Asia-Pacific
Economic Cooperation

Advancing Free Trade
for Asia-Pacific Prosperity

Promote Supply Chain Connectivity by Enhancing and Better Understanding Digital Innovation in APEC Port Industry

APEC Transportation Working Group

June 2022

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Glossary

Complete list of abbreviations used, as well as the meanings assigned to them for the purposes of this study, will be provided in full detail in the following table for the Final Report:

A	
APEC	Asia-Pacific Economic Cooperation
APEC TPTWG	APEC Transportation Working Group
APSN	APEC Port Services Network
C	
COVID-19	Coronavirus disease
I	
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IAPH	International Association of Ports and Harbours
IHO	International Hydrographic Organization
ICT	Information and Communication Technologies
M	
MPA	Maritime and Port Authority of Singapore
MVP	Minimum Viable Product
P	
PDS	Port Digital Scorecard
PCS	Port Community System
PortCDM	Port Collaborative Decision Making
PPP	Public Private Partnership
R	
R&D	Research & Development
S	
SW	Single Window
SWOT	Strengths-Weaknesses-Opportunities-Threats
U	
UNCTAD	United Nations Conference on Trade and Development
V	

VPN	Virtual Private Network
W	
WPSP	World Port Sustainability Program

Executive Summary

Introduction and approach

At the 26th APEC Economic Leaders' Meeting, APEC reaffirmed its commitment to promoting digital innovation as one of the primary goals of the TPT-WG's 2018-2021 Strategic Plan. Digital innovation has been acknowledged to transform port industries, and given the fundamental role of ports as nodes in the global supply chain, port digitalization will have a profound impact on the global economy. And, although port digitalization was already a major trend within the maritime industry before COVID-19, since the outbreak it even became more important, as ports had to find ways to sustain trade flows. Various ports around the world have launched digitalization strategies, however there are still a lot of ports seeking guidance for sustainable and digital growth. This also applies to ports in APEC economies.

In light of the above, People's Republic of China project TPT 02/2019A – Promote Supply Chain Connectivity by Enhancing and Better Understanding Digital Innovation in APEC Port Industry, has contracted STC-NESTRA, together with the Shanghai International Shipping Institute, to conduct a study on port digitalization in APEC economies. This being in accordance with the APEC Connectivity Blueprint for 2015-2025 and the TPT-WG's Strategic Plan 2018-2021. In this sense, the study herein presented will aim to give an answer to the following questions:

- RQ1. What is the current state of digitalization in the port industry in APEC economies?
- RQ2. What are some of the current best practices related to digitalization initiatives in ports?
- RQ3. What are the main challenges that APEC ports are facing in the digitalization process?
- RQ4. What recommendations can be drawn to improve port digitalization efforts, and thus supply chain connectivity in APEC?

Supported by a literature review, to answer the research questions, an assessment framework has been prepared to run a diagnostic scan of ports in APEC economies in their standing of digitalization efforts. The framework, referred to as the Port Digital Scorecard (PDS) formed the base for the design of an online survey, which has been distributed across APEC economies to collect information on the maturity of port digitalization in their ports, as well as their challenges and potential recommendations for ports and policy makers in the APEC region. In total, 26 valid responses from ports were received belonging to 10 APEC economies. In parallel to the online survey, the team carried out a set of interviews with key international experts in the field of port digitalization to validate the PDS; and to complement the survey results with experts views on best practices, bottlenecks and recommendations.

Current status of port digitalization in APEC economies (RQ1)

The current state of port digitalization was quantified via the online survey. Valid responses came from a total of 26 ports belonging to 10 APEC economies. Both the mode and mean were calculated for the entire group response, for which the results are outlined in table below.

Table 1. Statistics of the PDS from the online survey: mode and mean of the group response.

Pilar / Element	Mode[1-4]	Mean (1 – 4)
Management		
M1 - Digital strategy	[4]	3.12
M2 - Innovation ecosystem	[3]	2.96
M3 - Investment in digitalization	[2]	1.77
Human Capital		
HC1 - IT business -related knowledge and skills	[2]	2.38
HC2 - Training program on port digitalization	[2]	1.96
Technological Ecosystem		
T1 - Data standardization	[2]	2.19
T2 - Office & Business Management systems	[3]	3.08
T3 - Operations Management - PMS	[3]	2.81
T4 - Operations Management – TOS/ECS	[3]	3.23
T5 - Trade management – PCS/SW	[2]	2.42
T6 - Environmental Management – Air quality control	[2]	2.31
T7 - Environmental Management – water quality monitoring	[2]	2.00
T8 - Environmental Management – Noise monitoring	[1]	1.73
T9 - Energy Management – Energy consumption monitoring	[2]	2.42
T10 - Safety & Security – Early detection of extreme weather	[3]	2.58
T11 - Safety & security - Cyber risk management	[2]	2.62
T12 - Safety & security – Surveillance and safety control	[3]	2.96

From the results of the PDS, it is found that digitalization has moved high to the agenda of port managers (M1), with investment in digitalization ranging between 5% and 10% of total investments (M3). There seems to be less attention given to the development of Human Capital (HC1 and 2) in port digitalization. In the third pillar, Technological Ecosystem, most of the focus is placed in Operations Management (T3 and 4). The development of solutions like Terminal Operating Systems (TOS) or Equipment Control Systems (ECS), on the terminal side, or Port Management Systems (PMS) on the navigation side, are quite common tools in mid-to-large sized ports, also in APEC economies. Other activities such as environmental (e.g. air monitoring systems) or energy (e.g. monitoring of energy consumption) have only started receiving attention in the last years, this in contradiction to the monitoring of noise emissions, which receives little priority. Another element that seems to receive little attention concerns Data standardization (T1), which is in line with a common discussion or challenge brought forward in and by the maritime sector.

Best practices related to digitalization initiatives in ports (RQ2)

For consistency reasons with the proposed PDS, for each port, the highlighted best practices are, to the furthest extent possible, aligned with the pillars and elements of the assessment framework. The Port of Singapore and Port of Shanghai have been selected from APEC economies, cases outside APEC concern the Port of Rotterdam and the Port of Algeciras. The selected ports all have a unique character looking at the political, economic, social, environmental, technological or legal context in which they operate. While acknowledging that, still there are some common lessons that can be drawn that are relevant to other ports:

- Most of the cases depict an open culture to change and innovation, coming from the management levels as well as the rest of the human capital. This approach can pool knowledge together, leading to a common ground of understanding within organizations (from port authorities to port users), and between them, thus embracing the digital transformation in the entire community.

- In line with the previous, the reported port authorities play a proactive and "customer driven" role, including the rest of the stakeholders within the port community, in order to understand their unique problems and goals, and thus taking them in a long term digitalization journey and commitment. Stakeholder engagement is key to a successful implementation of digital initiatives.

Digitalization challenges in APEC ports (RQ3)

The implementation of digital-based initiatives can be a challenging endeavor for firms and organizations. This can be exacerbated in port clusters and communities, which are by nature highly complex systems and completely unique from one another. To define common constraints, based on survey responses, a step-wise approach was followed to cluster similar challenges into common bottlenecks (e.g. from a political, economic, technical, social or legal perspective). Challenges have been validated with literature, ports digitalization experts and by means of a workshop with port and transport experts from APEC economies and from non-APEC economies. The following challenges, or bottlenecks, were brought forward:

- **Lack of capacity by management levels –** which mostly highlights not having enough personnel within the decision-making process with knowledge about digital transformation in port communities. This is particularly common within public authorities and can strongly hamper digitalization efforts.
- **Changing priorities by management levels –** the implementation of digital initiatives within ports can take a long time, which requires continuous endorsement by the port management levels, also in case of management change. In many economies within APEC, it is not uncommon to see a high turnover in government positions, which can also spill to the management levels of port authorities, with new views or different priorities, which may hinder the digital transformation process of ports.
- **Misalignment of different external assistance bodies –** many international organizations, ranging from multilateral development banks to cooperation frameworks, have been providing financial, technical or policy assistance in emerging technologies for more sustainable and resilient use of current and new infrastructure. This trend moved to the front of the agenda as a result of the COVID-19 pandemic. While these efforts can generate a positive return, especially to ports in need of it, uncoordinated approaches by these different mechanisms can create overlaps and result in a sub-optimal allocation of resources for different projects, and therefore of project outcomes (e.g. no interaction between Maritime Single Windows and Port Community Systems).
- **Budget restrictions –** Developing digital infrastructure and solutions can require significant investment (hardware and interoperable software, maintenance, capacity building and cultural change management within entire organizations). Because return on investment of port digitalization initiatives are not always evident in the short term, ports tend to secure more funding on physical/hard infrastructure instead.
- **Skepticism by stakeholders –** Whenever changes are proposed, especially with respect to digitalization, skepticism by the different stakeholders, both within and between organizations, may be common ranging from lack of knowledge by the management levels to, a more conservative, ageing labor force. Also, solving operational or administrative inefficiencies could be perceived as a threat to (advantageous) positions.
- **Lack of stakeholder management –** Elaborating and executing a digital transformation roadmap in a port community, is not just an isolated, *'plug-and-play'* project. A lack of interaction between the different stakeholders involved throughout an entire project lifecycle can hinder and delay the effective development and implementation of digital initiatives.
- **Lack of ICT infrastructure –** Digitalization relies in a proper ICT infrastructure backbone (e.g. Wi-Fi or Long Term Evolution). In some cases or economies, computer equipment may not have enough bandwidth required for sharing of data, as underlined by a number of APEC ports in the survey.

- **Interoperability –** In practice, data is often siloed to a few proprietary systems, unstructured or not labelled, and sometimes not even available. Also within port communities, data may have been implemented in a siloed way, for instance when an ICT vendor has developed a system that improves a particular process or activity for a particular actor within the port. When scaling up to include more actors, and thus integrating different legacy systems, this may lead to practical problems connecting in an integrated and interoperable way with existing Business-to-Business (B2B), Business-to-Government (B2G), or Government-to-Government (G2G) platforms.
- **Cybersecurity –** Survey responses have indicated a lack of cyber risk management strategy, yet it was either planned or in development phase. As more port activities undergo an analog-to-digital transformation, the vulnerability of these processes against cyber-attacks becomes increasingly pervasive.
- **Lack of qualified workforce –** The dynamics of logistics are expected to change with the introduction of new technologies. Related, the human-machine interaction will change, and with that the skill needs of the human capital. This poses challenges not only for an ageing workforce, but also for the implementation of digital initiatives.
- **Business case not properly defined –** Digitalization initiatives often fail as a result of an inadequate business case. Steps within the business case may not be properly systematized, ranging from an inadequate re-engineering of a particular process to a poor design of the new systems architecture. An illustrative quote from the survey highlighting this: *"Everyone has a smart port plan, but nobody knows how to implement it"*.
- **Legal frameworks not properly established to ease digital transformation –** According to a recent survey conducted by the IAPH in 2020, many port authorities and operators still struggle to conform with mandatory requirements to introduce electronic data exchange between ships and ports, as stated in the new IMO FAL Convention. One of the biggest barriers identified in that hurdle was the difficulty to establish enabling legal frameworks, since it sometimes depends on competing or overlapping public administrations and governmental agencies at local or domestic level[1].

Recommendations for digitalization in APEC ports

Based on the nature of the study, the recommendations are targeted into two main groups. On the one hand, to the managers of the ports in APEC, which are key stakeholders within the decision making process. On the other hand, to the APEC government representatives and policy makers, which can play an important role in the promotion and establishment of guidelines. Similarly to the outlining of bottlenecks, the survey responses have been taken as main source, complemented with literature and opinions of port digitalization experts, whenever applicable.

Upfront, it is important to emphasize that instead of a one-time project, the list of recommendations, should be seen as continuously tailored and improvement based effort in relation to the changing dynamics of each economy and port. The suggested recommendation identified by the study team are:

- **Knowledge infrastructure –** In the context of port communities, the existing knowledge gap should be tackled not only within the organizational structures (from high-level managers to intermediate levels) of different port organizations, but also with respect to policy makers as well. Therefore, it is important to promote capacity building & educational programs in topics related to port digitalization within the port authority and port users and government agencies. Furthermore, the introduction of an innovative ecosystem as incubator for port digitalization start-ups should be facilitated.

[1] See IAPH global ports survey on the implementation of electronic data exchange to conform with the IMO Convention on Facilitation of International Maritime Traffic (FAL), January 2021.

- **From vision to implementation –** establishing a strategic vision can be a good starting point for organizations to embark in the digitalization journey. The vision should include the different stakeholders directly or indirectly involved in a particular port community; the vision should be flexible and open to continuous revision, with a time horizon of no more than 5 years and a strategy for implementation (with clear objectives, development paths, tools and ownership). Internal or external IT external experts can map current processes ('As Is'), identify bottlenecks for re-engineering of relevant processes ('To Be'), target Key Performance Indexes (KPIs), as well as the systems architecture.
- **Change management –** incorporation of systematic approaches are advisable that deal with transformation of goals, processes, and technologies of port organizations, for both port managers (internal level) and other port stakeholders (community level). Adoption of strategies and introduction of solutions should be based on a Mutual Gains Approach, to allow parties to improve their chances of creating and agreeing on solutions beyond existing alternatives, while protecting relationships. This makes the framework particularly interesting in the context of port communities, where digitalization can involve several organizations of which some may perceive digital progress as a threat.
- **Cybersecurity management –** Given the sensitivity and value of data, it is important to incorporate complementary defense mechanisms against potential cyber-attacks as part of a port digitalization strategy. The introduction of new technologies can expose business to potential vulnerabilities that can jeopardize sensitive data or digital assets, among others. In line with other industries, IT systems in port communities should be robust against cyber-attacks, following international standards (e.g. IMO MSC-FAL.1/Circ.3, European Union Agency for Cybersecurity, IAPH Cybersecurity Guidelines).
- **Interorganizational collaboration –** Lack of coordination between governing bodies, ranging from port bodies (e.g. port authorities) to external assistance bodies, should be avoided. Particularly for port authorities, an interesting initiative that was born under this philosophy of knowledge exchange is ChainPORT[2]. ChainPORT is an international network of ports whose shared goal is to advocate for a smart, innovative and sustainable port model. Port authorities in APEC could explore possibilities to join platforms such as the above mentioned as a starting point. For instance, a reduced group of digital-savvy profiles, preferably from a mid-to-high management position, from the port could be allocated to explore the potential benefits and costs of becoming an active member of initiatives like ChainPORT.
- **ICT infrastructure –** Several APEC economies lag behind in terms of ICT infrastructure readiness. Considering the need to improve supply chain connectivity in the Asia & Pacific region, policy makers should promote investment in ICT infrastructure to improve metrics such as bandwidth or mobile network coverage. This could serve as a more robust backbone underlying the implementation of digital solutions.
- **Standardization -** In the context of port and maritime digitalization, "standardization" should be seen from several angles. From the standardization of nautical, operational and administrative data that is needed around a port call process (maritime industry) to common standards around the Industry 4.0 technologies and processes, ranging from IoT, Cloud Computing, Big Data, connectivity, or cybersecurity. Both port organizations and political representatives in APEC should make sure that their digitalization initiatives, comply, insofar as possible, with internationally accepted standards. This ensures a common language of understanding not only in the processes and activities (e.g. semantics of a port call), but also for the interoperability of scalable IT systems.

[2] See more information about chainPORT.

Validation of results and next step

During an online workshop on 24 February 2022, the study results have been validated with a wide group of stakeholders (government officials from APEC economies, port authorities/management companies and member economy / international port and maritime experts). During the workshop some additional suggestions were made on the next steps for port digitalization in APEC economies that could be supported by the APEC Secretariat, which concern:

- Organization of port forums or workshops, specifically related to port digitalization initiatives (e.g. introduction of blockchain and industry 4.0 technology in the community of ports, logistics, shipping lines, shippers and consignees). Given the size of investments in ports, it is important to involve policy makers in the suggested forums/workshops.
- Support for the development of guidelines to protect port systems against cyber-attacks.
- Explore financing opportunities for developing economies to facilitate them in their port digital transformation journeys.
- Support with the development of standardized training courses for upgrading the skills of human capital on management and operational level.

1 Introduction

STC-NESTRA is pleased to present this Final Report to the APEC Secretariat to assist ports in the Asia & Pacific economies with their digitalization efforts, in line with the 2018-2021 Strategic Plan of the APEC Transportation Working Group (APEC TPT-WG).

Based on the specifications of the Request for Proposal (RFP), this report documents the findings and outcomes following desk research, stakeholder consultation, and a final workshop to ascertain different elements. That is, the current status of port digitalization in the APEC region, main bottlenecks and best practices on the digitalization journey of ports, and supported by a list of recommendation points to accelerate port digitalization efforts in the APEC region.

1.1 Structure of the Report

This report is structured as follows below:

- An overall **executive summary** with the main findings of the study arising from the desk research, stakeholder consultation and final workshop organized online, as well as the identified challenges, best practices and recommendations for ports in APEC.
- **Section 1** provides the reader with an introduction of the study. This includes the rationale behind the need for this research in the APEC port sector, as well as the objectives, methodology and scope of the study.
- **Section 2** presents the current status of port digitalization in the APEC region, based on a developed assessment framework which is outlined in the Appendix.
- **Section 3** contains a set of best practices on port digitalization, both inside and outside of APEC.
- **Section 4** provides the reader with main bottlenecks hindering the digitalization efforts in the port sector, in line with the developed assessment framework.
- **Section 5** builds on the previous to provide a set of recommendations for APEC ports to accelerate their digitalization journey, including a set of policy recommendations for APEC members how to incentivize and stimulate port digitalization.
- **Section 6** concludes the report with final remarks, including a reflection of the research methodology and suggestions for further research to APEC.
- **The Appendix** complements the main report with a literature review on port digitalization and port digital assessment, the construction of an assessment framework (known in this report as Port Digital Scorecard, or PDS), the protocols used for the stakeholder consultation phase (interviews and online questionnaire), as well as the overall results from such phase.

1.2 Background of the study

With about 80% of global trade carried by sea according to United Nations Conference on Trade and Development (UNCTAD), maritime ports have evolved to play an integral part of international logistics chains, and therefore the global economy. Both intra and inter port competition, coupled with increased global container traffic as a result of globalization and containerization, have significantly influenced the port geography and international traffic flows. Several regions have in this sense been historically exposed to port development to capture increasing trade flows, and therefore drive economic growth in their economies.

While it is true that maritime transport has been regarded as an environmentally-friendly mode of transport in terms of emissions per ton/kilometer, the negative impacts of port and maritime related activities cannot be neglected. On the port side, major sources of negative externalities can be found in energy consumption from buildings, industrial plants or equipment, dredging oil disposal, effluent discharge, noise or light pollution, among others. All these are having detrimental environmental impacts in port areas, as well as for neighboring

populations and wildlife. On the maritime side, inefficient port call processes can lead to a "hurry and wait" behavior for ships steaming towards ports, resulting in a sub-optimal use of fuel by vessels, and therefore enhance Greenhouse Gas (GHG) emissions. Other sources from vessels are (illegal) waste disposal, introduction of invasive species from ballast water or accidental spills, among others. Considering that these sub-optimal processes, influenced by many unpredictable factors, may occur on a daily basis within around 9.000 ports worldwide[3], the room for improvement is significant.

At the same time, ports are being challenged by disruptions of different nature and origins. These are affecting resiliency of essential functions within ports, and therefore are spilling over to the rest of supply chains. Some sources have been known for a while, such as those induced by the effects of climate change[4]. Other sources are more recent and have reshaped the way port resilience is conceived, such as the coronavirus disease (COVID-19) pandemic or the blockade of the Suez Canal.

Besides the sustainability and resiliency issues described above, ports have been under increasing pressure to remain competitive, trying to offer reliable services and capturing increasing flows. Being in many cases physically constrained, capacity expansion may not be a sustainable alternative. Against this, questions like the following can be common in the agendas of port authorities: *"What actions can we take as a port to become more sustainable, resilient and efficient in an increasing competitive environment?"*

The answer can be, at least partially, with the advent of Information and Communication Technologies (ICT). Their increasing access and versatility have allowed over the past years, for a *smarter* use of assets and resources in freight transport systems, including maritime ports. Their implementation has however been scattered and at different development levels across the world.

1.3 About APEC

The Asia-Pacific Economic Cooperation (APEC) region entails some of the largest and most dynamic economies in the world. Including economies like the United States, the People's Republic of China or Japan, the region accounts for about 48% of global trade[5].

Established in 1989, the Asia-Pacific Economic Cooperation (APEC) framework has supported sustainable economic growth in the region. With a total of 21 member economies, APEC operates as a cooperative, multilateral economic and trade forum. Different Working Groups emanate from the APEC and are composed by a multi-layered planning and decision structure composed by Leadership Groups and Experts Groups. One of them being the APEC TPT-WG, which promotes and enables a harmonized, liberalized, seamless, comprehensive, safe, sustainable, resilient, secure and reliable transport network in the Asia-Pacific region.

