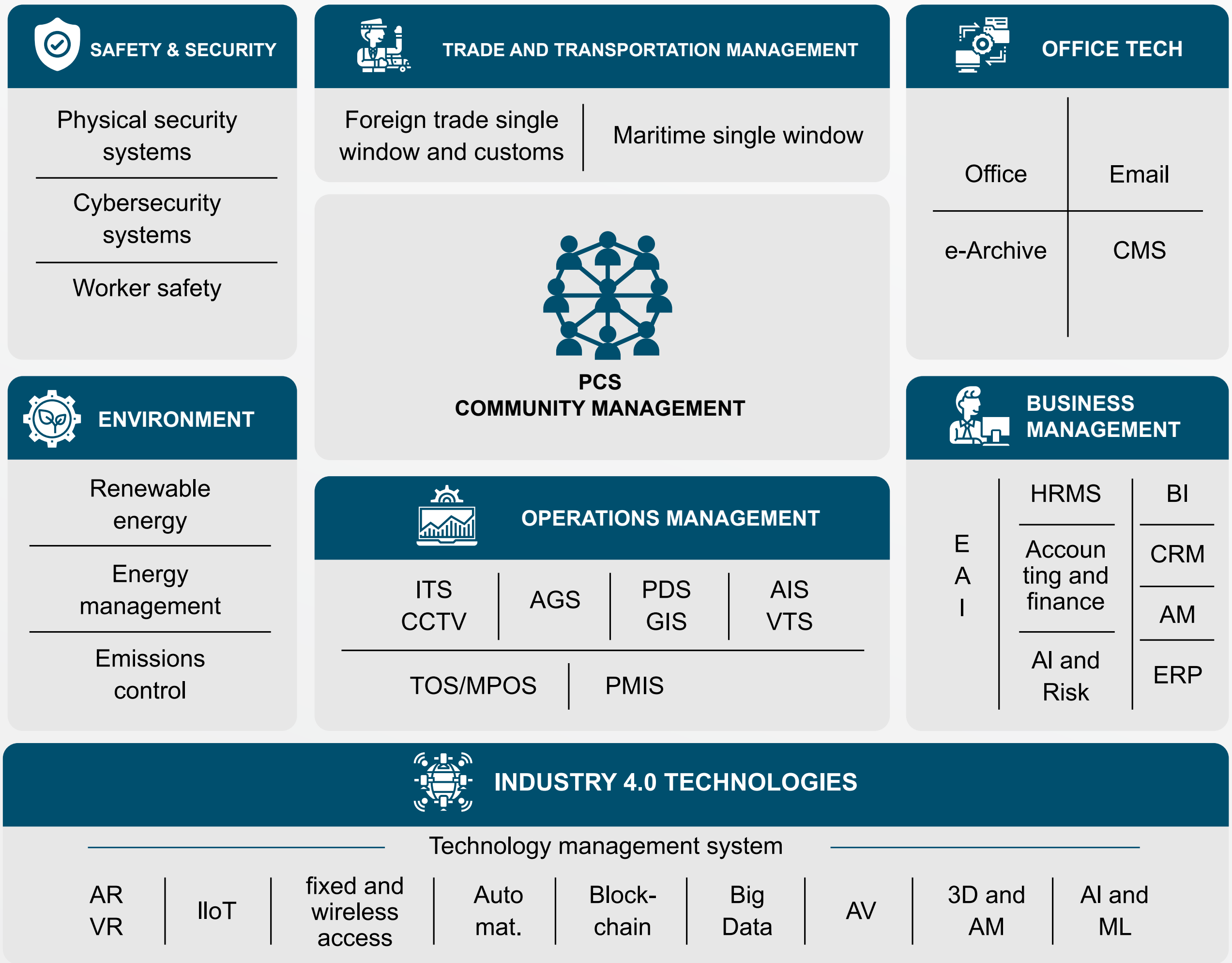
4.3 SMART APPLICATIONS FOR PORTS

Technological innovation and the specialization of support activities have a significant impact on the port industry. All major ports have begun to explore modernization and transformation initiatives to create unique value propositions that give them a competitive edge.