At the 26th APEC Economic Leaders' Meeting, APEC reaffirmed its commitment to promoting digital innovation as one of the primary goals of the TPT-WG's 2018-2021 Strategic Plan. Digital innovation is transforming port industries, and given the fundamental role of ports as nodes in the global supply chain, port digitalization will have a profound impact on the global economy.

Port digitalization was already a major trend within the maritime industry before COVID-19, but since the outbreak has become even more important as ports must find ways to sustain trade flows. And, although various ports around the world have launched digitalization strategies, there are still a lot that seek guidance in the smartest way for sustainable and digital growth. This also applies to ports in APEC economies.

As such, it is important to understand the process, impact, and best practices of port digitalization in order to facilitate trade and economic development in APEC economies.

[3] Number of ports according to the International Taskforce Port Call Optimization (ITPCO).
[4] See Climate change adaptation for seaports in support of the 2030 Agenda for Sustainable Development, UNCTAD (2020)
[5] StatsAPEC, Key Indicators Database.

1.4 Study objectives and methodology

In light of the above, People's Republic of China project TPT 02/2019A – Promote Supply Chain Connectivity by Enhancing and Better Understanding Digital Innovation in APEC Port Industry, has contracted STC-NESTRA, together with the Shanghai International Shipping Institute, to conduct a study on port digitalization in APEC economies. This being in accordance with the APEC Connectivity Blueprint for 2015-2025 and the TPT-WG's Strategic Plan 2018-2021. In this sense, the study herein presented will aim to give an answer to the following questions:

- *RQ1. What is the current state of digitalization in the port industry in APEC economies?*
- *RQ2. What are some of the current best practices related to digitalization initiatives in ports?*
- *RQ3. What are the main challenges that APEC ports are facing in the digitalization process?*
- *RQ4. What recommendations can be drawn to improve port digitalization efforts, and thus supply chain connectivity in APEC?*

The proposed methodological approach of the study is summarized in Figure 1:

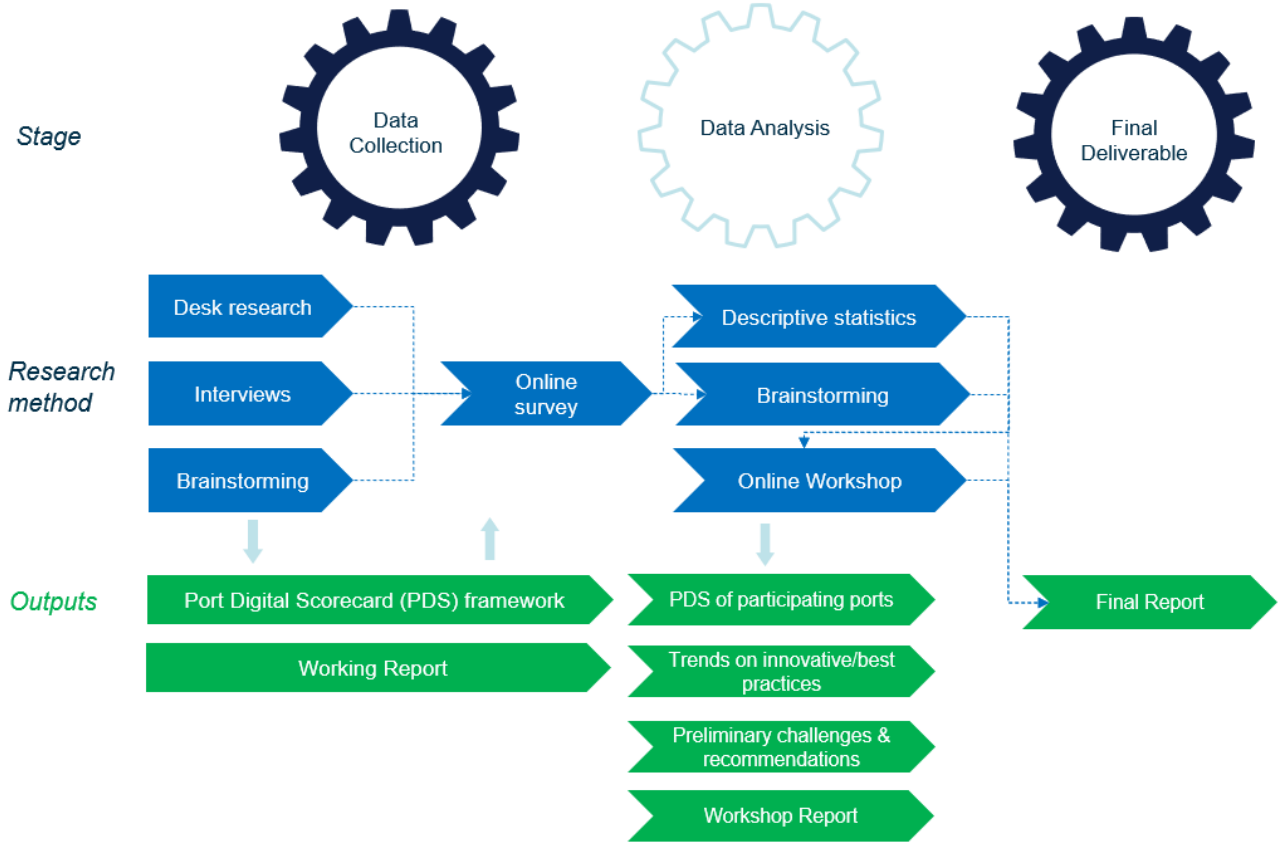

Figure 1. Proposed methodology.

With reference to the methodological framework, to answer the research questions, the study is structured in three stages: data collection, data analysis and final deliverable:

Data collection & Working Report

In this phase, data has been collected on the current status of port digitalization for ports in APEC economies, best practices, bottlenecks and recommendations. In order to do so, the study team has first conducted a literature review, which served as input for two elements. On the one hand, for the design of an assessment framework, referred to here as Port Digital Scorecard (PDS), which can serve a diagnostic for the chosen ports in APEC on where they currently stand in their digitalization efforts. The study team believes the design of

such framework adds significant value to the ongoing efforts by APEC to assist ports in the region in their digitalization journey**.**

On the other hand, the PDS was used as a base for the design of an online survey, which has been distributed across APEC economies to better understand the maturity of port digitalization of their ports, as well as their challenges and potential recommendations for ports and policy makers in the APEC region. The team attempted to reach as many stakeholders from different APEC ports as possible, mobilizing the APEC TPT-WG; depending on the network of the team; and, as well as requesting assistance from the APEC Port Services Network (APSN), assuming that the larger the targeted sample population, the larger the response rate would be. In total, valid responses were collected from 26 ports belonging to 10 APEC economies.

In parallel to the online survey, the team carried out a set of interviews with key international experts in the field of port digitalization. The purpose was twofold: to validate the PDS for future research; and to complement the above with best practices, bottlenecks and recommendations.

The literature review, the protocols of the stakeholder consultation (online survey and interviews), as well as the bulk of data collected from it can be found in the Appendix.

Data Analysis, Workshop and Workshop Report

The data collected from the questionnaire, complemented with any other further data that can be extracted from desk research or the stakeholder consultation (if applicable), is currently being analyzed.

For quantitative data, descriptive statistics are being performed with measures of central tendency (e.g. mean or mode). This is particularly applicable for the results of the PDS (Section 2), which result from the assessment of participants in the online survey via categorical questions. Qualitative data, which is applicable for the best practices, bottlenecks and recommendations, has been clustered into different domains for more clarity of results, in alignment with the PDS (Sections 3 and 4) and with target groups to provide recommendations (Section 5).

All findings reported and analyzed above were presented in an Online Workshop, held on the 24th February 2022 with participants from the different APEC economies. In the online event, the purpose of the study, the methodology followed, and the main findings were presented. The session was also used as feedback for the development of the study, where findings were validated. Also, a Workshop Summary Report including findings and highlights of discussion during the session was prepared.

Final Report

The Final Report herein presented has been prepared after the Workshop Summary Report, including all the data collected and analyzed as presented above.

2 Current status of port digitalization

RQ1. What is the current state of digitalization in the port industry in APEC economies?

This section presents the current status of port digitalization in the APEC region, based on the online survey and complemented with follow-up interviews and desk research. The results are reported following the structure of the Port Digital Scorecard, a framework constructed based on desk research and validation interviews with key experts in the field.

In short, the model conceptualizes the digitalization on the basis of three broad pillars: management, human capital and technological ecosystem. Each pillar is broken down into different elements which can be assessed in a 1 to 4 point categorical scale. For a more in-depth discussion on how the PDS was designed, see Appendices A through C.

The current state of port digitalization was quantified via Part A of the online survey (see Appendix D). Valid responses came from a total of 26 ports belonging to 10 APEC economies. Both the mode and mean were calculated for the entire group response, for which the results are outlined in Table 2:

Table 2. Statistics of the PDS from the online survey: mode and mean of the group response.

Pilar / Element	Mode[1-4]	Mean (1 – 4)
Management		
M1 - Digital strategy	[4]	3.12
M2 - Innovation ecosystem	[3]	2.96
M3 - Investment in digitalization	[2]	1.77
Human Capital		
HC1 - IT business -related knowledge and skills	[2]	2.38
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T7 - Environmental Management – water quality monitoring	[2]	2.00
T8 - Environmental Management – Noise monitoring	[1]	1.73
T9 - Energy Management – Energy consumption monitoring	[2]	2.42
T10 - Safety & Security – Early detection of extreme weather	[3]	2.58
T11 - Safety & security - Cyber risk management	[2]	2.62
T12 - Safety & security – Surveillance and safety control	[3]	2.96

Looking into the Management pillar, it is worth highlighting that several panelists reported their ports or organizations scored LoM=3 or higher when asked about the development stage of a digital strategy or vision for the port community [M1]. Regardless of whether they reported from the perspective of the roadmap being applicable to the entire port community, or to the digital transformation of one organization only, these results still imply that digitalization has moved high to the agenda of port managers. This finding is in line with outcomes

from previous studies[6]. When digging into the more granularized results, whenever *[M1]* scored high, the rest of the pillars scored higher than the total averages presented above. Moreover, investment in digitalization [M3] generally remains between 5% and 10% of total investment. This can be considered reasonable due to the inherent nature of ports, which are highly capital intensive.

With respect to the Human Capital, this pillar seems to be lagging behind, including both *[HC1]* and *[HC2]*. In fact, the later one scores the lowest after *[T8]*, suggesting that, in several cases, little importance at the moment is given to capacity building and training in the wide field of port digitalization.

In the third pillar, Technological Ecosystem, most of the focus is placed in Operations Management. The development of solutions like Terminal Operating Systems (TOS) or Equipment Control Systems (ECS), on the terminal side, or Port Management Systems (PMS) on the navigation side are relatively increasingly common in mid-to-large sized ports, not only in APEC, but also across the globe. This is also aligned with desk research, where the port digitalization literature mainly focuses on improving processes in port operations as the main goal. Moreover, industry solutions like TOS/ECS are led by private terminal operators, which have high levels of digitalized processes to remain competitive. Other activities such as environmental (e.g. air monitoring systems) or energy (e.g. monitoring of energy consumption) have only started receiving attention in the last years. Moreover, the element scoring the lowest was, as already mentioned, *[T8] noise monitoring*. This suggests that, either there is no necessary business case for a noise monitoring system in the ports that responded to the survey, or there is not enough technical, human, or financial capacity to implement such system. The next lowest scoring element is *[T1] Data standardization*, which is aligned with a common discussion in the sector, both on the maritime industry side (that is, with respect to nautical, operational, and administrative data), as well as on the Industry 4.0 technologies and processes.

[6] STC-NESTRA conducted a study on whether COVID-19 had accelerated port digitalization in the APEC region, with a particular focus on trade management. One of the main findings was that, while trade management solutions had not accelerated per se (partly because their full development time, it can take up to 2 years), the discussion on the need to digitalize processes had indeed been moved to the top of the agenda of management boards.

3 Best practices in port digitalization

RQ2. What are some of the current best practices related to digitalization initiatives in ports?

This section elaborates on a selection of best practices with respect to port digitalization, both within the APEC region (Section 3.1), and outside of it (Section 3.2).

For consistency reasons with the proposed PDS, for each port, the highlighted best practices are, to the furthest extent possible, aligned with the pillars and elements of the assessment framework.

3.1 Cases in APEC

3.1.1 Port of Singapore

Crowded as 'Best Seaport in Asia and named the 'Best Green Seaport' at the 2019 Asian Freight Logistics and Supply Chain Awards, Singapore can be considered a best practice on smart and sustainable port development. The Port of Singapore is regulated by the Maritime and Port Authority of Singapore (MPA), and includes two main terminal operators – PSA Corporation Limited and Jurong Port Pte Ltd. Its geographical position, coupled with a thriving innovative and open ecosystem, has made Port of Singapore one of the busiest hubs in the world. Two main areas are discussed below.

Innovation & knowledge hub

As can be seen in the results of the PDS (see Appendix E), Port of Singapore scores a Level of Maturity between [3] and [4] in all the elements related to the Management and Human Capital pillars. These results are in line with literature.

As part of the Sea Transport Industry Transformation Map, there is a clear commitment by MPA, together with the industry, unions and other government agencies, to promote digitalization in its port cluster. The Maritime Digitalization Playbook is one important toolkit that helps maritime companies accelerate their digital transformation[7]. Besides this clear commitment from senior industry leaders, the port city hosts a vibrant, innovative and entrepreneurial ecosystem, with PIER71™ as one of the largest maritime incubators in the world. It heavily involves the active participation of large stakeholders such as MPA and the National University of Singapore (NUS), as well as many other industry partners.

Through working with industry partners, academia, government, technology providers or start-ups to co-create innovative solutions for the maritime industry, Singapore has become a maritime innovation and technology hub. MPA and Singapore Maritime Institute (SMI) have jointly developed a Maritime R&D Roadmap to steer direction priorities and align R&D efforts across the entire maritime ecosystem. The leverage of smart technologies is present in all the five R&D thrusts of the R&D roadmap program[8]. Further, the SMI catalyzes industry-academia R&D collaborations, thus leading to accelerated capability development and technology transfer to the industry. In addition, the Maritime Transformation Program (MTP) leverages the capabilities and resources under the National Research Fund to support large-scale R&D projects.

On the training side, MPA takes a proactive approach to building a steady future-proof pipeline of local maritime talent. In close collaboration with industry stakeholders, MPA rolled out the Sea Transport Professional Conversion Program. MPA Academy, the training arm of MPA, runs different capacity building programs.

[7] See Maritime Digitalisaton Playbook, by MPA Singapore, launched in July 2020.
[8] See Page 18 of the of the R&D Roadmap 2030 by MPA.

Digital Ecosystem

Nearly all elements of the Technological Ecosystem in the PDS score a [3] or above. This is aligned with literature, which places Singapore as one of the "smarter" ports globally[9]. There are three initiatives worth mentioning within its current digital ecosystem:

First of all, the Singapore Maritime Data Hub (SG-MDH), a data sharing platform for partners of the ports, ranging from industry or government agencies to technology providers, so that these can co-create innovative applications and integrate their systems and services. As of now it contains more than 5 million data points available, which can be used by developers from the entire port community as backbone to come up with innovative use cases that can solve specific challenges within the port.

The SG-MDH also serve as digital infrastructure for the digital services of the second initiative, namely digitalPORT@SG™. This is Singapore's new Maritime Single Window, a one-stop portal for all regulatory port entry and clearance requirements between vessel and three public agencies, namely MPA, the Immigration and Checkpoints Authority (ICA) and the National Environment Agency (NEA). In its second phase of development, digitalPORT@SG™ will roll out a Just-in-Time services to orchestrate port call activities, leading to faster turnaround time for ships and hence lowering the carbon footprints in ports. digitalPORT@SG™ will be integrated with the current Port Community System (PCS) of PSA, Portnet™, and Jurong Port's Online, thus offering not only Government-to-Government (G2G) and Business-to-Government (B2G) services, but also enabling seamless access to the industry for services from PSA Corporation Limited and Jurong Port Pte Ltd within digitalPORT@SG™. Since 2019, the International Maritime Organization (IMO) has made mandatory, through the Facilitation (FAL) Convention, the electronic exchange of information for clearance processes in ports. Caused by the urgency of the new mandate, different digital platforms in the maritime sector proliferated with different paces of development and adoption across the world.

Against the need for system level interoperability between digitalPORT@SG™ and the various global digital logistics platforms that are proliferating in the maritime transport industry, Singapore launched in 2020 digitalOCEANS™, the third initiative in the entire ecosystem. This was done with strategic partners in the global industry, including shipping lines, port operators, digital platform providers or even port authorities[10]. The purpose is to advocate data exchange through the use of open or common exchange and network standardization, with common data standards and Application Programming Interfaces (APIs) specifications, thus allowing for efficient trade transactions across the entire vertical supply chain.

As per available information, these initiatives have helped to reduce the administrative burden of shipmasters in port call and reporting formalities. Moreover, the port authority reported they helped save an estimated 100,000 man-hours per year for its cluster. Where digitalization is concerned, MPA Singapore was announced as the winner of the IAPH World Ports Sustainability Program in 2021, under the category of "resilient digital infrastructure"[11].

Aside from the above, there are other recent initiatives which also enrich the overall technological ecosystem of Port of Singapore. One example is the remote marine surveying of vessels with the aid of smart mobile devices and optimized live-streaming application (considered a best practice, in line with safety measures against COVID-19)[12]. GeoSpace-Sea is another initiative that was launched in 2020. It is a marine spatial data infrastructure that harnesses and integrates Singapore's marine and coastal geospatial data from various sources[13].

[9] See Molavi, A., Lim, G. J., & Race, B. (2020). A framework for building a smart port and smart port index. International Journal of Sustainable Transportation, 14(9), 686-700.
[10] Port of Rotterdam Authority was included in the Memorandum of Understanding (MoU) of July 2020.
[11] See MPA Singapore – Digital Port Ecosystem. Project portfolio of World Ports sustainability Program (WPSP), 2020.
[12] See PSA Marine – Remote surveying of vessels. Project portfolio of WPSP, 2020.
[13] See MPA Singapore – Sustainability/Integrated Report, 2020.

3.1.2 Port of Shanghai

Port of Shanghai is located in the middle of the coastline of mainland China and at the mouth of the Yangtze River. In 2020, the container throughput of the port was 43.5 million TEU, ranking first in the world for eleven consecutive years.

Shanghai International Port Group (SIPG), the public operator of the port, has attached great importance to digitalization since its early days. In 2014, it released a research report on "Shanghai SIPG Smart Port: Driving Future Trade", which established a port development framework based on the “smart” concept. Following the logic of the PDS, the below paragraphs focus on different elements related to the management culture, the human capital and the technological ecosystem of the port.

An independent “Informatization Leading Group”

SIPG has set up an “Informatization Leading Group”, which plans and promotes all digitalization tasks on a whole level in the main port holding as well as its subsidiary companies. It plays a role on coordinating and advancing the informatization development of the entire SIPG. On the one hand, it directly reports to the group’s chief president, faces the leadership demand, and implements the leadership’s ideas. On the other hand, it connects with the three independent subsidiaries of the group which are responsible for informatization operation and maintenance; R&D; and e-commerce, and take the plans into action step by step.

In June of 2021, Shanghai Port re-organized the functions of some of the administrative departments in the headquarters. This included the establishment of a Science and Technology Information Department, which was assigned to the information management function. The Information Leading Group is located within such department.

A digital-savvy Strategy Research Department & Port Education Center

In 2016, the Strategic Research Department docked with a consulting company to carry out a “Smart Port” research. Many employed researchers in the department have the ability to analyze and make meaningful interpretation out of raw data. The Department has played an important role in the digital transformation and development of the port.

Aside from the previous, Shanghai Port pays significant attention to the cultivation of talents. In this sense, the Shanghai Port Education and Training Center was established, where an annual employee education and training plan has been made each year. It contains training courses related to port digital development, mainly related to technology and management. Only in 2020, there had have been 4024 person-times of technology-related training summing up to more than 14 thousand class hours.

At the same time, Shanghai Port has developed a Virtual Reality (VR) tire crane simulation operating system, officially installed in the education and training center. The simulation training system integrates physical hardware control. The trainees wear VR helmets and drive virtual RTGs to battle with the changing gust, balance the container weight, control the sway of the sling, and can collaborate with one or more users simultaneously. The device is equipped with multiple functions such as real-time flow monitoring, Business Intelligence (BI) analysis, and data tracking.

Innovative technology

The technological ecosystem at Port of Shanghai is extensive throughout many of the different port activities. SPIG has actively applied the thought of “Internet +”, and has tapped information technology (e.g. cloud, IoT, 5G mobile communication,…) to build the world’s largest intelligent terminal, namely Shanghai Tangshan’s automated terminal. Moreover, a comprehensive service information platform of the Yangtze River transport network was developed. This one-stop platform focuses on major functions of Shanghai Port in connection with several container terminals along the Yangtze River Basin by establishing an information sharing mechanism and unifying data exchange standards.

3.2 Cases outside of APEC

With the purpose of extending best practices to examples beyond APEC, this section focuses on a selection of European ports, which are considered as frontrunners in the digitalization journey.

3.2.1 Port of Rotterdam

There is sufficient literature on the success case of Port of Rotterdam (PoR), ranging from the automated terminals at the Maasvlakte 2 area, to recent connectivity developments with partner ports[14]. As a global frontrunner in port digitalization, it is interesting to remark some interesting elements from the story of PoR and its entire community. Following a similar logic than with the PDS, they are related to the management, human capital and technological ecosystem respectively.

Cluster of Rotterdam as an innovative ecosystem

Rotterdam is a clear example of how the clustering of port community, education centers, research institutions, start-up accelerators, and other public and private stakeholders can be a well-encompassed approach to embrace an innovative ecosystem. What can be interesting, for the purpose of this study, is to remark the active role that the port authority played over the years, embracing a culture of openness towards digitalization and seeing it as an opportunity rather than a threat fort the entire cluster.

With an agile and entrepreneurial mentality, the port authority initially set up a lab where digital products could be tested for added value with the customers at the port, eventually turning into a dedicated department for the development of digital products. Moreover, the port authority and other stakeholders decided to revitalize old port area into a future-proof areas. In this sense, the Rotterdam Makers District (RMD) was created as a breeding group, testing ground for the creative economy, with digitalization playing an important role.

Likewise, Port of Rotterdam Authority is a founding member of PortXL, one of the largest maritime accelerators in the world, which connects with key players in the industry to come up, together with start-ups, with innovative solutions – in many cases digital-based– that can tackle the challenges in the port and maritime sector.

An important common element behind the success case of Rotterdam has been the stakeholder management approach taken. Rather than working as siloed organizations, the port authority needed the collaborative efforts among private and public stakeholders has been key to make the entire Rotterdam cluster into the level of maturity of today.

A future proof human capital

It is important that the entire human capital understand and engage with the potential benefits and challenges of digitalization in the port community. This goes for the management levels, as ultimate strategic decision makers, but also for the workforce, which have to continuously adapt and become familiar with new tools.

Against the previous, there are several educational institutions which focus on innovative technologies as a means to boost competitive strength across different port areas within the cluster of Rotterdam[15]. The extensive training and educational offering is not limited to universities and educational institutions, but also to the port authority itself[16]. These programs can altogether (re-)train different organizational levels in a changing human-machine interface, but also boost new data-savvy professional profiles which are increasingly needed in port communities – and the wider logistics chain – to reap the full potential of data.

Aside from educational institutions, there are research partnerships which also contribute to knowledge development in the wider cluster of Rotterdam. An example is SmartPort, a neutral knowledge platform which stimulates alliances, including the active participation of the port authority and the Municipality of Rotterdam, funds scientific research and provides public knowledge dissemination, with port digitalization as a core topic.

[14] See Maasvlakte 2, and eBL pilot between Port of Rotterdam and Port of Singapore, dating on May 2021.
[15] See Talent & development fact sheet in the cluster of Rotterdam, by Rotterdam Maritime Capital of Europe.
[16] See examples of training and education being offered by the Port of Rotterdam Authority.

Digitization of the entire port

All the previous have over the time created a knowledge-base within the human capital of the port community to test, develop and implement a wide technological ecosystem, ranging from its PCS Portbase, to the Harbor Master digital platform (HaMIS).

An interesting case to mention is their ambitious project to create a full Digital Twin (DT) of the port. The definition of DT appears in literature with varying explanations[17], but in short it can be defined as a virtual representation of a physical object or system during its life cycle, using real-time data that allows to understand, learn and improve the processes of the objects or systems.

As a first step, the port authority carried out the Internet of Things (IoT) project[18], which included the deployment of a network of sensors across a port area of 12,500 hectares. These sensors can now provide loads of data about the state of different attributes, ranging from real-time positioning of objects (e.g. vessels) to hydrological or meteorological data. In a later stage, a full Digital Twin of the port will be created. That is, the descriptive capabilities of the sensing technologies can be coupled with the use of scenarios, via simulation/emulation an AI-based algorithms, to understand and eventually prescribe courses of action to improve efficiencies in different operations and activities in a cost-effective way.

3.2.2 Port of Algeciras

Located in the Strait of Gibraltar, Port of Algeciras is considered a key logistics and maritime node, linking trade between Europe and Africa, but also between the Mediterranean and the Atlantic Ocean. Taking advantage of its optimal geographical location, the Port Authority of Algeciras (in Spanish “Autoridad Portuaria de la Bahía de Algeciras”, or APBA) has embarked in a new ambition. That is, to “excel in infrastructure and quality of services”. In order to achieve this, in an ever-increasing competitive environment, APBA understood its much needed evolving role from a traditional landlord function to a proactive facilitator of orchestrator of the operations taking place in its port ecosystem. This means helping its port users improving their processes and coordination among stakeholders, reducing waiting times, increasing visibility and productivity, and reducing carbon emissions form port activities[19].

Following a similar structure as in the above cases, two elements are worth mentioning as part of the success story of APBA. The former is related to its Management Culture, while the latter refers to the Technological Ecosystem.

Algeciras Port Living Lab, leveraging an open innovation culture

In a similar fashion as other cases such as those in Singapore and Rotterdam, APBA has also embarked in a cultural transformation towards innovation as an integrated and systematized key pillar of the cluster[20]. One of the most important initiatives when it comes to growing digitally and making the culture of digital innovation a part of our daily life was the creation of the 'Innovation Office'.

This office, run by qualified staff, helps the port to keep up to date with any digital developments on a daily basis, and helps to involve the port community in digital innovation.

[17] See Chapter 6 “4.0 tools: digital twins in ports” for a thorough theoretical discussion. Book edited by Port Authority of Santander, September 2021.
[18] See IoT project in collaboration between Port of Rotterdam Authority and different IT service providers.
[19] See Chapter 3 “Eco-sistemas portuarios digitales para la excelencia operativa” (in Spanish). Book edited by Port Authority of Santander, September 2021.
[20] See Innovation Report of APBA, as part of the award-winning program “Travesía de la Innovación”.

Digital Platform for Operations Orchestration, a platform of platforms

As part of its Process Coordination Center (PCC), where specialized personnel work in shifts 24/7 controlling land and sea operations happening at the port, the APBA is implementing the so-called Digital Platform for Operations Orchestration (DPOO). Such platform is meant to become the main tool within the PCC. It is meant to be comprised of the following layers:

- Digital infrastructure and advanced communication (aka *the nervous system).* This digital layer is meant to provide real-time information on the different activities happening at the port. Sensors have been placed around the different areas of the port to monitor the state of different processes, from wind or wave conditions, to air quality, or water consumption. The sensors then send their data via advanced communication technologies (optical fiber, Wi-Fi, LTE, 5G) and can be visualized by the DPOO at the premises of the PCC.
- Port management platforms (aka *the heart of the system).* This layer is comprised of common platforms that allow the digitization of (manual) paperwork and the efficient management of port operations. It includes the Port Management System (PMS) and the Port Community System (PCS), among others. The later can be considered a core tool in the digitalization journey of APBA. A new generation PCS, known as Teleport 2.0, will evolve from its existing PCS (Teleport) to provide new added value services for a more efficient coordination of all stakeholders in the land side, sea side, and port side. With respect to the Ro-Ro traffic, an interesting initiative within the new PCS is to provide end-to-end traceability for all stakeholders involved in the logistics chain. This includes the connection of Teleport 2.0 with the PCS of Port of Tanger MED, located in Morocco, in the north of Africa. This example could become a first-of-its kind in terms of transnational (and regional) digital connectivity.
- Advanced platform (aka *the brain of the system).* This layer reaps the potential of the significant volume of data to transform it to valuable information that can be shared with all actors. Based on Artificial Intelligence (AI) and Machine Learning (ML) algorithms, the layer learns to predict relevant events, and prescribe courses of actions in the operations from a holistic perspective.

In short, the DPOO is meant to be the orchestrating tool of APBA towards its port users, acting as a platform of platforms to ensure excellent quality of services. The previous elements, besides others, have resulted in the international recognition of APBA for its best practices. In 2020 it was awarded by the European Sea Ports Organization (ESPO) for its culture and innovation management program. Moreover, according to the *Container Port Performance Index (CPPI)*[21], Port of Algeciras ranked in 2020 as the most efficient port in Spain and Europe, and tenth worldwide (led by Asian ports).

3.3 Findings from best practices

The examples above depict best practices in ports which are subject to unique circumstances, from a political, economic, social, environmental, technological or legal perspective. While acknowledging the previous, there are still some common elements which can be considered worth remarking as best practices. These are summarized below:

- Most of the above cases depict an open culture to change and innovation coming from the management levels, as well as the rest of the human capital. This approach can pool knowledge together, leading to a common ground of understanding within the organizations (from port authorities to port users), and between them, thus embracing the digital transformation in the entire community.
- In line with the previous, the reported port authorities play a proactive and "customer driven" approach, including the rest of the stakeholders within the port community to understand their unique problems and goals, and thus taking them in a long term digitalization journey and commitment. Stakeholder engagement is key to a successful implementation of digital initiatives.

[21] See CPPI, elaborated by the World Bank Group and IHS Markit.

4 Digitalization challenges in APEC ports

RQ3. What are the main challenges that APEC ports are facing in the digitalization process?

The implementation of digital-based initiatives can be a challenging endeavor for firms and organizations. This can be exacerbated in port clusters and communities, which are by nature highly complex systems and completely unique from one another. It therefore becomes relevant, via this section, to define common constraints hindering the adoption of digital solutions. These were determined following a step-wise approach. The bulk of valid responses, which can be found in Appendix F, were first retrieved from Part C of the online survey, as well as the validation interviews (see Appendix D), and also complemented from desk research, whenever applicable. The responses were then clustered into common bottleneck, whenever similarities were found (e.g. from a political, economic, technical, social or legal perspective), as outlined in Section 4.1. Such bottleneck were then cross-checked by the study team with the different elements of the PDS, as presented in Section 4.2. This is done with the purpose of understanding causalities and root-causes hindering higher scores in the assessment framework.

4.1 Bottlenecks

[B1] Lack of capacity by management levels

"Lack of capacity" in this case is meant from different angles. On the one hand, insufficient knowledge can sometimes start at the top of the management levels. A lack of understanding and engagement by the port managers with respect to digital transformation in the port communities can strongly hamper digitalization efforts. On the other hand, insufficient human capacity can also delay progress in the digitalization journey. In other words, it refers to not having enough personnel within the decision-making process, which is particularly common within public authorities. It is therefore common for port managers to seek external assistance, not only financial but also technical.

[B2] Changing priorities by management levels

The implementation of digital initiatives within ports can take substantially long periods of time. This requires constant endorsement by the management levels, which can frequently be subject to changes, especially on the public side. In many of the economies within APEC, it is not uncommon to see a high turnover in government positions, which can also spill to the management levels of port authorities. Rotating political representatives, which may be subject to different priorities, can hinder the effective development of a particular project, including a digital transformation roadmap.

[B3] Misalignment of different external assistance bodies

As mentioned in *[B1]*, ports may seek external assistance due to their lack of capacity to elaborate and execute their own digitalization roadmaps or initiatives. For this reason, many international organizations, ranging from multilateral development banks to cooperation frameworks, have been providing financial, technical or policy assistance in fields such as infrastructure development and transport connectivity. In the last years, more focus has been placed on assisting in the use of emerging technologies for more sustainable and resilient use of current and new infrastructure. This trend moved to the front of the agenda as a result of the COVID-19 pandemic. While these efforts can generate a positive return, especially to ports in need of it (see bottleneck *[B1]*), uncoordinated approaches by these different mechanisms can create overlaps and result in a sub-optimal allocation of resources for different projects, and therefore of project outcomes. An example can be the assistance in the development of different trade management solutions (e.g. Maritime Single Windows and Port Community Systems), with resulting platforms not being interoperable.

[B4] Budget restrictions

Developing digital infrastructure and solutions can require significant investment, not just on hardware and interoperable software, but also on maintenance, capacity building and cultural change management within entire organizations. This can be a costly and time consuming process, with return on investment not being clear in the short term. Budget restrictions, which were already a challenge, may have been further tightened as a result of the economic effects brought about by the COVID-19 pandemic in some of the economies of the region. This perception by the survey panelists may be common during decision making, where investment costs in an field that may not be familiar such as digitalization (as opposed to more traditional projects such as hard infrastructure expansion) can loom larger than expected cost savings between the management levels.

[B5] Skepticism by stakeholders

Whenever changes are proposed, especially with respect to digitalization, skepticism by the different stakeholders, both within and between organizations, may be common. This can be rooted in several elements. Disruptive technologies, like artificial intelligence, 3D printing, and advances in automation, robotics, and intelligent transportation systems, are changing the nature of work in the transportation sector in all APEC economies by creating new types of jobs while displacing others.[22] Also, from the lack of knowledge by the management levels, to an ageing labor force which can struggle to change its business-as-usual way of working, and thus keep up with the technological trends and developments. Moreover, some actors profit from the common inefficiencies of supply chains, be that in a licit or illicit way. Common inefficiencies can range from lack of visibility to lack of transparency in the way goods are transported throughout freight transport systems, with ports as relevant nodes. Solving such inefficiencies could be perceived as a threat to their advantageous position.

[B6] Lack of stakeholder management

Elaborating and executing a digital transformation roadmap in a port community, is not just an isolated, *'plug-and-play'* project. A lack of interaction between the different stakeholders involved throughout an entire project lifecycle can hinder and delay the effective development and implementation of digital initiatives. Moreover, inadequate dialogues can result in insufficient awareness of the ongoing developments within a port community, and thus in solutions that may be siloed for a few organizations only, and not fit for the entire port community. At the same time, a lack of stakeholder engagement can also lead to more skepticism in the medium and long term between the different stakeholders against proactive collaboration.

[B7] Lack of ICT infrastructure

Digitalization relies in a proper ICT infrastructure backbone. For instance, wireless technologies, such as Wi-Fi or Long Term Evolution (LTE), can be used for sharing of data or information generated by decides, equipment or other systems, depending on the context of the port. In some cases or economies, computer equipment may not have enough bandwidth required for sharing of data[23]. As stated by one of the respondents, "internet connectivity issues" can be common, affecting the reliability of quality of the above services. This is in line with official reports that suggest there is an ICT infrastructure readiness divide between different economies, including within the APEC region[24].

[22] See APEC Transportation Working Group (TPTWG) (2021). Disruptive Technologies and the Changing Nature of Work in the Transportation Sector.

[23] See Heilig, L., & Voß, S. (2017). Information systems in seaports: a categorization and overview. Information Technology and Management, 18(3), 179-201.

[24] See Global Information Technology Report 2016 (WEF) as a global benchmark of the IT readiness. One of its pillars, infrastructure, measures on a 1 to 7 point scale by metrics such as electricity production, mobile network coverage, international internet bandwidth, or secure internet servers. The results suggest a large divide in APEC between top performers, such as Japan (7), Singapore (6,6), or Korea(6,6) and other economies like Peru (4,1), Mexico (3,7), the Philippines (3,6), Indonesia (2,9), Viet Nam (2,4), just to name a few.

[B8] Interoperability

This bottleneck is aligned with the low score given to *[T1]* in the survey, as well as with literature. The use of technology as a tool to solve complex problems in different port activity domains, ranging from operations to energy consumption, environmental monitoring or safety and security, relies heavily on data as primary technical input. In practice, data is often siloed to a few proprietary systems, unstructured or not labelled, and sometimes not even available.

In line with the previous, many initiatives within port communities may have been implemented in a siloed way. For instance, an ICT vendor could have developed a system that improves a particular process or activity for a particular actor within the port. The issue can arise when trying to scale it up to include more actors, and thus integrating different legacy systems that may not be easily integrated and interoperable with existing Business-to-Business (B2B), Business-to-Government (B2G), or Government-to-Government (G2G) platforms.

[B9] Cybersecurity

This bottleneck was identified in the survey, where most panelists reported not having a cyber risk management strategy, yet it was either planned or in development phase. This is in line with literature. As more port activities undergo an analog-to-digital transformation, the vulnerability of these processes against cyber-attacks may become increasingly pervasive. There is a wide range of cyber-attack scenarios, which can have varying consequences Some of these can be the compromising of critical data to steal high value cargo; the propagation of ransomware leading to a shutdown of port operations; or the compromise of PCS for manipulation or theft of data[25]. It must be noted that within the port environment, cyber stakeholders include all administrative and operations personnel which can access digital assets to create, access, process, store, or transmit electronic data, internally or externally, to government and commercial third parties.

[B10] Lack of qualified workforce

This bottleneck is aligned with the low scores of the Human Capital pillar in the online survey (the mean was 2.38 and 1.96 for *HC1* and *HC2*, respectively). It also expands from the knowledge gap by the management levels to the rest of the organizational structures. Just like with the container revolution of the 1960s, the dynamics of logistics are expected to change with the introduction of new technologies. Thus, the human-machine interaction will change, and with that the skill needs of the human capital. This poses challenges not only for an ageing workforce, but also for the implementation of digital initiatives as well.

[B11] Business case not properly defined

Digitalization initiatives often fail as a result of an inadequate business case. Quoting one of the responses from the stakeholder consultation, *"everyone has a smart port plan but nobody knows how to implement it"*. This can be rotted in other bottlenecks, such as lack of knowledge or lack of stakeholder engagement, among others. But also in the fact that the steps within the business case may not be properly systematized, from an inadequate re-engineering of a particular process to a poor design of the new systems architecture.

[B12] Legal frameworks not properly established to ease digital transformation

This is in line with recent literature. According to a survey conducted by the IAPH in 2020, many port authorities and operators still struggle to conform with mandatory requirements to introduce electronic data exchange between ships and ports, as stated in the new IMO FAL Convention. One of the biggest barriers identified in that hurdle was the difficulty to establish enabling legal frameworks, since it sometimes depends on competing or overlapping public administrations and governmental agencies at local or domestic level[26].

[25] See ENISA, Port Cybersecurity, good practices for cybersecurity in the maritime sector, November 2019.

[26] See IAPH global ports survey on the implementation of electronic data exchange to conform with the IMO Convention on Facilitation of International Maritime Traffic (FAL), January 2021.

4.2 Influence of bottlenecks in the PDS

Table 3 below, referred to as the PDS/bottleneck matrix, outlines how the bottlenecks influence the PDS. A coloured cell means its corresponding bottleneck (column) hampers the development of an element of the PDS (row).

Table 3. PDS/bottleneck matrix: Identified bottlenecks (columns) and respective elements of the PDS (rows) that they affect. Source: Authors.

PDS elements \ Bottlenecks	[B1] Lack of capacity by Management levels	[B2] Changing priorities by management levels	[B3] Misalignment of different external assistance bodies	[B4] Budget restrictions	[B5] Skepticism by stakeholders	[B6] Lack of stakeholder management	[B7] Lack of ICT infrastructure	[B8] Interoperability	[B9] Cybersecurity	[B10] Lack of qualified workforce	[B11] Business case not properly defined	[B12] Legal frameworks not properly established
M1 - Digital strategy	High	High	Medium	Medium	High							High
M2 - Innovation ecosystem	High	High	Low	Medium	High			Low				
M3 - Investment in digitalization	High	High	High	High	High	High	High					High
HC1 - IT business -related knowledge and skills	Low	Low		Medium			Low			High		
HC2 - Training program on port digitalization	Medium	Medium		High								
T1 - Data standardization	High	High		High	High	High	High	High	High	High	High	
T2 - Office & Business Management systems	High	High		High			High	High	High	High	High	
T3 - Operations Management - PMS	High	High		High			High	High	High	High	High	
T4 - Operations Management – TOS/ECS	High	High		High			High	High	High	High	High	
T5 - Trade management – PCS/SW	High	High	Medium	High	High	High	High	High	High	High	High	High
T6 - Environmental Management – Air quality control	High	High		High			High	High	High	High	High	
T7 - Environmental Management – water quality monitoring	High	High		High			High	High	High	High	High	
T8 - Environmental Management – Noise monitoring	High	High		High			High	High	High	High	High	
T9 - Energy Management – Energy consumption monitoring	High	High		High			High	High	High	High	High	
T10 - Safety & Security – Early detection of extreme weather	High	High		High			High	High	High	High	High	
T11 - Safety & security - Cyber risk management	High	High		High			High	High	High	High	High	
T12 - Safety & security – Surveillance and safety control	High	High		High			High	High	High	High	High	

4.3 Findings from the digitalization challenges

The table above was constructed based on internal brainstorming of the study team. While being subjective, it can still provide insights around the bottlenecks, the PDS and how one the former influence the later. The most interesting findings are summarized below:

- Some of the bottlenecks identified by survey participants are equivalent to the lowest level of maturity of the elements in the PDS. As an example, the lowest level of maturity of "IT Business skills" (*[HC1]* in the PDS, see Appendix C) could be argued to be equivalent to bottleneck *[B10]*. This finding suggests that there could be dependencies inside the PDS as well, and thus some particular pillars or elements could influence others.
- Bottlenecks *[B1]* and *[B2]* highly influence all elements within the Management and Technological Ecosystem pillars, and play a moderate influence on the Human Capital as well. Budget restrictions *[B4]* also influences all the elements of the PDS, with higher influence on the Technological Ecosystem elements.
- The elements within the Technological Ecosystem (*[T1]-[T11]*) pillar seem to be exposed to more bottlenecks, somewhat in line with the lower scores that the pillar received than the other two in Section 2. Within this pillar, trade management tools, such as Single Windows or Port Community Systems *[T5]*, seem to be affected by all bottlenecks, while in varying degrees of influence. This is in line with recent literature, which identified the development of SW/PCS as a stepping stone to enable digitalization in the port and maritime sector[27].
- The elements within the Management pillar (*[M1]-[M3]*) are particularly exposed to bottlenecks *[B1]-[B5]*. This seems reasonable due to the political nature of these bottlenecks, which can affect not only private but also, and particularly, public decision makers.
- While the Human Capital is seemingly less exposed, bottleneck *[B10]*, arguably equivalent to LoM=1 of *[HC1],* can be a significant barrier in the development of the other pillars of the PDS, particularly the Technological Ecosystem.