However, ports do not run based on a single application used by a single company. Rather, they have an extensive ecosystem of specialized applications for each of their different activities and functions. These applications can be used by one or multiple organizations, depending on how each port is set up.

Figure 16 gives an overview of the ecosystem of applications used at ports and port facilities. Applying emerging technologies to create smart ports can lead to a change that sets the port apart in the services it provides to customers, users, and citizens, as well as in its economic performance.

FIGURE 16 • SYSTEM OF APPLICATIONS FOR PORTS



Among the applications in port environments are those common to all organizations and in charge of managing back-end enterprise and office management functions. Within **enterprise management systems**, there are applications designed for human resource management (HRMS), accounting and finance, management and control of assets and inventory, customer management, business intelligence, internal audits, or risk management. In many cases, all these functions can be covered by enterprise resource planning (ERP) systems.

Another set of back-end applications common to all organizations are **office applications**, like an office software suite (word processors, spreadsheets, multimedia presentation tools, databases), electronic filing systems, content and website management systems (CMS), e-mail programs, videoconferencing and instant messaging systems, etc.

For managing front-end activities, there are different systems for different functions. **Trade and transportation management systems** are crucial for meeting regulatory requirements when managing and automating foreign trade operations at ports. The purpose of these systems is to guarantee a secure cross-border flow of goods and vehicles by managing information that involves multiple authorities and entities, like the port authority, maritime authority, customs, inspection agencies, and the different border control services. In this area, entities have various systems for managing operations based on single window and electronic declaration systems, such as: ***foreign trade single window systems***, which give the different government and border protection agencies a digital channel to receive applications for permits and other documents for foreign trade transactions; customs systems, which are the set of applications used to make the customs declarations required in foreign trade processes; and ***Maritime Single Window Systems***, which provides a single portal for all processes and formalities required for a ship's arrival, departure, or stay at ports.

Operational management systems are especially important for covering a port's operational functions. ***Port management information systems (PMIS)*** are designed to control and manage all operations within ports. These systems' main client is the port authority or entity in charge of managing the port infrastructure. These systems can be connected to ***automatic identification systems (AIS)*** for vessels, ***vessel traffic services (VTS)***, other technical nautical systems, or the port terminals themselves. ***Terminal Operation Systems***, whether ***multipurpose (MPOS)*** or for ***containers (TOS)***, are designed to manage terminal operations, both to control container traffic and for the multipurpose management of freight movements. These systems can be linked up to other operations monitoring and control systems, like ***automated gate systems (AGS), positioning detection systems (PDS), geographic information systems (GIS), or intelligent transportation systems (ITS)***.

Both trade and transportation management systems and operations management systems will be complemented and orchestrated by ***port community management systems***, which encompass all players in a port's logistics chain, including the port authority, port operators, logistics operators, customs brokers, shipping lines, carriers, container loading stations, etc. Within this category of systems, ***the port community system***, or PCS, is designed to allow all parties in the port and logistics chain to instantly send and exchange information in a way that meets the confidentiality and protection requirements for handling personal or commercially sensitive data.

PCS are electronic platforms designed to connect different systems run by the organizations within the port community. These systems facilitate smart and secure exchanges of information using a single communication channel that interconnects all logistics and transportation players, whether public or private. By providing this channel, PCS can optimize and automate the different processes for moving goods and containers, thus maximizing the efficiency of infrastructure and operations, increasing organizations' competitiveness and revenue, and bringing down operating costs. Additionally, PCS are designed to coexist and cooperate with other systems, like PMIS, TOS/MPOS, or single window systems.