A few things should be however noted with respect to the findings, suggesting that more research may be needed. First of all, the bottlenecks should not be seen as isolated and independent from one another. Instead, it could be argued that there are dependencies between some of them. As an example, skepticism by stakeholders *[B5]* may be rooted in a lack of awareness and knowledge around port digitalization by managers *[B1]* or the rest of the workforce *[B10]*.

Second of all, a bottleneck *affecting* a higher number of elements of the PDS could give the reader the idea that such bottleneck is necessarily more *relevant* than others affecting a fewer number of elements of the PDS. This should however be subject to further research. For instance, *[B12]* could hinder, if not completely halt, the development of a digitalization initiative. The same could be argued with respect to *[B10]*, as stated above. The study team tried to account for this by adding new granularity and assigning different levels of relevance (Low-Medium-High) for every bottleneck influencing an element of the PDS.

Third of all, the matrix does not reveal the *occurrence* of a particular bottleneck. For instance, the higher scores of the Management pillar in Section 2 (reaching a mode of 3 to 4), based on the educated yet subjective opinion of participants, could give the misleading idea that the above bottlenecks (e.g. *[B1]* to *[B5]*) are not common in the sample ports. To account for the fact that the above bottlenecks could be applicable to any port, not just in Asia & Pacific, but also to other regions, no occurrence was given.

[27] See World Bank-IAPH report (2020). Accelerating digitalization, critical actions to strengthen the resilience of the maritime supply chain.

5 Recommendations for digitalization in APEC ports

RQ4. What recommendations can be drawn to improve port digitalization efforts, and thus supply chain connectivity in APEC?

Considering the different findings discussed previously, this section provides a comprehensive plan of actions that can be generic enough while providing room for each port to tailor it to its own unique context. Based on the nature of the study, the recommendations are targeted to two main groups. On the one hand, to the managers of the ports in APEC, which are key stakeholders within the decision making process. On the other hand, to the APEC government representatives and policy makers, which can play an important role in the promotion and establishment of guidelines.

Following a similar line of reasoning as in Section 4, the recommendations were proposed based on the following steps. The bulk of valid responses, which can be found in Appendix G, were first retrieved from Part C of the online survey, as well as the validation interviews (see Appendix D), and also complement from desk research, whenever applicable. The responses were then filtered, based on internal brainstorming of the study team, into a set of concrete recommendations depending on the target group, namely port managers in the APEC region, as well as policy makers in APEC economies.

In order to give the audience an idea of the time resources needed for each recommendation, it would be logical to provide a tentative execution timeframe to each recommendation. The study team believes that all these recommendations should be put into practice, insofar as possible and considering the unique case of each economy and port, as soon as possible. Moreover, instead of a one-time project, the list of recommendations, which can be found in Table 4 and are further explained in Section 5.1, should be subject to continuous tailoring and improvement based on the changing dynamics of each economy and port.

Table 4. Proposed recommendations and target group.

Recommendations	Target Group	
	Port managers in APEC	Policy makers in APEC
[R1] Knowledge infrastructure		
[R2] From vision to implementation		
[R3] Change management		
[R4] Cybersecurity management		
[R5] Interorganizational collaboration		
[R6] Standardization		

5.1 Recommendations

[R1] Knowledge infrastructure

With economies and industries progressively being more knowledge-dependent, the role of knowledge infrastructure can be one of the basic elements supporting digital development. In the context of port communities, the existing knowledge gap should be tackled not only within the organizational structures (from high-level managers to intermediate levels) of different port organizations, but also with respect to policy makers as well. Improving the knowledge infrastructure can be done by focusing on one or several of the following actions, which are based on the best practices presented in Section 3:

- Promote capacity building and educational programs in topics related to port digitalization within the port authority, the different port users, and the government agencies. For more effectiveness, such programs should be continuous and regularly updated to keep up with the fast-paced developments within the different technologies that englobe the field of port digitalization.
- Promote an innovative ecosystem within port communities. Stakeholders, including not only port users but also regulators, should more closely collaborate with different research institutes on R&D programs. Moreover, start-ups can bring a fresh perspective and 'know-how' to solve complex problems in the port via the use of emerging technologies. As a starting point, working groups, represented by the main stakeholders within the port community, could be created to elaborate an entrepreneurial roadmap within the port. Concrete actions could be proposed, such as the establishment of an open innovation lab, where the port can be used as a testing ground for pilots coming from entrepreneurial initiatives. Start-up and scale-up accelerators should also be promoted, at either port or economy level, to professionalize the entrepreneurial efforts within port communities.

Improving the digital knowledge infrastructure could bring several benefits for ports in APEC. First, it can strengthen their human capital with new skills that are increasingly needed, such as data-savvy job profiles, software developers, or cybersecurity experts, among others. Second, it would give improve the understanding and engagement of the management levels with the 'ins and outs' of digitalization, and thus better allocation of budget and use cases, which fit the unique context of their port community, can be proposed. Third, digitalization is not just an ICT project, but instead a multi-stakeholder and multi-disciplinary road of continuous learning and improvement. In this sense, increasing knowledge within organizations can break down silos across departments and enhance a culture of proximity between them, by sharing knowledge and findings on (smart) business case ideas.

[R2] From vision to implementation

As mentioned in Section 2, several panelists reported their ports or organizations scoring LoM=3 or LoM=4 when asked about the development stage of a digital strategy or vision for the port community *[M1]*. Whether they interpreted the question for the entire port community or just their own internal organization, it could be argued that establishing a strategic vision can be a good starting point for organizations to embark in the digitalization journey.

The following steps could be tentatively considered when elaborating a port community vision:

- The vision should include the different stakeholders directly or indirectly involved in a particular port community[28]. This involves understanding previously the unique problems and goals of port management bodies, authorities of (member) economies, transport companies, providers of other essential nautical services, or the local neighboring communities. If the perspective of a port management body is considered (e.g. a landlord port authority), then analyzing its relationship with the port community context can be carried out via a SWOT analysis.

[28] This step assumes that a proper diagnostic, similar to the PDS but more detailed to the context of a particular port community, has already been carried out.

- In a short paragraph, the vision should be comprehensive enough, taking into account, insofar as possible, the above mentioned unique problems and goals of each of the stakeholder groups in that particular port community. At the same time, in order to account for the increasing changing dynamics in trends influencing the port, the transport sector, and industries in general, the vision should be flexible and open to continuous revision, with a time horizon of no more than 5 years. Many organizations opt for the mission-vision-value helix, suitable for their own strategic planning.
- Once the vision is formulated, it can be broken down into different strategic goals. How these strategic goals are defined depend on each context. Examples of pillars could be operational efficiency, energy efficiency, safety and security, or environmental management, among others. It is important that a pillar like environmental management not only looks at operational efficiency gains of port digitalization, but, in terms of decarbonization objective, a wider view on the net benefits is needed and, for instance, the energy consumption of IT systems driving port digitalization processes should be considered as an integrative element.
- In practice, a vision may fail to translate into an implementation plan. This is somewhat aligned to one of the bottlenecks identified in Section 4.1 *([B10]* 'business case not properly defined').To systematize the process of measuring progress of each of the strategic goals, operational goals and measurable indicators can be defined. From this point, initiatives can be defined to help reach the above mentioned goals.

The above steps systematically give sense of the '*Why'* to end up with the initiatives (the '*What'*), which can be of digital nature or not. For instance, looking into the elements of the Technological Ecosystem from the PDS, the need for a neutral electronic platform that can enable the secure exchange of B2B and B2G information (e.g. in the form of a PCS) could be identified in a particular port community[29].

The missing link from the above is about how to develop the initiative into a tangible solution and run it in a sustainable way (the '*How*'). Elements such as governance of the initiative (e.g. 'who owns it?', 'who runs it?'), financial model (e.g. 'how to make revenue out ot it? Is it a subscription fee or a per-unit charge?'), or target group (e.g. 'which are the parties involved?') need to be addressed.

Once the previous elements are agreed upon, the IT development can be done either in-house or with the assistance of external service providers. Common steps in this stage would involve, without being exhaustive, the mapping of current processes ('As Is'), the identification of key pain points to focus on, the re-engineering of relevant processes ('To Be'), target Key Performance Indexes (KPIs), as well as the systems architecture. Agile methodologies, that is, iterative development through cross-functional teams adopting quick sprints through a short time span could allow to quickly come up with a Minimum Viable Product (MVP) of the digital solution to be implemented in the port community.

[R3] Change management

While this particular recommendation could be argued to be strongly linked to the previous recommendations (especially "knowledge infrastructure"), they should rather be seen as complementary. A training session in the field of port digitalization may not find much resistance, and can increase awareness in the topic from a theoretical side. Yet, translating that into an actual project case to be designed, developed and maintained, with the organizational changes that it may imply, is more complex. For different stakeholders, either within or between organizations, any change in the current way of working can often be confronted by skepticism and resistance. This can be more acute for larger organizations.

[29] In fact, the development of trade management tools such as SW or PCS is recognized in the literature as a keystone in the acceleration of digitalization in the port sector. In this report, the study team, while acknowledging the vital importance of these type of tools (the *What*), tries to complement the previous by using it as an example, while also stressing out the need to focus on the elements that are usually left out of the discussion (the *Why* and *How* as discussed in this point) to ensure a successful rollout.

Therefore, a systematic approach that deals with the transformation of the goals, processes or technologies of port organizations should be applied. At the organizational level, there is plenty of literature with respect to the different methodologies and tools that organizations can make use of internally, from Kotter's eight-stage process or Luecke's Seven steps, or the ADKAR model, among others[30]. The benefits of good change management seem logical. From a more efficient and effective adaptation by employees, and thus organizations, to a better engagement of the human capital during disruptive change.

Looking beyond one organization, there are also models that promote constructive and sustainable engagement between different stakeholders. One being the Mutual Gains Approach (MGA), a 4-phase model that allows parties to improve their chances of creating and agreement superior to existing alternatives, while protecting relationships.

A key tenet of this framework is that it acknowledges parties involved in a negotiations in the real world have more than one goal or concern in mind, and more than one issue that could be addressed in the agreement they reach[31]. Therefore, the model recognizes that opposing sides may have legitimate interests that need to be recognized, and approaches such issues as problems to be solved by finding an outcome of mutual gain. This framework can particularly interesting in the context of port communities, where digitalization can involve several organizations, some of which may perceive digitalization as a threat.

[R4] Cybersecurity management

As mentioned already, the introduction of new technologies can expose business to potential vulnerabilities that can jeopardize sensitive data or digital assets, among others. In line with other industries, IT systems in port communities should be robust against cyber-attacks, following international standards. Common complementary defense mechanisms can be digital signatures, the use of public and private keys, Virtual Private Networks (VPN) or double authentication systems.

The following documentation serves as a non-exhaustive list of guidelines to build cyber-resilient organizations in the port and maritime sector:

- IMO MSC-FAL.1/Circ.3 "Guidelines on maritime cyber risk management" from July 2017[32], which provides a foundation for better understanding and managing cyber risks, and thus enable a risk management approach to tackle vulnerabilities. APEC economies which are members of IMO are encouraged to bring the contents of this circular to the attention of maritime stakeholders concerned.
- The European Union Agency for Cybersecurity (ENISA) published in 2019 a study that aimed to address the cybersecurity challenges related to the evolution of maritime port Information Technology (IT) and Operations Technology (OT) systems and services, and thus build a baseline of good practices[33].
- The IAPH Cybersecurity Guidelines for Ports and Port Facilities (2021)[34].

[R5] Interorganizational collaboration

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[30] For more information on change management models, the following links may be useful to the reader:

- [(1)]By, R. T. (2005). Organizational change management: A critical review. Journal of change management, 5(4), 369-380. Available at link.
- [(2)]Errida, A., & Lotfi, B. (2021). The determinants of organizational change management success: Literature review and case study. International Journal of Engineering Business Management, 13, 18479790211016273.
- [(3)]Smarp: 5 Change Management Models to Take a Look At.

[31] See Mutual Gains Approach to Negotiation, by Consensus Building Institute (CBI).

[32] See MSC-Fal.1/Circ.3 Guidelines on maritime cyber risk management.

[33] See ENISA, Port Cybersecurity, good practices for cybersecurity in the maritime sector, November 2019.

[34] See IAPH Cybersecurity Guidelines for Ports and Port Facilities.

Lack of coordination between governing bodies, ranging from port bodies (e.g. port authorities) to external assistance bodies (see bottleneck *[B3]*), should be avoided.

Particularly for port authorities, an interesting initiative that was born under this philosophy of knowledge exchange is ChainPORT[35]. Founded by the Port Authorities of Hamburg and Los Angeles in 2015, in collaboration with the Global Institute of Logistics, ChainPORT is an international network of ports whose shared goal is to advocate for a smart, innovative and sustainable port model. Under a philosophy of knowledge exchange, the port partners are involved in hackathons, annual gatherings and an educational program (known as the "Academy") to build knowledge capacity. Moreover, the initiative comprehensively addresses smart solutions, the digital culture change needed in Port Authorities, and the global dialogue with the entire maritime industry. As of today, ports like Hamburg, Rotterdam, Felixtowe, Antwerp, Montreal, Los Angeles, Panama, Singapore, Shanghai or Busan are involved in the initiative.

Port authorities in APEC could explore possibilities to join platforms such as the above mentioned as a starting point. For instance, a reduced group of digital-savvy profiles, preferably from a mid-to-high management position, from the port could be allocated to explore the potential benefits and costs of becoming an active member of initiatives like ChainPORT.

Collaboration and cooperation should also be promoted within bodies providing, in one way or another, technical assistance. In line with the same philosophy of ChainPORT, cross-organizational working groups (involving for instance, multilateral banks with UN agencies or other cooperation frameworks) could be arranged to exchange knowledge, learnings and developments. This collaboration could start with simple steps, even in an informal way, with a few organizations, and then expanding to more of them.

[R6] ICT infrastructure

As identified in bottleneck *[B7]*, several APEC economies lag behind in terms of ICT infrastructure readiness. Considering that the need to improve supply chain connectivity in the Asia & Pacific region, policy makers should promote investment in ICT infrastructure to improve metrics such as bandwidth or mobile network coverage. This could serve as a more robust backbone underlying the implementation of digital solutions.

There can be many formulas to promote investment. Public funds could be an alternative, yet lack of budget, sub-optimal allocation of resources or poor maintenance have been common challenges for the public sector to fund such investments. Partnering with the private sector has been an ongoing trend to fill in the financial (and technical) gap, via Public-Private Partnership (PPP) schemes[36]. A strong motivation for the use of PPPs is to improve value of money, by optimizing the way in which (ICT) infrastructure is planned, prepared, designed, constructed, operated, funded and maintained. A PPP can be designed to allow the government to keep its primary regulatory role, while the private sector injects investments and expertise into developing infrastructure projects. Especially, when knowledge and capacity about port digitalization with publicly owned ports or at the level of policy makers is missing, a more dominant role for the private sector may prove to be more effective. At the same time, both positive and negative examples are present still nowadays when applying PPP models, in any sector. Therefore, a good practice manual, supported by a workshop as part of an APEC port forum, may be a valuable tool to support APEC ports seeking to attract private investment and support in implementation of their port digitalization strategy, with specific attention for dealing with (potential) misalignment of public and private interests such as gaps in data transparency, accountability and public port (administrative) processes.

[R7] Standardization

In the context of port and maritime digitalization, "standardization" should be seen from several angles. From the standardization of nautical, operational and administrative data that is needed around a port call process

[35] See more information about chainPORT.

[36] A Public-Private Partnership can be defined as a contractual agreement formed between a government agency and a private sector entity that allows for greater private sector participation in the delivery of public infrastructure projects.

(maritime industry) to common standards around the Industry 4.0 technologies and processes, ranging from IoT, Cloud Computing, Big Data, connectivity, or cybersecurity.

Both port organizations and political representatives in APEC should make sure that their digitalization initiatives, regardless of their scope, comply, insofar as possible, with internationally accepted standards. This ensures a common language of understanding not only in the processes and activities (e.g. semantics of a port call), but also for the interoperability of scalable IT systems.

With the purpose of bringing as much clarity as possible in a topic that can sometimes be confusing, Table 5 below provides a non-exhaustive list of initiatives and standardization bodies to be considered within wide port digitalization field, and what the different target groups in this chapter can do:

Table 5. Overview of initiatives and standardization bodies that are involved in the port digitalization field. Source: Authors.

Initiatives & standards	Description	Recommendation
Standards related to the Maritime Industry		
IMO FAL	• Compendium on facilitation and electronic business[i]	• port managers: Ensure port communities conform with mandatory requirements on electronic data interchange (EDI) under FAL Convention • Policy makers: Ensure, via domestic legal frameworks, that there is no overlapping of governmental agencies to conform with FAL Convention
ISO Technical Committee 8	• Standards on ship-to-shore interface, among others, subject to IMO requirements. Under ISO TC8, there is a new initiative bringing in different NGO's to create a global digital ISO standard for exchange of administrative and operational data	• Port managers and focal departments within the port to become familiar and stay up to date with latest developments
IALA S211	• Port call message standard developed on the bases of Port Collaborative Decision Making (PortCDM), compliant with IHO	• Port managers and focal departments within the port to become familiar and stay up to date with latest developments
DCSA	• Industry-driven initiative (Shipping Lines) proposing standards for different use cases in the maritime field (e.g. track&trace, electronic Bill of Lading)	• Port managers to become familiar and stay up to date with latest developments
TIC 4.0	• Industry-driven initiative (Terminal Operating companies)	• Port managers to become familiar and stay up to date with latest developments
Standards related to Industry 4.0 technologies which can be applied to port use cases		
Cybersecurity	• ISO/EIC 27001 standard on information technology, security techniques, information security management systems, requirements. • ISO/IEC JTC 1, where expects come together to develop worldwide ICT standards for business and consumer applications. As part of it, SC 27 is the committee that deals with information security, cybersecurity and private. Its scope of work ranges from cryptographic techniques and mechanisms to security guidelines, criteria for IT security evaluation, and management support documentation	• Port managers, especially those involved in IT departments, to become familiar and stay up to date with latest developments
Connectivity	• Recommendation ITU-R M.2150-0 – Detailed specifications of ITM-2020 (known as fifth generation of mobile communication systems, or 5G) link • Recommendation ITU-R M.2012-4 - Detailed specifications of ITM-Advanced (known as Long Term Evolution Advanced, LTE	• Port managers, especially those involved in IT departments, to become familiar and stay up to date with latest developments

	Advanced, supporting wireless communication for fourth generation of mobile communication systems, or 4G) (link)	
Other (IoT, Cloud Computing, Big data)	• ISO/IEC JTC 1/WG 10 Internet of Things • ISO/IEC JTC 1/SC 38 Cloud Computing and Distributed Platforms • ISO/IEC JTC 1/WG 9 Big Data	• Port managers, especially those involved in IT departments, to become familiar and stay up to date with latest developments

[i] See guidelines for setting up a Maritime Single Window, published in July 2021 in line with the Fal Compendium under FAL.5/Circ.42/Rev.1.

5.2 Tackling the bottlenecks

Following a similar logic than in Section 4.2, a matrix that cross-checks the bottlenecks that each recommendation could tackle is presented in Table 6, which serves as a summary of what has been outlined in Section 5.1:

Table 6. Bottleneck-to-recommendation matrix. Identified recommendations (columns) and the bottlenecks they can tackle (rows). Source: Authors.

Bottlenecks \ Recommendations	[R1] Knowledge infrastructure	[R2] From vision to implementation	[R3] Change management	[R4] Cybersecurity management	[R5] Interorganizational coordination	[R6] ICT infrastructure	[R7] Standardization
[[B1] Lack of capacity by Management levels							
[B2] Changing priorities by management levels							
[B3] Misalignment of external assistance bodies							
[B4] Budget restrictions							
[B5] Skepticism by stakeholders							
[B6] Lack of stakeholder management							
[B7] Lack of ICT infrastructure							
[B8] Interoperability							
[B9] Cybersecurity							
[B10] Lack of qualified workforce							
[B11] Business case not properly defined							

[B12] Legal frameworks not properly established

5.3 Findings from the recommendations

As done in Section 4.3, the following paragraphs serve to discuss a set of findings from Section 5. Starting with the timeframe, it would be logical to provide a tentative execution timeframe to each recommendation. However, as already explained, the study team however believes that all these recommendations should be put into practice, insofar as possible and considering the unique case of each economy and port, as soon as possible, with no end date. These recommendations should not be merely translated into a one or two-year budgeted projects. Instead, they should be subject to continuous revision and upgrading. That is, from keeping a knowledge infrastructure up-to-date at all times, to regularly systematizing the process of turning an overarching vision to the implementation and execution of digital initiatives, and dealing with change management, cybersecurity, standardization or interorganizational collaboration.

Moreover, it must be noted that the logic of the recommendations herein presented is to tackle all the bottlenecks, which are the root cause hindering a better digital maturity (via a better PDS result), as suggested in the above presented matrix. Important to remark is that more shaded cells (which mean that a recommendation tackle a particular bottleneck) does not necessarily imply, or should not be interpreted as such, that one recommendation is more *relevant* than other. For instance, 'change management' *[R3]*, while seemingly tackling two bottlenecks directly, could still indirectly spill over to a better enforcement of other recommendations (such as *[R2]* 'from vision to implementation'). This is in line with the proactive and customer-driven approach of some of the ports reported in as best practices in Section 3, which continuously engage with their stakeholders. In order to properly tackle all bottlenecks herein exposed, all recommendations should be given somewhat similar priority.

While acknowledging the previous, it could be argued the important role that knowledge infrastructure can play in the short, medium and long term. This is again in line with the best presented best practices, where the management levels embrace a culture of openness towards innovation and change. This approach of pooling knowledge together can create a common level of understanding within and between the organizations, thus better embracing their digital transformation and therefore a higher PDS score. As can be inferred from the above line of reasoning, and just like with the bottlenecks from Section 4, the recommendations should not be considered isolated from one another. For instance, improving the knowledge of organizational structures, not only within port managers but also within policy makers *[R1]*, can positively spill over to the rest other recommendations herein presented (*[R2]-[R6]*).

6 Concluding Remarks

This section concludes the main body of the report, summarizing the methodological steps taken to fulfil the goals and contributions of the study, the potential shortcomings in the methodology, as well as a set of suggestions for future research to the APEC Secretariat.

The report herein presented has the purpose to assist ports in the Asia & Pacific economies with their digitalization efforts, in line with the 2018-2021 Strategic Plan of the APEC TPT-WG. The study documents the findings and outcomes following desk research, stakeholder consultation, and a final workshop to ascertain different aspects. That is, the current status of port digitalization in the APEC region, main bottlenecks and best practices in the digitalization journey of ports, and supported by a list of recommendation points to tackle such bottlenecks, and thus accelerate port digitalization efforts in the APEC region.

Findings have been reported for each of the main Sections. From the group response of the survey, which includes 26 ports from 10 APEC economies, most of the ports reported developing or having developed already a digital strategy. This suggests that digitalization has moved high to the agenda of port managers. Human Capital seems to be lagging behind, implying that little importance is being given to capacity building in the wide field of port digitalization. Within the Technological Ecosystem, most of the focus is being placed in Operations Management, with solutions like TOS/ECS or PMS being increasingly common. Data standardization is one of the lowest scoring elements, which is aligned with a common discussion in the sector. With respect to the bottlenecks, lack of capacity and changing priorities by the management levels, as well as budget restrictions, seem to hinder all PDS elements. The elements of the Technological Ecosystem pillar seem to be more exposed to different bottlenecks, particularly trade management tools such as Port Community Systems. While the Human Capital pillar is seemingly less exposed, a low qualified workforce can be a significant barrier in the development of other pillars of the PDS.

Out of all recommendations, improving knowledge infrastructure could particularly play a key role in tackling all reported bottlenecks, thus increasing PDS maturity of ports. This is also in line with most of the reported best practices, where management levels embrace a culture of openness towards innovation and change. This approach of pooling knowledge together can create a common level of understanding within and between the organizations, thus better embracing their digital transformation and therefore a higher PDS score.

The main contributions of this research are twofold. First, the elaboration of the assessment framework, referred to here as Port Digital Scorecard (PDS). As a next step, further research could use the PDS herein proposed as a keystone towards a full port digitalization toolkit. Besides descriptive capabilities (*'where this particular port stands'*), a digitalization toolkit could also have prescriptive capabilities (*'what this particular port should do'*). The study team believes this next step could add significant value to the ongoing efforts by APEC to assist ports in the region. Second, the response rate has been relatively high, when compared with literature. The report herein presented outlines results of digitalization maturity of 26 ports from 10 APEC economies. This provides a significantly large data set that can be used as input for future research, thus enriching the body of literature.

While acknowledging the previous, there are still shortcomings in the proposed methodology worth mentioning. While the PDS can be considered to be comprehensive, all elements may still not cover the complete spectrum behind 'port digitalization'. Based on the feedback provided by key experts in the validation interviews (see Appendix D.2), it can still be subject to improvements and further research. Moreover, most of the outcomes of this report, namely the PDS results, bottlenecks and recommendations, depend on the subjective opinions of the interviewed panelists, both via the survey as well as the consultation with key experts. While the final workshop was used as an opportunity to get additional feedback on the outcomes, more time should have been dedicated for further validation of findings. This was however not possible due to the time constraints. Third, while the PDS allows an analysis of how digitally mature is with respect to other ports, no comparison between the ports, based on their PDS results. Acknowledging again the fact that such results came from the subjective opinions of personnel which may have different backgrounds and understanding of the topic, language barriers, or professional interests, such comparisons were left out on purpose.

Finally, during an online workshop on 24 February 2022, the findings of this study, including methodology, bottlenecks, recommendations and conclusions, have been validated with a wide group of stakeholders (government officials from APEC economies, port authorities/management companies and member economy / international port and maritime experts). During or after the workshop not any negative comment was received on the technical content of the study results. However, some additional suggestions were brought forward on next steps for port digitalization in APEC economies that could be supported by the APEC Secretariat. These suggestions include:

- Organization of port forums or workshops, specifically related to port digitalization initiatives (e.g. introduction of blockchain and industry 4.0 technology in the community of ports, logistics, shipping lines, shippers and consignees). Given the size of investments in ports, it is important to involve policy makers in the suggested forums/workshops.
- Support for the development of guidelines to protect port systems against cyber-attacks.
- Explore financing opportunities for developing economies to facilitate them in their port digital transformation journeys.
- Support with the development of standardized training courses for upgrading the skills of human capital on management and operational level.

To continue the efforts in port digitalization, the APEC TPT-WG should consider to include the recommendations from APEC economies in their Working Program.

List of appendices

Appendix A – Literature review on port digitalization

This Appendix serves to give clarity in a topic that has been subject to increasing attention and hype within the industry. Keywords such as port digitalization, smart ports or Ports 4.0 have gained significant attention in the last years, in many cases without a clear distinction between these terms.

Early references to "smart ports" are still recent. A collaborative initiative called "Smart Port" was signed in 2010 by several Dutch organizations, including the municipality of Rotterdam, Port of Rotterdam Authority, Erasmus University and other branch organizations. The purpose was to cluster supply of know-how in the port sector, since knowledge is "one of the most important sources of competitive advantage for a port environment" (Zuidwijk et al., 2014). An initiative with a similar name, smartPORT, was launched in 2012 by the Hamburg Port Authority (HPA), aimed at optimizing logistic processes in the port by adopting smart technologies, together with other industry partners within the cluster (Schrimer et al., 2016).

Increasing references to the use of "smart" technology in maritime ports could be found particularly around the application of sensing technology such as the Internet of Things (IoT), capable of collecting and monitoring data in the port. (Rivero et al., 2015, Belfkih et al., 2017, Yang et al., 2018, Rajabi et al., 2018).

Yet, the use of technology to improve port activities and processes is not limited to the last decade. Heilig et al. (2017) carried out a chronological analysis around the digital transformation of ports. From the early attempts in the 1980s to transform manual processes by developing electronic Data Interchange (EDI) systems, to the more recent "smart" processes, were keywords such as "IoT", "cloud", or "Machine Learning" have gained significant attention. Literature reviews around these type of technologies, and their application in the port context, have also been carried out more recently (de la Peña Zarzuelo et al., 2020, Yau et al., 2020, Gizelis et al., 2020)[37]. Literature has also focused on benchmarking frameworks to compare the degree of development, or maturity, of ports with respect to digitalization. These have received different names, from Smart Port Index to Digital Readiness Index Assessment (Molavi et al., 2019, Philipp, 2020).

The COVID-19 pandemic caused a complete disruption in global supply chains (UNCTAD, 2020). Early responses from ports ranged many areas, including operations, finance, safety and security protocols or reorganization of work stations. Other responses included the use of technologies to ensure business continuity. An original example was the test of smart watches to ensure physical distance between workers, in line with distance protocols (World Bank, 2020). With the purpose to assist ports in their regions to assist them in their journeys to become smart ports, some of the regional multilateral banks also published their own roadmaps (IDB, 2020, ADB, 2020).

While the body of literature is growing, there is still no full consensus on the definition of Smart Ports, or what port digitalization actually entails. As mentioned by a key international stakeholder in a previous APSN study, "everyone talks about digitalization now, but nobody knows how to do it"[38]. However, there seems to be certain agreement, from a conceptualization point of view, around step-wise frameworks, where ports "evolve" in different levels until reaching the status of Smart Port (for examples, see Deloitte, 2017, Port of Rotterdam Authority, 2018). This is in line with the early approaches by UNCTAD to categorize points into different "port generations" (UNCTAD, 1992).

[37] The last papers mentioned in the paragraph, while being published in 2020, were elaborated before the COVID-19 pandemic.

[38] See APRO webinar on Port Digitalization against the COVID-19 pandemic, as part of a study conducted by the team of STC-NESTRA.

Appendix B – Literature review on port digital assessment

Based on the previous, this Appendix aims to provide a literature review on port digital assessment, which is used as input to develop the PDS (Appendix C).

Measuring performance of ports, or Port Performance Measurement (PPM), has been for some time a widely accepted practice (see Woo et al., 2012). In such models, Key Performance Indicators (KPIs) are generally incorporated to quantify the performance of the port for a set of dimensions. Past research efforts have been focused mainly on operative performance of larger ports, assessing performance of the container as the primary cargo segment (see for instance Talley, 2006, Yang et al., 2017, Ha et al., 2019). UNCTAD's port performance scorecard aims to become an industry standard and a globally accepted benchmark on port efficiency (UNCTAD, 2020).

Yet, the attempts to model and measure the digital performance of ports is still scarce and limited in the literature (see Table 7). Molavi et al. (2019) attempted to develop a framework for a Smart Port and a quantitative metric known as *smart port index*. Such SPI was organized around what the authors considered to be four key activity domains in a smart port: operations, environment, energy, and safety & security. Rodrigo González et al. (2020) tried to quantify the smartness of Spanish ports by adding up together the scores of different *smart port indicators,* which were also clustered around 4 weighted distinct pillars: operational economic, social, political and institutional, and environmental. A similar attempt was made by Philipp (2020) by developing a digital readiness index for ports (DRIP), based on the "research landscape and practice about PPIs, as well was digital and Industry 4.0 readiness indexes and maturity models".

Table 7. Overview of port digital performance frameworks available in literature.

Framework Name	Overall dimensions considered	N. ports assessed	Source
Smart Port Indicator	Operational economic Environmental Political and institutional Social	10 ports in Spain	Rodrigo González et al (2020)
Smart Port Index (SPI)	Operations Environment Energy Safety & Security	14 ports worldwide	Molavi et al (2020)
Digital Readiness Index for Ports (DRIP)	Management Human Capital Functionality (IT) Technology Information	5 ports in Europe	Phillip (2020)
Digital Acceleration Index	35 dimensions	+200 maritime organizations in Singapore	Maritime Port Authority of Singapore (2021)

Reference to a digital audit was also made in the Smart Ports Manual, a study by the Inter-American Development Bank (IDB, 2020), where the levels of maturity of 10 distinct port management areas are presented in a graphic representation model.

Acknowledging the overlap between *smart ports* and *green ports*, terms which are becoming less distinct in the literature, Meyer et al. (2021) built on the previous author to incorporate a Sustainability index. The World Bank Group (WBG) developed the Digital Government Readiness Assessment (DGRA) toolkit[39], yet to the best of the team's knowledge, no work has yet been made publicly available by the WBG on port digital benchmarking yet.

[39] See Digital Government Readiness Assessment Toolkit by the World Bank.

As part of the Sea Transport Industry Transformation Map, Maritime and Port Authority of Singapore (MPA) has co-developed the Maritime Digitalization Playbook (MDP). It is a comprehensive framework that serves as a guide to help maritime companies (shipping lines, ship agencies, harbor crafts, …) uncover opportunities in digital transformation, and highlights some first steps that maritime companies can take. It builds on the Digital Acceleration Index (DAI), a 3-year survey to assess the state of digitalization of organizations in Singapore.

Port of Rotterdam Authority developed the Digital Quick Scan for ports, where users can quickly come up with a the level of maturity of their port[40]. Moreover, the International division of the Port Authority also offers a more comprehensive digital assessment, focusing not only on a particular port authority, but on its entire port cluster.

In short, for all models, common methodologies to gather performance data are desk research and stakeholder consultation, understanding the later as interviewing stakeholders from the sample port directly or making use of online surveys. The grading assessment is usually done on a categorical scale (e.g. 1 as in “very low level of maturity for this indicator” up to 6 as in “very high level of maturity for this indicator”). The grade of each dimension can be assessed as the sum of the grades of all indicators included in such dimension. The resulting value is then weighted to account for the relative importance of each dimension. Adding all weighted dimension scores gives the overall digital level of maturity of the port.

[40] See Digital Quick Scan for Ports, by Port of Rotterdam Authority.

Appendix C – Port Digital Scorecard

Giving an answer to "state of port digitalization in the port industry", or "recommendations to improve port digitalization", as formulated in Section 1.4, can be subject to several interpretations. *Digitalization* or *smart* are keywords that have gained significant attention in the past years around academic or professional port communities.

This trend has even gained more momentum as a result of the outbreak of the COVID-19 pandemic. The need for more resilient supply chains in the form of remote operations, paperless administrative or financial processing, or any other digital exchange of data and information between public and/or private stakeholders, has been further emphasized. Not only to ensure the benefits of efficient and environmentally friendly operations, but also to increase safety of the port labor.

Despite the hype, there is a lack of internationally accepted definitions around "smart", "digitization" or "digitalization" (the last two sometimes used indistinctly) in the context of ports. In either case, they can be considered to be rooted in digital or technological innovation, also subject to interpretation. The lack of a unified approach can blur collaborative efforts in the field.

In a previous study conducted by STC-NESTRA, we referred to port digitalization broadly as *"the continuous use of technology as a tool to come up with solutions that can help ports, port users and the workforce improve some or many of their processes and activities, and therefore bring added value to the port community and the supply chain as a whole".*

This abovementioned definition can be used as starting point, and expanded based on further desk research, for the construction of the PDS. For a more in-depth discussion around the topic, Appendix A and B provide a literature review around port digitalization and port digital assessment. Its elaboration needed to consider a few elements with respect to the scope of the present study, which are summarized below:

- Conducting a full digital assessment of one port can take up to half a year, based on preliminary discussions by the study team with key international experts. For that reason, the framework herein presented should be considered as a quick scan, to be continuously improved in subsequent studies by APEC.
- Ports are inherently complex and unique from each other, ranging from the type of activities and services they offer, to their governance models. Therefore, the framework has to be broad enough while suitable and understandable for local stakeholders to translate it to their unique circumstances. At the same time, the management and regulatory body of the port (usually referred to as port authority) was chosen as the main target audience for the PDS, which are assumed to have a broad idea of their entire port community.
- The online questionnaire depends on the scope of the PDS, meaning that the broader the later, the longer the former becomes. From previous studies, low to non-response has been a concern from a methodological perspective. Therefore, for pragmatic reasons, the PDS needs to be as condensed as possible.
- It is not the intention of the PDS to compare ports vis-à-vis, but instead give them an overview of where they stand from a digital perspective and as a port community.

Acknowledging the abovementioned points, three pillars have been defined which, based on the literature reviews on port digitalization and port digital assessment (Appendix A and B), capture a broad idea around port digitalization. These have been referred to as Management, Human Capital and Technological Ecosystem:

[M] Management.

This pillar refers to the extent the management levels in a port are reacting to the digitalization wave in the port sector. As ultimate decision-makers, a port that continuously makes use of technology as a tool to add

value (as summarized from our definition of port digitalization from Section 1.4) needs to have a management organizational structure that understands the benefits and risks of digitalization, and can play a proactive role in promoting digital-savvy policies, an innovative ecosystem and smart investments. Three elements were defined from this pillar:

- *[M1] Digital strategy for the port community*. The extent to which a digital strategy or vision exists for the port community
- *[M2] Innovation ecosystem in the port community*. The extent to which stakeholders within the port community collaborate to come up with (digital) innovative solutions to add value to their activities
- *[M3] Investment in digitalization in the port community*. The share of digital investment compared to total investment in the port community

It must be noted that, depending on the governance model of ports (e.g. landlord, public, private, etc.)[41], as well as the fact that port communities comprise different actors that come from the public or private side, this framework refers to the "management levels" broadly. That is, it may consider both private decision makers (e.g. from private port operators) as well as public decision makers (e.g. port authorities directly dependant on a particular national Ministry).

[HC] Human Capital.

This pillar refers to the extent the Human Capital in a port is being prepared for the digital future. Three elements are also defined as well:

- *[HC1] IT business-related skills.* The extent to which there is IT-based knowledge and skills in the port community, and how that translates to business cases.
- *[HC2] Training programs in port digitalization.* The extent to which IT or digital-based programs are being followed within the port community.

[TE] Technological Ecosystem.

This pillar builds on the initial definition of port digitalization from Section 2.1. It refers to extent digital-based solutions are being applied in a port. The several elements that are drawn from this pillar consider the development of solutions that are common in the field, which can be allocated to different domains, from operations management (e.g. Port Management System) to Trade management (Port Community Systems) or Environmental Management (e.g. air quality monitoring)

- *[T1] Data Standardization.* Refers to the extent rules and data standards are defined to allow for system interoperability
- *[T2] Office & Management Systems.* Refers to the development stage of office and management systems such as Enterprise Resource Planning (ERP).
- *[T3] Operations Management – PMS.* Refers to the development stage of Port Management Systems (PMS)
- *[T4] Operations Management -TOS/ECS.* Refers to the development stage of Terminal Operating Systems (TOS)/Equipment Control System (ECS)
- *[T5] Trade management -PCS/SW.* Refers to the development stage of Port Community Systems (PCS)/Single Windows (SW)
- *[T6] Environmental Management-Air quality control.* Refers to the development stage of an air quality control system in the port area.
- *[T7] Environmental Management -Water quality control.* Refers to the development stage of a water quality control system in the port area.

[41] See World Bank, Port Reform Toolkit, Module 3.

- *[T8] Environmental Management -Noise quality control.* Refers to the development stage of a noise control system in the port area.
- *[T9] Energy Management -Energy consumption control.* Refers to the development stage of an energy consumption control system in the port area.
- *[T10] Safety & Security -Early detection of extreme weather events.* Refers to the development stage of an early detection system for extreme weather events in the port area.
- *[T11] Safety & Security -Cyber Risk Management.* Refers to the development stage of a protocol plan against cyber-attacks
- *[T12] Safety & Security -Surveillance and safety control.* Refers to the development stage of surveillance and safety control system in the port area.

Table 8 summarizes the chosen pillars, their corresponding sub-pillars or components, as well as the maturity scale on which each sub-pillar will be assessed at port level. Such framework was then used as input for one of the main elements of the online survey (see Appendix D).

Table 8. Port Digital Scorecard. Source: Authors. PC: Port Company (e.g. port authority or equivalent).