Increased commercial activity and operations in the port and logistics sector makes ensuring physical and digital security another key task. Furthermore, the greater complexity of industrial operations makes it necessary to design occupational safety systems for workers. To protect against these risks, most ports have safety and security systems with physical, cybernetic, and industrial protection components. ***Physical security systems*** are the set of applications needed to protect port facilities from any attack or intrusion involving illegal or fraudulent activity. These systems are usually composed of different subsystems, like CCTV surveillance systems, automated gate systems (AGS), presence detection systems, video-based license plate or vehicle recognition systems, maritime traffic management systems (AIS and VTS), NFC personal identification systems, etc. On the other hand, ***virtual or cybersecurity systems*** consist of applications and tools designed to protect all assets and users within a digital environment. Within the systems, there are other subsystems such as, for example, the digital signature and certificate system, public and private key systems, encryption and authentication systems, or early warning systems for cyber threats. Finally, ***the industrial and worker safety system*** is the set of applications designed to prevent, reduce, and respond to any work accidents that take place within port facilities, terminals, or cities. Industrial and worker safety systems can complement their operations with systems like intelligent traffic services (ITS), CCTV systems, automatic vessel identification services (AIS and VTS), maritime signaling systems (buoys, lighthouses, radio beacons), or systems for monitoring worker safety. Many of the systems are used to manage physical, industrial and worker safety and security, so some ports combine the management of these two components in a single command center.

Environmental Management Systems are the set of applications designed to ensure energy efficiency and the protection of the marine and coastal environment from different threats like environmental contamination or noise pollution. Environmental management systems include tools designed to track energy consumption and use energy in a smarter, more efficient way. Examples are environmental monitoring and prediction systems or smart grids. Additionally, other tools like weather stations, air quality sensors, noise pollution sensors, smart buoys, or pollution detection systems are also used to monitor air quality, water quality, or noise levels. Finally, another purpose of environmental management systems is to instate an automated electrical model that reduces carbon emissions by using renewable energy (wind, electrical, etc.) and alternative fuels like liquefied natural gases or hydrogen. This strategy moves ports towards models with low greenhouse gas emissions.

5 • ROADMAP

In today's world of constantly changing and evolving technology, inaction is an error that often brings failure. Each port community must respond to these changes and adapt if it wants to remain competitive, efficient, and green.

Certain smart port initiatives based on developing and implementing new technologies are already underway, but in these cases it is important to correctly structure and connect the initiatives, and properly define the support activities, direction, and efforts needed to make them sustainable over the long-term.

To this end, this chapter of the Smart Port Manual lays out a “roadmap” for developing a Smart Port Plan. Using this method, each port and logistics community can analyze trends in the sector and see how they compare, structure initiatives that are already in progress, set priorities, and establish courses of action for becoming a smart port. The plan also serves as a starting point for fostering collaboration and creating synergies between all companies and institutions in the cluster, promoting private-sector investment, and encouraging the participation of SMEs, universities, and knowledge hubs.

According to the roadmap, the first step is an analysis of a port cluster’s current status to assess the port's overall degree of technological development (macro level), followed by a similar evaluation focused on specific areas (micro level). The port community should then develop the smart port plan, helping identify technologies and projects that could have a major impact on port operations and their own businesses. To do so, the community should form working groups to discuss and prioritize initiatives. Lastly, the community creates an implementation plan with short-, medium-, and long-term actions to put the roadmap into practice. Along with this plan, the community defines the KPIs to be used to track and monitor the strategy.

5.1 ANALYSIS OF THE SMART PORT'S STATUS

To achieve digital transformation, ports have to reach the objectives for each level of digitization. Each port and port community member will create a smart port strategy to take simultaneous action on all four levels of digital transformation defined in Chapter 2: internal digital transformation, connected port, connected port community, and hyperconnected port. A port is considered to have reached a certain level of digital transformation when it achieves the different objectives and meets the different requirements established for each level of digitization. These requirements, which are listed in Figure 17 and described in Table 4, directly correlate to the level of modernization and technological development in different areas (technological, operational, environment, social, economic, etc.).

While certain individual organizations might be very technologically advanced, this does not necessarily mean a port can be considered a smart port. At the port level, the operation of the entire port ecosystem must be considered.

FIGURE 17 • LEVELS OF DIGITAL TRANSFORMATION INTO A SMART PORT

LEVEL 1 Internal Digital Transformation	Developing systems for operations management, business management, and office technology on an internal level.	Digital devices for internal use.	There are many manual processes in relationships with third parties.	Internal environmental protection, security, and safety systems.
LEVEL 2 Connected Port	Implementing systems for trade facilitation and electronic formalities.	Replacing manual processes with eletronic and automated solutions at port facilities.	Online port.	Facility-level environmental protection, security, and safety systems.
LEVEL 3 Connected Port Community	Creating a connected and coordinated logistics node.	Adding port community systems (PCS)	Adopting digital platforms for logistics and transportation.	Systems for ensuring environmental and social protection, safety, and security for the community (port and local city)
LEVEL 4 Hyperconnected port.	Applying industry 4.0 technologies like internet of things, big data, blockchain, artificial intelligence, and virtual and augmented realty.	Interconnectivity between vehicles, equipment, freight, infrastructure, people, companies, cities, surroundings, and digital platforms.	End-to-end logistics connectivity through interoperability with different digital platforms and systems.	

Having evaluated the different levels of digital transformation of a port, it is important to highlight the various areas of action for implementing the port environment's digital transformation, and the smart solutions available for each area. Often a specific department of a port authority is investing in digital platforms at the port community level, while other parties continue to use manual processes for these functions.

This manual specifies up to 10 port management areas (Figure 18) in which ports need to act to implement the smart port concept.

FIGURE 18 • PORT MANAGEMENT AREAS

Ports should assess each of these management areas, identifying the assets that are already implemented, those under development, and those that should be developed in each level of transformation described above. This provides a micro-level analytical framework for identifying the areas' degree of development within each level. More specifically, the framework takes the form of a matrix that describes each of the 10 port management areas for the four levels of digital transformation explained above. The matrix can be used to examine the systems, applications, solutions, and technologies that already exist (see Appendix I), are under development, and that need to be developed. Figure 19 provides an example of this matrix.

The different key players that interact in the port ecosystem can complete the matrix by filling out a form that is provided. The form has the port management areas to be analyzed on the left, followed by the different levels of digital transformation to be addressed (internal, port, port community, and hyperconnected). Within each level, it is important to consider and identify assets that are already available, assets or actions that are currently being developed or undertaken, and assets or actions still lacking at the time of the analysis.