Pilar / Element		Scale applied [1-4]
Management	[M1] Digital strategy	[1] There is no digital strategy for the port community; [2] There is a plan to develop a digital strategy for the port community; [3] A digital strategy roadmap for the port community is in development phase (drafting); [4] There is a published digital strategy roadmap whose guidelines are being followed in the port community
	[M2] Innovation ecosystem	[1], Innovation is non-existent; [2], Innovation is limited to a few siloed organizations in the port community; [3], There are small innovation clusters within the port community (e.g. innovation initiatives between two or more organizations); [4] Innovation is widespread in the port community, with large presence of entrepreneurial initiatives (e.g. innovation labs, start-up accelerators, …)
	[M3] Investment in digitalization	The share of digital investment with respect to total investment of the port community is (x): [1] (x ≤ 5%); [2], (5% ≤ x ≤ 10%); [3] (10% ≤ x ≤ 20%); [4] (x ≥ 20%)
Human Capital	[HC1] IT business - related knowledge and skills	[1] Knowledge limited to a few (IT) departments within the organizations of the port community, with little understanding with other units [2] Knowledge is limited to IT departments and a few other units within the organizations of the port community. Port executives still lack knowledge. [3] Most of the departments and organizational levels, including executives, have a proper understanding of the implications of port digitalization [4] All levels within the organizations of the port community understand the benefits, risks, challenges of port digitalization, and can propose business cases which fit their context
	[HC2] Training program on port digitalization	[1] There are currently no training programs on port digitalization within the port community; [2] There are plans to develop one or several training program on port digitalization for the port community; [3] One or more training program for the port community are currently being developed'; [4] There are currently one or several digitalization training program within the port community involving different staff members and executive personnel
Technological ecosystem	[T1] Data standardization	[1] Data bases and structures are non-defined or standardized [2] Data bases and structures are siloed within organizations [3] Data bases and structures are defined and standardized for some organizations of the port community [4] Data bases and structures are defined at port community level, allowing for full system interoperability
	[T2] Office & Business Management systems	[1] Non-existent usage in the port community [2] Siloed usage of systems, limited to a few organizations [3] Usage among several port organizations [4] Widespread usage among the port organizations
	[T3] Operations Management - PMS	[1] System(s) not used and not planned [2] System(s) not used but planned to be developed [3] System(s) currently being developed [4] Widespread usage by the Port Company (or updated to next generation system, if applicable)
	[T4] Operations Management – TOS/ECS	[1] System(s) not used and not planned [2] System(s) not used but planned to be developed [3] System(s) currently being developed [4] Comprehensive use of up-to-date system(s) in terminals (or updated to next generation system, if applicable)
	[T5] Trade management – PCS/SW	[1] System(s) not used and not planned [2] System(s) not used but planned to be developed [3] System(s) currently being developed [4] Widespread use of system among port organizations (or updated to next generation system, if applicable)
	[T6] Environmental Management – Air quality control	[1] System not used and not planned [2] System not used but planned to be developed [3] System currently being developed [4] Widespread use of system by Port Company (or updated to next generation system, if applicable)
	[T7] Environmental Management – water quality monitoring	[1] System not used and not planned [2] System not used but planned to be developed [3] System currently being developed [4] Widespread usage by Port Company (or updated to next generation system, if applicable)
	[T8] Environmental Management – Noise monitoring	[1] System not used and not planned [2] System not used but planned to be developed [3] System currently being developed [4] Widespread usage by Port Company (or updated to next generation system, if applicable)
	[T9] Energy Management – Energy consumption monitoring	[1] System not used and not planned [2] System not used but planned to be developed [3] System currently being developed [4] Widespread usage by Port Company (or updated to next generation system, if applicable)
	[T10] Safety & Security – Early detection of extreme weather	[1] System not used and not planned [2] System not used but planned to be developed [3] System currently being developed [4] Widespread usage by Port Company (or updated to next generation system, if applicable)
	[T11] Safety & security - Cyber risk management	[1] No existence of a cyber risk management strategy [2] No existence of a cyber risk management strategy but planned [3] No existence of a cyber risk management strategy but planned and being developed [4] Existence of a cyber risk management strategy and plan at the Port Company
	[T12] Safety & security – Surveillance and safety control	[1] No existence of a surveillance and/or safety control system [2] No existence of a surveillance and/or safety control system but planned [3] No existence of a surveillance and/or safety control system but planned and being developed [4] Existence of a surveillance and/or safety control system at the Port Company

Appendix D – Stakeholder Consultation

D.1 Online Questionnaire

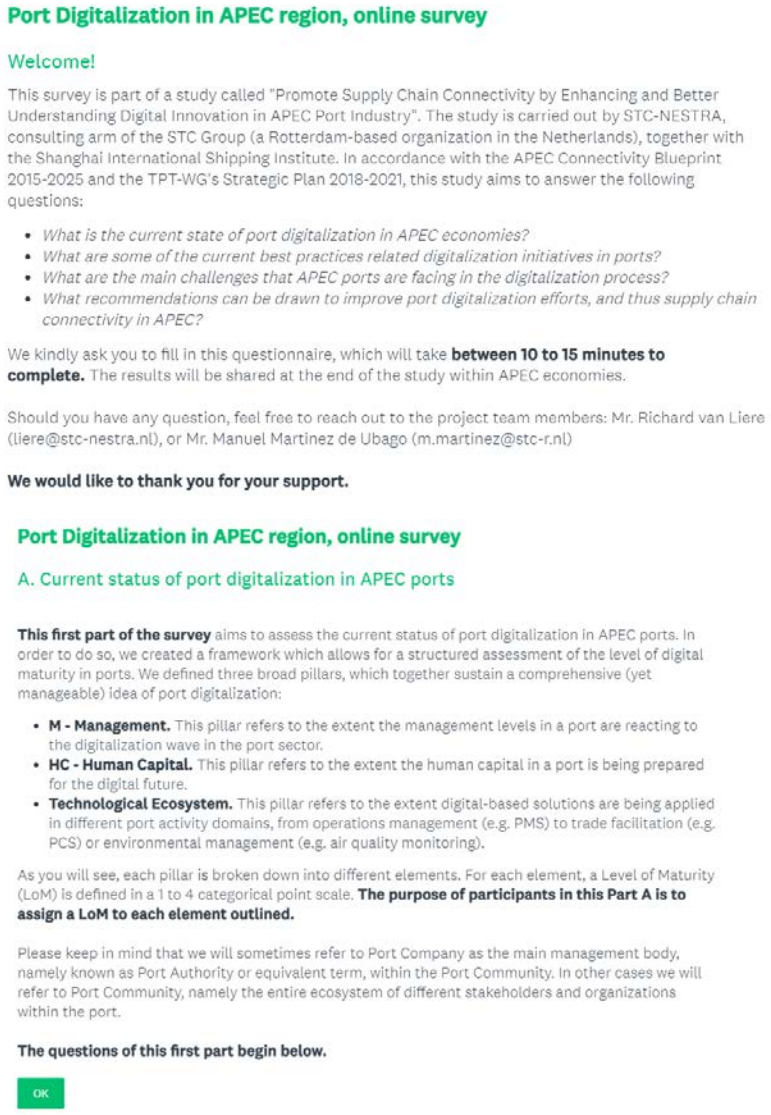
With ports located geographically apart, a user-friendly software tool was used for the distribution of the online survey[42]. Considering the risk of fatigue, and therefore of low response rate, the questionnaire was designed in such a way that it could be completed within no more than 15 minutes. In this sense, the questionnaire combined a set of closed-ended and open-ended questions, and was divided into three main parts:

A. Status of port digitalization in APEC ports

B. Digitalization initiatives

C. Bottlenecks hindering the implementation of digital initiatives, and recommendations

The interface of the online survey is outlined below:



Port Digitalization in APEC region, online survey

Welcome!

This survey is part of a study called "Promote Supply Chain Connectivity by Enhancing and Better Understanding Digital Innovation in APEC Port Industry". The study is carried out by STC-NESTRA, consulting arm of the STC Group (a Rotterdam-based organization in the Netherlands), together with the Shanghai International Shipping Institute. In accordance with the APEC Connectivity Blueprint 2015-2025 and the TPT-WG's Strategic Plan 2018-2021, this study aims to answer the following questions:

- *What is the current state of port digitalization in APEC economies?*
- *What are some of the current best practices related digitalization initiatives in ports?*
- *What are the main challenges that APEC ports are facing in the digitalization process?*
- *What recommendations can be drawn to improve port digitalization efforts, and thus supply chain connectivity in APEC?*

We kindly ask you to fill in this questionnaire, which will take **between 10 to 15 minutes to complete.** The results will be shared at the end of the study within APEC economies.

Should you have any question, feel free to reach out to the project team members: Mr. Richard van Liere (liere@stc-nestra.nl), or Mr. Manuel Martinez de Ubago (m.martinez@stc-r.nl)

We would like to thank you for your support.

Port Digitalization in APEC region, online survey

A. Current status of port digitalization in APEC ports

This first part of the survey aims to assess the current status of port digitalization in APEC ports. In order to do so, we created a framework which allows for a structured assessment of the level of digital maturity in ports. We defined three broad pillars, which together sustain a comprehensive (yet manageable) idea of port digitalization:

- **M - Management.** This pillar refers to the extent the management levels in a port are reacting to the digitalization wave in the port sector.
- **HC - Human Capital.** This pillar refers to the extent the human capital in a port is being prepared for the digital future.
- **Technological Ecosystem.** This pillar refers to the extent digital-based solutions are being applied in different port activity domains, from operations management (e.g. PMS) to trade facilitation (e.g. PCS) or environmental management (e.g. air quality monitoring).

As you will see, each pillar is broken down into different elements. For each element, a Level of Maturity (LoM) is defined in a 1 to 4 categorical point scale. **The purpose of participants in this Part A is to assign a LoM to each element outlined.**

Please keep in mind that we will sometimes refer to Port Company as the main management body, namely known as Port Authority or equivalent term, within the Port Community. In other cases we will refer to Port Community, namely the entire ecosystem of different stakeholders and organizations within the port.

The questions of this first part begin below.

OK

[42] SurveyMonkey© was chosen as online tool for ports, excluding ports from People's Republic of China.

Promote Supply Chain Connectivity by Enhancing and Better Understanding Digital Innovation in APEC Port Industry

Port Digitalization in APEC region, online survey

A. Current Status of Port Digitalization in APEC - Management

M - Management

This pillar refers to the extent the management levels in a port are reacting to the digitalization wave in the port sector. Three elements are considered:

- **M1 - Digital Strategy in the port community.**
- **M2 - Innovation ecosystem in the port community.**
- **M3 - Investment in digitalization in the port community.**

An explanation of each element is provided for each question.

M1 - Digital Strategy in the port community. This element relates to the extend in which a published digital strategy exists within your port community (that is, including the different stakeholders within the port). The four Levels of Maturity (LoM) are the following:

- **LoM 1** - There is no digitalization strategy within the Port Community
- **LoM 2** - There is a plan to develop a digitalization strategy within the Port Community
- **LoM 3** - There is a digitalization strategy being developed at the Port Community
- **LoM 4** - There is a (published) digitalization strategy roadmap whose guidelines are being followed by the Port Community

* 1. **Please indicate below the LoM**, based on the current situation in your port and on the abovementioned explanation, by ticking on the proper box:

	LoM 1	LoM 2	LoM 3	LoM 4
M1 Digital strategy in the port community	○	○	○	○

M2 - Innovation ecosystem. This element relates to the extend in which stakeholders collaborate within the port community to come up with (digital) innovative solutions to add value to their activities. The four Levels of Maturity (LoM) are the following:

- **LoM 1** - Innovation is almost non-existent.
- **LoM 2** - Innovation is limited to a few siloed organizations in the port community.
- **LoM 3** - There are small innovation clusters within the port community (e.g. innovation initiatives between two or more organizations).
- **LoM 4** - Innovation is widespread in the port community, with large presence or entrepreneurial initiatives (e.g. innovation labs, start-ups accelerators, ...).

* 2. **Please indicate below the LoM**, based on the current situation in your port and on the abovementioned explanation, by ticking on the proper box:

	LoM 1	LoM 2	LoM 3	LoM 4
M2 Innovation ecosystem in the port community	○	○	○	○

M3 - Investment in digitalization. This element refers to the (approximate) share of digital investment, in the port community, compared to total investment in the port community, on a yearly basis. The four Levels of Maturity (LoM) are the following:

- **LoM 1** - Digital investment represents **less than 5%** of total investment in the port community.
- **LoM 2** - Digital investment represents **between 5% and 10%** of total investment in the port community.
- **LoM 3** - Digital investment represents **between 10% and 20%** of total investment in the port community.
- **LoM 4** - Digital investment represents **more than 20%** of total investment in the port community.

* 3.
Please indicate below the LoM, based on the current situation in your port and on the abovementioned explanation, by ticking on the proper box:

	LoM 1	LoM 2	LoM 3	LoM 4
M3 Investment in digitalization in the port community	○	○	○	○

Port Digitalization in APEC region, online survey

A. Current Status of Port Digitalization in APEC - Human Capital

HC - Human Capital

This pillar refers to the extent the Human Capital in a port is prepared for the digital future. Two elements are considered

- **HC1 - IT Business knowledge and skills**
- **HC2 - Training programs on port digitalization**

HC1 - IT business knowledge and skills. This element refers to the extent to which there is IT-based knowledge in the port community, and how it translates to business cases which fit the unique context of the port. The four Levels of Maturity (LoM) are the following:

- **LoM 1** - Knowledge limited to a few (IT) departments within the organizations of the port community, with little understanding with other units or departments.
- **LoM 2** - Knowledge is limited to IT departments and a few other units within the organizations of the port community. Port executives still lack knowledge.
- **LoM 3** - Most of the departments and organizational levels, including executives, have a proper understanding of the implications of port digitalization.
- **LoM 4** - All levels within the organizations of the port community understand the benefits, risks, challenges of port digitalization, and can propose business cases which fit their context.

* 4. **Please indicate below the LoM**, based on the current situation in your port and on the abovementioned explanation, by ticking on the proper box:

	LoM 1	LoM 2	LoM 3	LoM 4
HC1 IT business knowledge and skills	○	○	○	○

HC2 - Training programs on port digitalization. This element refers to the extent to which educational programs on digitalization are followed within the port community. The four Levels of Maturity (LoM) are the following:

- **LoM 1** - There are currently no training programs on port digitalization within the port community.
- **LoM 2** - There are plans to develop one or several training program on port digitalization for the port community.
- **LoM 3** - One or more training programs for the port community are currently being developed.
- **LoM 4** - There are currently one or several digitalization training program within the port community involving different staff members and executive personnel.

* 5.
Please indicate below the LoM, based on the current situation in your port and on the abovementioned explanation, by ticking on the proper box:

	LoM 1	LoM 2	LoM 3	LoM 4
HC2 Training programs on port digitalization	○	○	○	○

Promote Supply Chain Connectivity by Enhancing and Better Understanding Digital Innovation in APEC Port Industry

Port Digitalization in APEC region, online survey

A. Current Status of Port Digitalization in APEC - Technological ecosystem

T - Technological ecosystem

This pillar refers to the extent a digital-based ecosysterm is being applied in the port. Twelve elements are considered here:

- **T1 - Data standardization**
- **T2 - Office & Bussines Management**
- **T3 - Operations Management - PMS.**
- **T4 - Operations Management - TOS.**
- **T5 - Trade Facilitation - PCS/SW.**
- **T6 - Environmental Management - Air quality.**
- **T7 - Environmental Management - Water quality.**
- **T8 - Environmental Management - Noise.**
- **T9 - Energy Management.**
- **T10 - Safety & Security - Early detection of extreme natural events.**
- **T11 - Safety & Security - Cyber Risk Management.**
- **T12 - Safety & Security - Surveillance and safety control.**

T1 Data standardization. This element refers to the extent rules and data standards are defined to allow for system interoperability. The four Levels of Maturity (LoM) are the following:

- **LoM 1** - Data bases and structures are defined and standardized within a few individual siloed organizations, still little to no interoperability.
- **LoM 2** - Data bases and structures are defined and standardized within some organizations of the port community, allowing for some interoperability.
- **LoM 3** - Data bases and structures are defined at port community level, allowing for full system interoperability.
- **LoM 4** - Data bases and structures are defined beyond port community level, allowing for full system interoperability between ports.

* 6. **Please indicate below the LoM,** based on the current situation in your port and on the abovementioned explanation, by ticking on the proper box:

	LoM 1	LoM 2	LoM 3	LoM 4
T1 Data standardization	○	○	○	○

T2 Office & Business Management systems. This element refers to the extent office management systems, such as Enterprise Resource Planning (ERP) or equivalent, are being used among port organizations of the port community. The four Levels of Maturity (LoM) are the following:

- **LoM 1** - Usage of system(s) in the port community is non existent.
- **LoM 2** - Usage of system(s) in the port community are siloed and limited to a few organizations.
- **LoM 3** - Usage of system(s) in the port community is spread to several organizations.
- **LoM 4** - Usage of system(s) in the port community is widespread across all organizations.

* 7. **Please indicate below the LoM**, based on the current situation in your port and on the abovementioned explanation, by ticking on the proper box:

	LoM 1	LoM 2	LoM 3	LoM 4
T2 Office & Business Management systems	○	○	○	○

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The remaining elements (from **T3** to **T12**), refer to common digital-based solutions applied in different port activity domains, from operations management (e.g. PMS) to trade facilitation (e.g. PCS) or environmental management (e.g. air quality monitoring). Therefore, the same LoMs are considered for all of them:

- **LoM 1 -** System(s) non existent and not planned to develop.
- **LoM 2 -** Up-to-date system(s) non existent but planned to develop (greenfield or brownfield).
- **LoM 3 -** Up-to-date system(s) non existent but in development phase (greenfield or brownfield).
- **LoM 4 -** Use of up-to-date system(s) is widespread across corresponding port companies.

* 8. **Please indicate below the LoMs**, based on the current situation in your port and on the abovementioned explanation for each element, by ticking on the proper boxes:

	LoM 1	LoM 2	LoM 3	LoM 4
T3 Operations Management (PMS)	○	○	○	○
T4 Operations Management (TOS)	○	○	○	○
T5 Trade Facilitation (PCS/SW)	○	○	○	○
T6 Environmental Management (Air quality)	○	○	○	○
T7 Environmental Management (Water quality)	○	○	○	○

* 9. **Please indicate below the LoMs**, based on the current situation in your port and on the abovementioned explanation for each element, by

	LoM 1	LoM 2	LoM 3	LoM 4
T8 Environmental Management (Noise)	○	○	○	○
T9 Energy Management	○	○	○	○
T10 Safety & Security (Early detection extreme weather events)	○	○	○	○
T11 Safety & Security (Cyber risk management)	○	○	○	○
T12 Safety & Security (Surveillance and safety control)	○	○	○	○

Port Digitalization in APEC region, online survey

B. Digital Initiatives

In the previous section you assessed where your port stands. **In this second part of the survey** you have the opportunity to tell us about any particular digitalization initiative from your port which could be worth sharing within the APEC Port industry.

10. Feel free to tell us about any particular digitalization initiative within your port. Perhaps something in a development phase that you may have thought of, while filling in the previous questions? If so, what makes such initiative so special?

Port Digitalization in APEC region, online survey

C. Bottlenecks hindering digitalization initiatives & recommendations

This last part of the survey is divided into two sections. First (C1), we aim to understand the issues that your port community has experienced while trying to develop or implement digitalization initiatives. To ease the responses, we want to divide the bottlenecks into different group domains (e.g. political, economic, legal, ...).

(C2) Second, we aim to gather a set of recommendations that could be useful for policy makers in the APEC region.

C1 - Bottlenecks. In a previous study, we gathered different bottlenecks hindering port digitalization in the APEC region. These were grouped into different domains, as displayed below:

Domain	Identified bottlenecks
Political	[1] High turnover of government representatives in the port sector, and therefore changing priorities [2] Lack of capacity by the government bodies, in need of external assistance [3] Lack of alignments at regional level between cooperation frameworks and assistance bodies, but also at national/provincial levels
Economic	[4] Budget restrictions by stakeholders, worsened by COVID-19 [5] Economic assessment not considered comprehensively from a sustainability perspective
Social & Cultural	[6] Lack of stakeholder management, which delays implementation [7] Skepticism by port stakeholders towards collaboration and digital transformation in general (organizational & cultural challenge).
Technical	[8] Quality and availability of data, lack of standards [9] Lack of ICT infrastructure, large digital divide within APEC economies [10] Cybersecurity [11] Lack of qualified workforce, ageing workforce [12] Integration of several different systems - interoperability
Legal	[13] Inadequate legal and regulatory basis to adopt digital transformation

* 11. **C1 - Bottlenecks.** Based on the previous, **please specify challenges** that your port community experienced (or is experiencing) while developing or implementing digitalization initiatives.