FIGURE 19 • PORT MANAGEMENT AREAS AND LEVELS

AREAS	INTERNAL LEVEL	PORT LEVEL	PORT COMMUNITY LEVEL	HYPERCONNECTED PORT LEVEL
Trade and transportation facilitation and commercial management	Use of business management systems (CRM, BI, etc.)	Use of single windows systems, customs systems.	Use of container traffic indexes, creating online directories of companies and information services.	Integrations with cities and the business environment, use of technologies 4.0 to enhance traceability.
Administrative and office technology management	Use of office software technology, cloud storage, group work areas, videoconferencing tools, ERP.	Electronic administrations (online procedures, electronic clock-in, document validation).	Integration of the different trade and transportation facilitation systems with the PCS.	Maximun development by integrating industry 4.0 technologies like big data or artificial inteligence.
Operations Management	Internal development of operations management systems like PMS, TOS, MPOS, PDS, etc.	Development of automated systems like AGS, AJS, ITS, and integration with single windows and customs.	Integration of operations systems through PCS systems.	Connections with digital platforms, use of industry 4.0 technologies to achieve operational hyperconnectivity.
Cluster Management	Does not need a system that shares information in the cluster	Does not need a system that shares information in the cluster.	Use of quality management tools.	Developing a port cluster innovations plan.
Logistics and Hinterland Development	Use of information systems to manage the port´s logistics and hinterland data.	Use of operations systems like AGS, or AJS, prior appointment for accessing the port.	Logistical control through PCS systems enhances ITS/VTS transportation systems.	Integration and interconnection of port with maritime and land corridors and global logistics chains.
Environmental Management	Energy efficient terminals, use of renewable energy, reduced emissions, refactorizing machinery.	Monitoring and controlling emissions and spils, managing waste, supplying sustainable fuels.	Performance of environmental management projects within the port community.	Development of environmental management projects use of industry 4.0 technologies for environmentalsurveilance and control.
Safety and Security	Use of AGS control systems, video surveilance, and checks on persons.	Development of ITS, Scanner, AJS, VTS systems.	Integration and connection of security systems through PCS systems.	National cybersecurity strategy, use of industry 4.0 technology like virtual reality or machinery automation.
Technological Development	Introduction of digital tools for business operations, and office management.	Digitization of port facilities, security and surveillance systems, and positioning-based services, etc.	Promotion of digital platforms as well as collaboration, coordination, and cyber security tools.	Port 4.0 programs for introducing new technologies (IoT, blockchain, big data, artificial inteligence, etc.)
Innovation Management	Innovation based only on developing internal systems.	Research and innovation projects are encouraged. Financing is sought for facility innovations.	Promotion of port community innovation programs	Participation in port innovation plans, development of accelerators, business launchers, innovation hubs, startups.
People Management	Estabilishing human resources plans, internal training.	Development of training programs at the port level.	Delevopment of regional, national, or international training programs at the community level.	Use of industry 4.0 technologies (virtual and augmented reality) to increase worker and industrial safety and improve digital training.

In the white paper on preparing the roadmap (Report V), this form (see Table 4) lists the players involved in each port management area and level of transformation, together with example questions for gathering relevant information to fill out the matrix. It should be noted that the term "port authority" can in some cases mean the company or manager in charge of the port facility, which in certain countries may not technically be considered a port authority. All components of the evaluation matrix should include a reflection on how emerging technologies (like IoT, big data, artificial intelligence, advanced data visualization, or cloud technologies) are being used and a description of the opportunities that could be created by implementing those technologies. Another general question in each component of the evaluation matrix is whether ports have, or have a need for, specialized personnel for each specific port management area and level. The current maturity level of each port management area in the matrix will then be evaluated (from 0 to 4) based on assets already in place, steps currently being taken, and future actions considered necessary.

TABLE 4 • TEMPLATE FOR DESCRIBING EACH MANAGEMENT AREA

AREA	LEVELS	ASSETS, ACTIONS, AND INITIATIVES
OPERATION MANAGEMENT MATURITY LEVEL **0 • 1 • 2 • 3 • 4**	INTERNAL	☐ AVAILABLE ASSETS
		☐ ASSETS BEING DEVELOPED/ACTIONS UNDERWAY
		☐ ASSETS/ACTIONS STILL NEEDED
	PORT	☐ AVAILABLE ASSETS
		☐ ASSETS BEING DEVELOPED/ACTIONS UNDERWAY
		☐ ASSETS/ACTIONS STILL NEEDED
	PORT COMMUNITY	☐ AVAILABLE ASSETS
		☐ ASSETS BEING DEVELOPED/ACTIONS UNDERWAY
		☐ ASSETS/ACTIONS STILL NEEDED
	HYPERCONNECTED	☐ AVAILABLE ASSETS
		☐ ASSETS BEING DEVELOPED/ACTIONS UNDERWAY
		☐ ASSETS/ACTIONS STILL NEEDED

After defining what is still lacking in order to reach the different levels of digitization in different port management areas, evaluators can then quantify ports' progress in these 10 areas using a graphic representation method. This graphic model is shown in Figure 20.

FIGURE 20 • GRAPHIC REPRESENTATION MODEL

5.2 CHOOSING VIABLE SOLUTIONS AND PROJECTS

The field of economic analysis of projects offers well-established methods for correctly choosing projects and solutions. In the context of this roadmap, the focus is on guaranteeing that the process of choosing the actions for the smart port plan is transparent and involves the participation of the port community.

The proposed method recommends conducting field research and forming working groups with the different players in the port and logistics cluster to decide which areas of work have the greatest impact on companies and the port environment and to gage port cluster organizations' level of interest in the different initiatives.

5.2.1 • METHOD

5.2.1.1 • FIELD RESEARCH WITH PLAYERS IN THE PORT CLUSTER

To compare international trends in the sector, this step seeks to identify new trends based on the experience and perspective of different local actors, prioritize them by importance and feasibility, and propose a timeframe for implementing them in the logistics and port cluster. To meet these objectives, a survey is designed for conducting the field research.

The survey participants should represent a cross section of the different groups at the port being analyzed and should primarily be managers and directors of strategic departments at the companies. The survey should be conducted in person and contain the following questions on each trend:

- **The importance of the trend:** the degree of importance the survey participant assigned each trend in the sector for their port community. The participant gives a score from 1 to 5: 1 is very little importance, 2 is little importance, 3 is moderate importance; 4 is high importance; and 5 is very high importance.

- **The consolidation of the trend:** the likelihood or feasibility of the trend or challenge becoming a reality. There are two questions on this aspect.

    - The first is a yes or no question about whether the survey participant thinks the trend could become a reality.

    - If they answered yes, the respondent should specify how long they think it will take for the trend to materialize: 1 to 5 years, 5 to 10 years, 10 to 15 years, 15 to 20 years, or more than 20 year.

- **The impact of the consolidation of this trend:** The survey participant answers two questions. The first is about how this trend affects the sector, and the second is on how it affects their specific organization. The participant gives a score from 1 to 5: 1 is very little impact; 2 is little impact; 3 is moderate impact; 4 is high impact; and 5 is very high impact.

It is also important to consider the survey participants' open-ended responses regarding possible smart port actions to be taken within each of the trends analyzed, the importance they assign it, the steps being taken by the organizations they belong to, or the likelihood that they will materialize within a specific timeframe.

After gathering all the responses, the people conducting the survey will need to consolidate and sort them to create a ranking and identify which trends the port and logistics cluster considers most important and which of the broad trends in the sector is considered to have the highest impact.

5.2.1.2 • WORKING GROUPS

The next step is creating working groups for debate and discussion that seek to identify and prioritize the key areas of work to be included in the port community's smart port plan.

These working groups will be issue-based, and the entity that manages the port will invite subject-matter experts, executives from organizations in the port cluster, or department heads from those organizations to participate.

These groups should discuss the trends or areas of innovation that on the surveys were scored as the most important or relevant to the port community.

Each of these trends will be presented to the group, together with different specific lines of action taken from the Inter-American Development Bank's Smart Port Manual in order to consider these lines of action for implementing the plan. To reach a conclusion and prioritize the lines of action suggested by those who attended the working group session, the groups will do a scoring exercise after the discussion. Each participant will be given several votes based on the number of lines of action to be evaluated. Participants can give all their votes to a single line of action or spread them out according to how important they think each one is.

This dynamic yields a specific number of lines of action to be pursued to build the Smart Port Action Plan.

5.3 SHORT-, MEDIUM-, AND LONG-TERM IMPLEMENTATION PLAN

A smart port plan should cover the governance, investments, and operations needed for the solutions.

The governance model provides the structure needed to establish standard processes and procedures supported by the solutions introduced at the smart port, as well as to determine which services the smart port should offer, define policies for how the systems will run, build relationships and partnerships, set strategies, and obtain commitments from the entire port community.