Political

Economic

Social

Technological

Environmental

Legal

OTHER

12. **C1 - Bottlenecks.** Do you think any of the bottlenecks that you have indicated should be given higher priority among the rest? If so, feel free to mention it below:

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C2 Recommendations. In a previous study, we gathered the following recommendations:

- Conduct a digital scan of ports in APEC (work in progress with this new study, as part of Section A of this survey)
- Promote a collaborative environment within and between organizations of port communities.
- Continuous commitment to education and capacity building in the port digitalization field within port communities.
- Promote and innovative and entrepreneurial ecosystem within port communities.

* 13. **C2 - Recommendations.** Is there **anything that you would recommend** to policy decision-makers within the APEC region to scale up the port digitalization efforts? It can either be about the previous mentioned recommendations, or about something else.

Port Digitalization in APEC region, online survey

Authorization

* 14. Please indicate whether you accept us contacting you in case of clarifying questions about your survey responses:

- [ ] Yes
- [ ] No

* 15. Please indicate whether you would like to be invited for a webinar/conference where the study results will be presented, along with presentations on best practices in port digitalization:

- [ ] Yes
- [ ] No

* 16. Please indicate whether you would like to receive a copy of the final study report (only possible if a valid email address is provided in the next question):

- [ ] Yes
- [ ] No

Lastly, we would like to ask you for your contact details. Your personal information will not be shared with anyone outside the research team and the APEC Secretariat. It will be collected by APEC's appointed research contractor, STC-NESTRA, who is bound by a confidentiality clause. No individual or organisation name or contact details will be identified in STC-NESTRA's report without prior consent nor will any information be displayed by which a respondent may be identifiable.

* 17. Please share the following:

E-mail address:	
Name of the organization you work for:	
APEC economy you belong to:	

18. **Anything else that you would like to share with us** with respect to port digitalization or the content of the survey?

Many thanks for your input! We will follow-up with the results of the study.

PREV DONE WITH THE SURVEY!

D.2 Validation Interviews

In parallel to the Online Survey, validation interviews were conducted with international experts in the field. The purpose was to (i) validate the PDS, so that the framework can be improved for future research; (ii) use the opportunity to expand the data collection with an outside view in terms of bottlenecks, best practices and recommendations to improve the digitalization efforts in ports. For these interviews, the following stakeholders were approached:

- 1 PhD student whose research is involved in a topic that has a significant overlap with the field of port digitalization
- 1 high-level digitalization manager in a global terminal operating company.
- 3 Mid-to-high level managers in the leading port authorities of Rotterdam, Algeciras and Valencia.

With respect to the validation of the PDS (i), they were given five open-ended questions about the accuracy, relevance and added value that the PDS can bring to ports in APE. A selection of their anonymous feedback is provided in Table 9. The remaining data (ii) is provided in Appendices F and G, together with the responses from the online survey.

Table 9. Validation of the PDS with key international experts in the field of port digitalization.

Q1. While understanding the uniqueness of each port, do you think the framework (PDS) above captures, to a certain extend, the idea behind port digitalization? Please explain.
• '"Yes, to a certain extent."
• "Yes but perhaps some elements should be made more explicit."
• "Yes, absolutely. The selected pillars and their associated elements fully cover all the points that have to be taken into account when addressing the digitization of a port. Checking them, I see a synergy with the aspects that we take into account in the port where I am currently working."
• "To a certain extent, but perhaps it focuses too much on the port authority/terminal level. There are other (public or private) stakeholders within the port community that should be considered as well. In the end, if we measure the maturity of a system by its *weakest link*, then those actors may be relevant."
Q2. Is there any pillar/element that you would add or remove? Please explain.
• "I would also include general 'digital' capabilities that ports need for digitalization, like (wireless) connectivity, sensory, geographical information system, cloud, etc. Most of the 'technological ecosystem' elements require facilitating technologies like above."
• "The following should be there more explicitly: o PROCESSES: to what extent has the organization focused on defining and undergoing a re-engineering of processes related to digitalization" o DATA: at what level have the different Databases that the organization possesses been examined, at what level are they structuring, standardizing and defining the ecosystem o CUSTOMER FOCUS: Perhaps implicit under the Innovation Pillar, but still important to remark the importance on the level under which the port is being customer oriented
• "No. As I mentioned in the previous question, these are all the points we addressed in my port. I cannot think of any better ones that could be added, nor, of course, would I remove any of them.
• "Technological Ecosystem is an extremely broad pillar. Perhaps it would be an idea to subdivide? It could be a suggestion to make a separate environmental/sustainability pillar, where you include the environmental elements, and have a separate pillar for Information Systems and Platforms."

- "In the Management Pillar, perhaps it could somehow be added that active participation of the mid-to-high management levels of the port (authority) in different organizations and Working Groups where knowledge in the topic is shared. For instance, in Europe, the Digital Transport & Logistics Forum brings together representatives from different Member States and stakeholders from the transport community. Other international examples could be the IAPH or IPCSA, which also have Working Groups.

  Moreover, in the Technological Ecosystem, I missed solutions like Automated Gate Systems (which are increasingly common), as well as infrastructure capabilities (e.g. 5G) that are needed for automated operations. Also, decision making tools could be considered (e.g. PortCDM, or Port Collaborative Decision Making)."

Q3. To a certain extent, are the Levels of Maturity clear enough? Please explain

- "Very clear and consistent throughout all the elements"
- "Yes, they are very clear. In addition, they cover the entire possible spectrum of levels for each element."
- Yes, but understanding they may need further discussion on a case to case basis.

Q4. Do you think a standardized (and potentially more complete) version of this Port Digital Scorecard could add value to ports in Asia & Pacific (e.g. to small and medium ports)? Please explain.

- "Yes, when more complete."
- "The idea is good, and I believe that proposing something like this will eventually become necessary. What value would it add? :It could allow to establish a point of reference with respect to the pillars in which ports that are lagging behind digitally should focus on, from a roadmap perspective. Also, this could serve as a starting point for Governments and other Institutions to know where and how to get started."
- "Yes, absolutely. Based on the proposed PDS, any APEC port can start, develop or test its digitization process. This will bring huge value to them, as they will be confident that they will be able to take the right steps towards a full digitalization status that will allow them to bring value to customers, as well as being able to collaborate with other ports in the region."
- "I think it can be interesting for benchmarking purposes, of course provided there is a sufficiently large sample of ports."

Q5. Anything else that you would like to comment about the framework shown above?

- "The Digitalization Playbook of MPA Singapore could be a good reference."
- "Nothing additional. Just congratulate you for the complete framework you have defined."

Appendix E – Results Stakeholder Consultations: PDS

This Appendix reports on the preliminary results of the PDS of the ports which participated in the online survey, adding up to a total of 26 ports belonging to 10 APEC economies (Canada; Chile; Hong Kong, China; Indonesia; Peru; Philippines; People's Republic of China; Republic of Korea; Singapore; and Viet Nam). The results are shared in the following tables.

Port of Vancouver (Canada)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[2]
M2 - Innovation ecosystem	[2]
M3 - Investment in digitalization	[1]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[2]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[3]
T7 - Environmental Management – water quality monitoring	[3]
T8 - Environmental Management – Noise monitoring	[3]
T9 - Energy Management – Energy consumption monitoring	[3]
T10 - Safety & Security – Early detection of extreme weather	[2]
T11 - Safety & security - Cyber risk management	[3]
T12 - Safety & security – Surveillance and safety control	[2]

Port of San Antonio (Chile)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[3]
M2 - Innovation ecosystem	[2]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[3]
HC2 - Training program on port digitalization	[3]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[4]
T4 - Operations Management – TOS/ECS	[4]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[4]
T7 - Environmental Management – water quality monitoring	[4]
T8 - Environmental Management – Noise monitoring	[4]
T9 - Energy Management – Energy consumption monitoring	[4]
T10 - Safety & Security – Early detection of extreme weather	[4]
T11 - Safety & security - Cyber risk management	[4]
T12 - Safety & security – Surveillance and safety control	[4]

Port of Hong Kong (Hong Kong, China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[3]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[3]
Human Capital	
HC1 - IT business -related knowledge and skills	[3]
HC2 - Training program on port digitalization	[4]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[4]
T4 - Operations Management – TOS/ECS	[4]
T5 - Trade management – PCS/SW	[3]
T6 - Environmental Management – Air quality control	[4]
T7 - Environmental Management – water quality monitoring	[4]
T8 - Environmental Management – Noise monitoring	[4]
T9 - Energy Management – Energy consumption monitoring	[4]
T10 - Safety & Security – Early detection of extreme weather	[4]
T11 - Safety & security - Cyber risk management	[4]
T12 - Safety & security – Surveillance and safety control	[4]

Pelindo (Indonesia)[43]

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[2]
M2 - Innovation ecosystem	[2]
M3 - Investment in digitalization	[1]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[1]
Technological Ecosystem	
T1 - Data standardization	[1]
T2 - Office & Business Management systems	[2]
T3 - Operations Management - PMS	[2]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[1]
T7 - Environmental Management – water quality monitoring	[1]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[1]
T10 - Safety & Security – Early detection of extreme weather	[1]
T11 - Safety & security - Cyber risk management	[1]
T12 - Safety & security – Surveillance and safety control	[2]

[43] Indonesian ports have for many years been managed by four state-owned enterprises geographically divided. These are These are PT Pelabuhan Indonesia I (Persero) or Pelindo I; PT Pelabuhan Indonesia II (Persero) or Pelindo II; PT Pelabuhan Indonesia III (Persero) or Pelindo III; and PT Pelabuhan Indonesia IV (Persero) or Pelindo IV. The participant filled in the questionnaire on behalf of Pelindo, the organization resulting from the merge of the above stated four enterprises, effective since October 1st of 2021. While this new management body, headquartered in Jakarta, is responsible for many ports around the archipelagic economy, it still gives an orientation of the state of digital maturity of Indonesian ports.

Port of el Callao (Peru)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[2]
M3 - Investment in digitalization	[1]
Human Capital	
HC1 - IT business -related knowledge and skills	[3]
HC2 - Training program on port digitalization	[1]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[4]
T3 - Operations Management - PMS	[2]
T4 - Operations Management – TOS/ECS	[4]
T5 - Trade management – PCS/SW	[4]
T6 - Environmental Management – Air quality control	[1]
T7 - Environmental Management – water quality monitoring	[1]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[4]

Port of Cagayan de Oro, PMO Misamis Oriental (Philippines)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[2]
M2 - Innovation ecosystem	[2]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[1]
Technological Ecosystem	
T1 - Data standardization	[1]
T2 - Office & Business Management systems	[2]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[1]
T10 - Safety & Security – Early detection of extreme weather	[2]
T11 - Safety & security - Cyber risk management	[1]
T12 - Safety & security – Surveillance and safety control	[2]

Port of Shanghai (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[3]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[3]
T2 - Office & Business Management systems	[4]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[4]
T5 - Trade management – PCS/SW	[3]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[2]
T9 - Energy Management – Energy consumption monitoring	[3]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Ningbo-zhoushan, ZHEJIANG (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[3]
M2 - Innovation ecosystem	[4]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[3]
HC2 - Training program on port digitalization	[3]
Technological Ecosystem	
T1 - Data standardization	[3]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[4]
T5 - Trade management – PCS/SW	[3]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[1]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Shenzhen, GUANGDONG (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[4]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[3]
T2 - Office & Business Management systems	[4]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[4]
T5 - Trade management – PCS/SW	[3]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[1]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[3]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Guangzhou, GUANGDONG (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[2]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[1]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[4]
T3 - Operations Management - PMS	[4]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[1]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Qingdao, SHANDONG (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[4]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[3]
HC2 - Training program on port digitalization	[3]
Technological Ecosystem	
T1 - Data standardization	[3]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[2]
T4 - Operations Management – TOS/ECS	[4]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[1]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Tianjin (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[3]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[3]
HC2 - Training program on port digitalization	[1]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[4]
T3 - Operations Management - PMS	[1]
T4 - Operations Management – TOS/ECS	[2]
T5 - Trade management – PCS/SW	[1]
T6 - Environmental Management – Air quality control	[4]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[4]
T10 - Safety & Security – Early detection of extreme weather	[4]
T11 - Safety & security - Cyber risk management	[4]
T12 - Safety & security – Surveillance and safety control	[4]

Port of Xiamen, FUJIAN (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[3]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[3]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[2]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[2]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[2]

Port of Suzhou, JIANGSU (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[3]
M2 - Innovation ecosystem	[2]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[3]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[3]
T6 - Environmental Management – Air quality control	[3]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[3]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Yingkou, LIAONING (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[3]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[3]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[2]
T9 - Energy Management – Energy consumption monitoring	[3]
T10 - Safety & Security – Early detection of extreme weather	[2]
T11 - Safety & security - Cyber risk management	[4]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Dalian, LIAONING (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[4]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[4]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[1]
T7 - Environmental Management – water quality monitoring	[1]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[3]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[3]
T12 - Safety & security – Surveillance and safety control	[4]

Port of Beibuwan, GUANGXI (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[3]
M2 - Innovation ecosystem	[4]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[3]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[2]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[1]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[3]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[1]
T11 - Safety & security - Cyber risk management	[3]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Rizhao, SHANDONG (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[2]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[1]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[1]
Technological Ecosystem	
T1 - Data standardization	[3]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[2]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[2]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[2]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[2]

Port of Lianyungang, JIANGSU (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[2]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[1]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[1]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[3]
T10 - Safety & Security – Early detection of extreme weather	[2]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Dongguan, GUANGDONG (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[2]
M2 - Innovation ecosystem	[2]
M3 - Investment in digitalization	[1]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[2]
T3 - Operations Management - PMS	[2]
T4 - Operations Management – TOS/ECS	[2]
T5 - Trade management – PCS/SW	[2]
T6 - Environmental Management – Air quality control	[2]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[2]
T9 - Energy Management – Energy consumption monitoring	[2]
T10 - Safety & Security – Early detection of extreme weather	[2]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[2]

Port of Yantai, SHANDONG (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[1]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[1]
Technological Ecosystem	
T1 - Data standardization	[1]
T2 - Office & Business Management systems	[4]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[1]
T6 - Environmental Management – Air quality control	[1]
T7 - Environmental Management – water quality monitoring	[1]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[1]
T10 - Safety & Security – Early detection of extreme weather	[1]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Qinghuangdao, HEBEI (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[3]
T6 - Environmental Management – Air quality control	[3]
T7 - Environmental Management – water quality monitoring	[2]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[3]
T10 - Safety & Security – Early detection of extreme weather	[2]
T11 - Safety & security - Cyber risk management	[3]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Nanjing, JIANGSU (People's Republic of China)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[2]
Human Capital	
HC1 - IT business -related knowledge and skills	[2]
HC2 - Training program on port digitalization	[1]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[2]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[3]
T5 - Trade management – PCS/SW	[3]
T6 - Environmental Management – Air quality control	[3]
T7 - Environmental Management – water quality monitoring	[3]
T8 - Environmental Management – Noise monitoring	[3]
T9 - Energy Management – Energy consumption monitoring	[3]
T10 - Safety & Security – Early detection of extreme weather	[2]
T11 - Safety & security - Cyber risk management	[3]
T12 - Safety & security – Surveillance and safety control	[3]

Port of Busan (Korea)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[3]
Human Capital	
HC1 - IT business -related knowledge and skills	[3]
HC2 - Training program on port digitalization	[3]
Technological Ecosystem	
T1 - Data standardization	[4]
T2 - Office & Business Management systems	[4]
T3 - Operations Management - PMS	[4]
T4 - Operations Management – TOS/ECS	[4]
T5 - Trade management – PCS/SW	[4]
T6 - Environmental Management – Air quality control	[3]
T7 - Environmental Management – water quality monitoring	[3]
T8 - Environmental Management – Noise monitoring	[3]
T9 - Energy Management – Energy consumption monitoring	[3]
T10 - Safety & Security – Early detection of extreme weather	[4]
T11 - Safety & security - Cyber risk management	[4]
T12 - Safety & security – Surveillance and safety control	[4]

Port of Singapore (SGP)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[4]
M2 - Innovation ecosystem	[4]
M3 - Investment in digitalization	[3]
Human Capital	
HC1 - IT business -related knowledge and skills	[4]
HC2 - Training program on port digitalization	[3]
Technological Ecosystem	
T1 - Data standardization	[2]
T2 - Office & Business Management systems	[3]
T3 - Operations Management - PMS	[3]
T4 - Operations Management – TOS/ECS	[4]
T5 - Trade management – PCS/SW	[4]
T6 - Environmental Management – Air quality control	[4]
T7 - Environmental Management – water quality monitoring	[3]
T8 - Environmental Management – Noise monitoring	[3]
T9 - Energy Management – Energy consumption monitoring	[3]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[3]
T12 - Safety & security – Surveillance and safety control	[3]

Tan Cang – Cai Mep International Terminal (VN)

Pilar / Element	Result [1-4]
Management	
M1 - Digital strategy	[1]
M2 - Innovation ecosystem	[3]
M3 - Investment in digitalization	[1]
Human Capital	
HC1 - IT business -related knowledge and skills	[1]
HC2 - Training program on port digitalization	[2]
Technological Ecosystem	
T1 - Data standardization	[1]
T2 - Office & Business Management systems	[2]
T3 - Operations Management - PMS	[2]
T4 - Operations Management – TOS/ECS	[2]
T5 - Trade management – PCS/SW	[1]
T6 - Environmental Management – Air quality control	[1]
T7 - Environmental Management – water quality monitoring	[1]
T8 - Environmental Management – Noise monitoring	[1]
T9 - Energy Management – Energy consumption monitoring	[1]
T10 - Safety & Security – Early detection of extreme weather	[3]
T11 - Safety & security - Cyber risk management	[2]
T12 - Safety & security – Surveillance and safety control	[2]

Appendix F – Results Stakeholder consultation: Bottlenecks

Bulk of valid responses below based on the validation interviews and the online survey. Since some of them came in other languages (e.g. Spanish or Chinese) they have been translated to English. Moreover, repeated responses have been clustered into one:

Bottlenecks

- "Political cycles of 4 years can result in high rotation of government representatives and authorities, thus leading to often changing priorities"
- "The planned infrastructure expansion of our port will eat most of the budget resources"
- "Inadequate stakeholder management makes it difficult to implement digital initiatives"
- "Lack of standards negatively impacts interoperability of systems"
- "Regulatory frameworks can sometimes hinder the development of digital initiatives"
- "Budget restrictions by private stakeholders"
- "Lack of human resources within Port Authorities"
- "Skepticism by stakeholders towards collaboration and digital transformation in general (change management)"
- "Lack of urgency and/or scale of ports"
- "The business case for digitalization for smaller ports is more difficult to make than for bigger ports"
- "Bigger ports, bigger challenges, higher impact"
- "Lack of stakeholder management"
- "Quality and availability of data, lack of standards"
- "High turnover of government representatives in the port sector, and therefore changing priorities" [
- "Economic/financial assessment not considered comprehensively (only financial gains/losses, leaving out social or environmental elements)"
- "We struggle to integrate systems from different IT vendors"
- "Lack of alignments at regional level between cooperation frameworks and assistance bodies, but also at national/provincial levels, if applicable"
- "Lack of ICT infrastructure"
- "Cybersecurity"
- "Lack of study on the environmental impact of digitalization, lack of information on the balance between accelerating digital initiatives and environmental protection"
- "Inadequate legal and regulatory basis to adopt digital transformation"
- "Systems integration"
- "Capacity building at IT level and implementation"
- "Defining a proper legal framework"
- "Awareness at port community level"
- "Political intervention in prioritization of port development"
- "Lack of institutional framework and arrangement"
- "Need to have cooperation with customs for the relay cargo in the same cluster (terminals in same local customs), need to have an application to connect data between neighbor terminals to share available infrastructure."
- "Changing priorities"
- "Lack of standards"
- "Increase level of environmental requirements"
- "Lack of regulatory standards"
- "No template for IT technical support personnel at local level"
- "Comprehensive program for digitalization to integrate inter-agency processes is either still at early stage or needs push and budgetary support"
- "Lack of intention on innovation"

- “Scarce application scenes of digitalization”
- “Everyone has a smart port plan but nobody knows how to implement it”
- “Hard to achieve data sharing”
- “Economic cost and return”
- “Lack of the transformation standard for port digitalization”
- “Internet connectivity issues”

Appendix G – Results Stakeholder consultation: Recommendations

Bulk of responses below based on the validation interviews and the online survey. Since some of them came in other languages (e.g. Spanish or Chinese) they have been translated to English:

Recommendations

- "Looking beyond the need for collaboration between the different stakeholders, we think it is very relevant to promote the development of an innovative and entrepreneurial ecosystem within port communities"
- "Promote start-up initiatives where Port Authorities, gov agencies and private sector are involved (e.g. Ports 4.0 in Spain or PortXL in the Netherlands)"
- "Promote open innovation initiatives like Hackathons"
- "Work together, share insights, use standards, think global!"
- "It is very important that each and every member of the port community is involved in the technological development of the port. Therefore, I would especially highlight recommendations [R2], [R3], [R3]"
- "Strengthening cooperation with departments related to informatization and industrialization."
- "Various port cities may consider enhancing experience sharing regarding the adoption of digitalized systems and innovative technology in port operations."
- "Considering that the global pandemic has affected all economies within the APEC region, it is recommended that further study in terms of the economy capacities be prioritized as it may directly affect the digitalization initiatives of all industries including the port community."
- "Disseminate the importance of port digitalization"
- "Continuous commitment to education and capacity building in the port digitalization field within port communities"
- "This should be part of the APEC strategy and the port digitalization should focus on enhancing network capacity, supply chain resiliency and port competitiveness"
- "Decision makers should understand more and pay more interest to digitalization"
- "Promote standardization of policies"
- "Establish one-window facility for inter-agency transactions (e.g. ticketing, cargo processing, accreditation, etc.)"
- "Port Digitalization requires the join efforts of the government and enterprises. The government should promote the construction of interconnected information platforms and the construction of port networks, including the cooperation between ports, and the construction of a multimodal transport information network for important logistics nodes in the port and inland. construction of port digitalization is a process that combines management logics. On one hand, it requires government guidance and support and, on the other hand, it calls on the active participation of every enterprise."
- "The port community carry out the innovation career as an alliance, creates an innovative environment to promote digitalization tasks docking among the stakeholders in the port community, and opens up and connect the information islands among terminals, shipping companies, shipping agents, freight forwarders, shippers, customs, transportation service providers and other logistics participants. At the same time, the cooperation between different government departments is also particularly important for the port digitalization, such as customs, inspection and quarantine authorities, maritime and other administrations."
- "Port companies should put digitalization to the integrally strategic level of the group for comprehensive governance, publish strategic plans and implementation timetables for port digital transformation, sort out the development route, clarify the key tasks at each stage, and the bottlenecks faced in the process and produce solutions. At the same time, every port has its own background and goals, so the digitalization strategies should be formulated taking this in mind. Moreover, the three dimensions of port digital internal operation and maintenance, external platform services, and innovative product development should be effectively separated from traditional concept, and different legal entities should be established to promote related tasks."
- "Port digitalization requires mutual collaboration and cannot only rely on the strength of a single port stakeholder. Each stakeholder cooperates to formulate a coordination mechanism. In the course of business operations, the port authority should combine digital technology and coordination mechanisms based on the business objectives of each ones. All parties provide conveniences to each other so as to provide satisfactory services to customers as a whole."