The business model, in turn, establishes who will contribute to the investments needed for the different initiatives in the smart port plan, as well as the applicable return on investment policy.

Finally, the operations model will determine the extent and structure of the human and physical resources needed and how they will be organized to run the different systems that make up the smart port. The operations model will also specify the technical and enterprise architecture that provides the service needed to carry out the initiatives. The physical location of offices and digital assets (servers, network infrastructure, identification systems, automation, sensors, actuators, etc.) should be planned out.

5.3.1 • MANAGEMENT MODEL

Each port community's Smart Port Plan should contain numerous actions and provide effective tools and mechanisms for each action in order to reach the proposed objectives.

Since the plan involves the entire port community, coordination and synergies are crucial to the success of all the proposed initiatives.

The management model must be based on the following principles:

- **Leadership:** It is essential for the plan to have a visible management team pushing it forward and taking the lead to achieve the objectives.

- **Coordination:** The plan is cross-cutting, so it involves the entire port community. This means that its actions will take all companies and institutions in the sector into account, and that all of them will need to participate in order to achieve the plan's objectives.

- **Follow-up actions:** After being launched, the plan will require many follow-up measures in order to gain momentum and stay on track through everyone's efforts.

- **Updating:** The plan should be designed as a living document that can be quickly adapted to changes in the port space. Predicting the future of the sector and of our context is a very complex task, so people have to be able to update this document to reflect future changes in technology or regulations, or the results of new studies that could lead to the need to substantially revise the current plan.

5.3.2 • ORGANIZATIONAL MODEL

In the plan's organizational model, there should be two key bodies. The first, in charge of management, is the Management Committee. The second is the Smart Port Committee, which is responsible for making sure the plan is followed.

The members of the Management Committee promote and lead the plan and ensure its objectives are achieved. The Smart Port Committee is made up of key members of the working groups, and it is tasked with implementing the plan. The role of this committee is to push the plan forward through various activities, like organizing debate forums and sessions, launching projects, analyzing initiatives in other sectors, etc.

5.3.3 • DEVELOPING THE PLAN'S ROADMAP

The plan must have a roadmap with a detailed sequence of steps in the form of a timeline of actions in order to be successfully implemented (Table 5).

TABLE 5 • EXAMPLE STRUCTURE OF A SMART PORT PLAN ROADMAP

AREAS OF WORK	STEPS	SHORT-TERM	MEDIUM-TERM	LONG-TERM
• Increase freight visibility for users	• Implement a port community system (PCS)			
• Increase the quality of operational data for decision-making	• Equip all port access points and equipment with sensors			
	• Implement a big data system to manage operational data.			
• Use energy in a smarter and more efficient way in the port area.	• Implement an environmental monitoring and prediction system.			
	• Perform studies and develop pilot projects with renewable energy, especially hydrogen and solar.			

This roadmap contains the most relevant areas of work identified by the port community, together with the steps proposed for the process of implementing the plan in order to achieve its objectives. It should also include a deadline for implementing each area of work to ensure the work is completed.

5.3.4 • DEFINING OBJECTIVES AND INDICATORS TO MONITOR THE PLAN

The SMART method is the suggested way to define the objectives and indicators for each of the plan's actions. As shown in Figure 9, this method's criteria are reflected in its name:

- S: Specific. Is your objective specific? —What?
- M: Measurable. Is the progress towards that objective measurable? —How much?
- A: Attainable/Achievable. Can the objective truly be achieved? —How?
- R: Relevant. How relevant is the objective for your organization? —With what?
- T: Time-Related. How much time is allowed for achieving this goal? —When?

These basic tenants give a clearer idea of the plan's capacity and avoid creating gaps between the objectives and the actual capabilities of the entity responsible for implementing it.

5.3.5 • UPDATING THE PLAN

To properly manage the plan, its implementers need mechanisms for constantly updating it. For this purpose, we suggest performing routine and special updates that adapt the plan to the context and any global changes that occur.

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