Promote Supply Chain Connectivity by Enhancing and Better Understanding Digital Innovation in APEC Port Industry

- "We must train as many as quality comprehensive skilled talents as possible, and establish a talent introduction mechanism. Renovate the introduction mechanisms of these talent and training methodology from time to time, welcome more multi-skilled talents with a mastery of both IT and business. Put high-end shipping talents in the port talents recruiting list and provide these talents with preferential policy like housing, children's education, and even employment of their family members. At the same time, explore the exchange training mode in universities and also the collaborative cooperation between enterprises and universities."
- "Strengthen the continuous training of talents and effectively plan for their career promotion. On one hand, broaden the way of training such talents, carry out professional training projects on digitalization regularly. The ageing problem of the talents also will be carefully attended and a good age structure should be there. On the other hand, from corporative executives, mid-level cadres to grassroots employees, digital-related positions must be set to make relevant jobs full-time and to ensure that such talents have vertical development and smooth promotion channels within the company."
- "Encourage employees' reporting their own digital innovation ideas, thus inspire the vitality of the internal personnel. Help to present feasible and genius ideas to local government and industry-related innovation awards for supportive funding. Meanwhile, as a company, it should try its best to establish an innovation project incubation mechanism within the group to provide different development channels for people with innovative ideas, from internal innovation project application, research and development support, establishment of a company, until listing in the stock market. Awards such as the Key Technology Breakthrough Award for Digitalization of Port Enterprises, the Application Innovation Award, and the Technology Achievement Transformation Award have stimulated the Group's continuous innovation and construction in digital solutions. At the same time, staff forum activities can also be carried out, and innovative applications can be regularly selected for internal sharing and discussion."
- "Improve the port's digital infrastructure and build a *cloud-network-side-end* digital base. The port digitalization depends on a series of digital infrastructure, especially technologies such as IoT perception and muti-dimensional data fusion. Upgrade the cloud computing, 5G tech, Beidou positioning, Internet of Things, big data, edge computing and other digital bases in the port, enabling more and more port infrastructures to have automatic and fast data collection capabilities, realizing a complex information and IoT system, and strengthening intensified software and hardware infrastructure so as to further improve port operation efficiency and intelligent management and control capabilities."
- "Build creative port digitalization application scenarios. Lead to the automation and transformation upgrade of older-styled quays; combining with digital twin technology, establish real-time monitoring and operation simulation platforms for quays, anchorages, and waterways; combining with predictive models, simulate and optimize the operations of ships and vehicles in the port area in advance, and optimize the working efficiency of the port area. At the same time, the port community should optimize the port logistics service platforms and participate in the blockchain alliance cooperation to further enhance the system integration capabilities, data resource integration and application capabilities, data resource integration and application capabilities, and effectively raise the port logistics business intelligence level and operational efficiency. Optimize intelligent service application such as paperless customs clearance and cargo information tracking. By combining big data technology, the port's own data is mined, and external data sharing and interaction are strengthened to realize the implementation of richer port big data application scenarios."
- "Unify digital standards and establish a data security system. Accelerate the regulating of relevant standards for port business digitization, and regulate the use of data from multiple aspects such as basic codes, data exchange formats, and data specification standards. Accelerate to write down the hierarchical rules for the new shipping data security level, desensitization rules, cross-border exchange and commercial transaction related rules. Concern the data security protection in smart port application scenarios, and strengthen unified authentication and data transmission protection. Build a network security support platform that integrates situational awareness, risk early warning, emergency response and disposal, and joint command, strengthen threat risk early warning research and judgment, and establish a risk assessment system. Effectively promote the application of commercial cryptography and other technologies, actively promote trusted computing, and raise the active immunity level of the information system."

Note: [R2], [R3], [R4] refer to the concluding recommendations of a previous study, which was shown to participants in both the online survey as well as the validation interviews (See Appendix D).

Appendix H – Final Online Workshop

Asia-Pacific Economic Cooperation

PROMOTE SUPPLY CHAIN CONNECTIVITY BY ENHANCING AND BETTER UNDERSTANDING OF DIGITAL INNOVATION IN APEC PORT INDUSTRY

Workshop report

19:00 – 21.00, Singapore Time (GMT+8), 24 February 2022

No. of participant: 33

Promote Supply Chain Connectivity by Enhancing and Better Understanding Digital Innovation in APEC Port Industry

WORKSHOP AGENDA

24 February 2022	
19:00 – 19:05 (5 min)	Opening remarks and introduction by Chair of Workshop. Mr. Lu Cheng Project Overseer
19:05 – 19:35 (30 min)	Status of port digitalization in APEC economies, bottlenecks and recommendations. Mr. Richard van Liere & Mr. Manuel Martinez de Ubago Alvarez De Sotomayor Consultants, STC-NESTRA & NextPort.AI
19:35 – 19:45 (10 min)	Q&As & Interactive questions
19:45 – 20:05 (20 min)	Best practices: Port of Shanghai. Mr. Fang Huaijin Vice President, Shanghai International Port Co.
20:05 – 20:10 (5 min)	Q&As
20:10 – 20:25 (15 min)	International speaker on port digitalization: “You have to change to stay the same”. Mr. Hans Rook Chairman, IPCSA
20:25 – 20:30 (5 min)	Q&As
20:30 – 20:50 (20 min)	Best practices: Saigon Newport. Ms. Pham Thi Thuy Van Vice Marketing Director, Saigon Newport Corporation (SNP)
20:50 – 20.55 (5 min)	Q&As
20:55 – 21.00 (5 min)	Closing Remarks by Chair of Workshop Mr. Lu Cheng Project Overseer

Opening remarks and introduction by Chair

The Chair, Mr. Lu Cheng, Project Overseer, welcomed the participants to the workshop to promote supply chain connectivity by enhancing and better understanding of digital innovation in APEC port industry.

The Asia-Pacific Economic Cooperation region entails some of the largest and most dynamic economies in the world. Including economies like the United States, the People's Republic of China, Japan and others, the region accounts for about 48% of global trade. Various Working Groups within APEC target to sustain and enhance trade in the region and between the region and other parts of the world. One of them being the APEC TPT-WG, which promotes and enables a harmonized, liberalized, seamless, comprehensive, safe, sustainable, resilient, secure and reliable transport network in the Asia-Pacific region.

In the last few years TPT-WG re-acknowledged that digital innovation is transforming port industries, and given the fundamental role of ports as nodes in the global supply chain, port digitalization will have a profound impact on the global economy. And, as a result of COVID-19, the need for ports to sustain transport flow even became more clearer. Therefore, the Chair highlighted, it was decided to launch a study in order to understand the process, impact, and best practices of port digitalization in order to facilitate trade and economic development in APEC economies. The Chair outlined that the intermediary results of the study, carried out by STC-Nestra, are discussed during the workshop along with some best practices of digitalization in ports of the APEC economies, also with the objective to bring together policy makers, port authorities and other port organizations.

Status of port digitalization in APEC economies, bottlenecks and recommendations (Presentation STC-NESTRA, by Mr. Richard van Liere & Mr. Manuel Martinez de Ubago Alvarez De Sotomayor)

Summary of presentation

STC-NESTRA presented the draft results of the study for the APEC Transportation Working Group on port digitalization, with a focus on promotion of supply chain connectivity and better understanding of digital innovation in the APEC port industry. The study is conducted in cooperation with experts from the Shanghai International Shipping Institute (SISI).

The outline of the presentation mirrors the structure and sequencing of the study, starting with the objective of the study and ending with main challenges found and recommendations for potential future endeavors.

Today, ports are facing challenges in the context of a changing world, which comes down to questions on how they can remain competitive, be resilient, be respondent, be efficient and clean. On top, the COVID outbreak, has added to this complexity, exposing the resiliency and inefficiency issues of global supply chains of which ports are vital components. As a result, questions like: "What actions can we take as a port to become more sustainable, resilient and efficient in an increasing competitive environment?" can be common in the agendas of port authorities. The answer can be partly found in smarter use of assets with the help of Information and Communication Technologies (ICT), but their implementation has been scattered and they are at different development levels within and between economies worldwide. Against this background, and the target of APEC to enhance trade in the regional and between the region and other parts of the world, it is important to understand the process, impact, and best practices of port digitalization in order to facilitate trade and economic development in APEC economies.

Therefore, the APEC Transport Working Group launched a study with the objective to research:

- RQ1. What is the current state of digitalization in the port industry in APEC economies?
- RQ2. What are some of the current best practices related to digitalization initiatives in ports?
- RQ3. What are the main challenges that APEC ports are facing in the digitalization process?
- RQ4. What recommendations can be drawn to improve port digitalization efforts, and thus supply chain connectivity in APEC?

STC-NESTRA explained the outline of a Port Digital Scoring that has been used to answer the research questions and assess the digital maturity of ports in the APEC region. Information was collected through an online survey, to which 26 ports responded from 10 different APEC economies.

It was emphasized that several ports in the APEC region reported a high level of port digitalization maturity. Regardless of whether, survey respondents answered for the entire port community or just their own organizations, digitalization has moved high into the agenda of port managers. Investments in digitalization generally remain between 5%-10% of total investments, which is reasonable given the high capital-intensive nature of investments in ports. Investments in developing a port strategy, in office & business management services and (terminal) operation management systems have been prioritized in ports in the APEC region. Human capital development, Environmental or Energy management and Standardization of data, are lagging behind. Although these components are slowly starting to receive more attention.

Within presentation, special attention was given to bottlenecks observed in the answers of respondents to the survey, of which some are:

- Insufficient knowledge & insufficient personnel.
- High turnover of gov representatives, and therefore changing priorities.
- Investment costs are larger than expected cost savings (especially when unfamiliar with the topic).
- "Internet connectivity" may be an issue in some places.
- If you want digital solutions, you need data, but sometimes such data is provided in a siloed manner, unstructured or not labelled. Sometimes it is not even available.
- As we digitize, vulnerability against cyber-attacks may become more pervasive.
- "Everybody has a smart port plan, but nobody knows how to implement it".
- Digitalization may depend in some cases on competing or overlapping public administrations and government agencies.

A particular interest of the workshop was to validate recommendations, in response to the bottlenecks relating to the introduction of port digitalization based on literature review and the survey. The recommendations were introduced to be "timeline continuous", as port digitalization in general should not be seen as a one-time budgeted project. A constant buy-in from decision makers level is required.

Some of the recommendations discussed during the presentation were the following:

- Promote capacity building & educational programs in topics related to port digitalization within the port authority and port users and government agencies, including the realization of an innovative ecosystem (as incubator for port digitalization start-ups).
- Important to also incorporate systematic approaches that deals with transformation of goals, processes, and technologies of port organizations, for both port managers (internal level) and other port stakeholders (community level). Adopt strategies and introduce solutions based on a Mutual Gains Approach.
- Incorporate complementary defense mechanisms against potential cyber-attacks.

- Support APEC inter- and intra-regional coordination between governing bodies for smart, innovative, and sustainable port models and arrange/join cross-organizational working groups meetings (multilateral banks, UN agencies, etc.) to exchange knowledge, learnings and developments.
- Bridge the ICT infrastructure readiness gap within APEC and promote investments (direct or privatized models) in ICT infrastructure as backbone for enhanced levels.
- Strive for more “standardization” to ensure a common *language* of understanding for connectivity within the maritime industry and in the adoption of industry 4.0 technologies.

Discussion

The floor is opened to participants for questions or to provide feedback, both during of after workshop. A few statements are presented as input for discussion:

1. In general, ports in the APEC region consider port digitalization mostly as a technology gap.
2. Could ports in the APEC region benefit more from interorganizational collaboration in APEC and through adopting joint port digitalization strategies?
3. For most ports in the APEC region, the first step for adopting port digitalization tools is to run diagnostics scan of the port community, activities and (digitalization) processes.

A participant from Canada requests some further elaboration on the "Mutual Gains Approach". Further explanation is given by STC-NESTRA experts on stakeholder management in relation to defining and adopting digitalization strategies in ports. As port digitalization does not only affect the port authority or management company, but the entire port and hinterland processes, a pro-active participatory management approach is advised in order to develop port digitalization strategies. Such an approach can start with running a diagnostics assessment of stakeholders, operations and processes in the port. Based on the mapping of stakeholders, operations and processes, gaps and solutions can be identified and a plan based on mutual gains be implemented. Port digitalization is not about optimizing an individual tool for a specific bottleneck, but a holistic approach for the wider port community to optimize processes for more efficient (global) supply chains. A practical example is given of a planning tool to maximize the occupancy of berths with minimum delay. Such a solution only has added value of all supporting services are connected (e.g., for change of crew, customs clearance, bunkering services, etc.).

Best practices: Port of Shanghai - Global Blending Reaching Everywhere (Presentation by Shanghai International Port Group Co., by Mr. Fang Huaijin)

Summary of presentation

SIPG shortly introduces the magnitude and outreach of Shanghai Port. Ports in People’s Republic of China have developed rapidly over the last two decades, and the current size of operations in the Port of Shanghai is exemplary: Shanghai has been dominating the global charts in container throughput for 12 consecutive years.

To maintain a leading international port, SIPG explains that the construction of smart ports has become inevitable. Due to spatial constraints and available resources, there is a demand for more efficient port operations in order to remain competitive on a global scale.

The main content for Smart Port development in Shanghai is built around four pillars: automatic terminal operation; maritime logistics synergy; intelligent scheduling; and facilitation of financial popularization. Developments are facilitated through independent R&D programs. Some practical examples are presented illustrating the remote control of vessels and terminal equipment, accelerated upgrading of terminal operating systems for high levels of autonomy, realtime planning of vessel arrivals and departures, multimodal port hinterland planning through connection of terminal operating systems with inland ports, and cost-efficient multimodal

planning for port-hinterland transport.

In terms of (short-term) outlook, SIPG has a number of priority focus areas, such as: enhancing towards a world class shipping port (in line with domestic policy); continue efforts to enroll autonomous technologies; and further endeavors towards implementation of zero-emission technology.

Discussion

An expert from Viet Nam asks about the transition of existing technologies to smart technologies and related investments. SIPG explains that currently the emphasize is on replacing existing, manual controlled equipment, to remote-controlled or automated equipment is one of their major capital expenditures momentarily.

STC-NESTRA asks how SIPG deals with the knowledge gap in terms of operating "traditional" equipment in comparison to more automated equipment. SIPG has dedicated training programs, but, for some port workers, dealing with newer technology is challenging and they struggle with upskilling according to new life-long learning principles. For example, existing staff needs to be upskilled for remote operations, which is quite challenging.

International Speaker on port digitalization - Stakeholder management in a fast changing world: 'I have to change to stay the same' (Presentation by International Port Community System Association, by Chairman Mr. Hans Rooks)

Summary of presentation

The IPCSA covers the interest of 50 members around the world, ranging from Port Community System operators, Single Window operators, port authorities (seaports and airports). In the presentation, the Chairman of IPCSA, highlighted the importance of stakeholder management in a fast changing world, and the need to "change to stay the same" referring to the continuous process of adopting to new technologies. Standing still is equivalent to going backwards, adoption of new technology in general, and in port environments more specifically, is needed given (COVID-19-related) market dynamics, facilitated by moving from bilateral exchange (cooperation) to more collaborative exchange of port data between stakeholders.

IPCSA advocates advise and support with the introduction port community systems (PCS) for (air)ports. It is important to understand that a PCS is not an IT system, but a change management system, a neutral and open electronic platform for intelligent and secure exchange of information between public and private stakeholders with the aim to optimise, manage and automate port and logistics processes according to a "sharing data only once" principle.

To move away from bilateral exchange of information and digital or electronical ways of communication takes trust, which is the key element of Change Management. As COVID-19 has shown, trust within the port community is needed in order to keep global supply chains open to facilitate trade. Due to COVID-19, new methods to keep supply chains open have been found through digitalization initiatives (with support from Governments and administrations) and have been accepted. PCS has become a necessity for ports, rather than a potential investment for the (near) future, but implementation takes time and change. It requires close involvement of port stakeholders, taking them step by step to illustrate impacts of digitalization by listening to their needs (requires about 70% of the effort), as the stakeholders are the experts in operations and processes. Various methodologies can be followed to facilitate change (Kotter's model or Bridges' Transition Model), moving forward with digitalization as the same person or with the same (port) company.

Discussion

An expert from Canada refers to the mentioning of just-in-time operations, with the question whether the way of working will be continued, or will there be a rebound from that to "just in case" -- i.e., redundancy to strengthen resilience? The answer to this question is not so straight forward. As COVID-19, and also the blocking of the Suez Canal, have shown the vulnerability in global supply chains. Just-in-time and just-in-case are likely to co-exist, with just-in-case supply chains built up for critical supply chains. As an alternative to just-in-case, economies may also decide to invest in near-shoring of critical industries.

A port digitalization expert from Spain mentions electronic data interchange (EDI) is still the most commonly used system-to-system standard used in ports and logistics data exchange. The question is raised whether APIs will become the new standard in the short term, as this would allow for more real-time communication channels between stakeholders. The Chairman of IPCSA acknowledges the benefits of using APIs in view of big data transfers and compatibility for application of new technologies (e.g., blockchain for realtime visibility of data in supply chains). At the same time data security of using APIs is perhaps a bit more challenging (compared to EDI systems, which are known for their robust security and privacy), and it is also costly to replace EDI with API technology. For now, EDI is likely to be the primary system for data transmission, but that may change in the next decade or so.

An expert from Canada questions whether PCS have a role to play in achieving greater contract certainty in marine shipping. Absolutely, PCS have facilitated digital administration and financing processes in a transparent manner. And, for example, subsequent phases of PCS, involving real-time information exchange in logistics supply chain, further contributes to more resilient and secure supply chains, and therefore to greater contract certainty.

Best practices: Saigon Newport - Initial success and challenges in port digitalization in Tan Cang Saigon (Presentation by Ms. Pham Thi Thuy Van, Vice Marketing Director)

Summary of presentation

Saigon New Port (SNP) presents the highlights of the port digital transformation process. SNP is the largest container terminal operator in Viet Nam. A vast portion of this renowned growth over the last decades can be attribute to the Tan Cang – Cat Lai terminal, which has developed a consistent increase in container throughput since the installation Terminal Operating System in 2008. By the end of 2015, a real-time business solution (RBS) has been adopted and now a full Terminal On-Line Payment System (TOPS) is in place. As part of the ePORT initiative (2016) the emphasize turned to provision of information about containers, vessels, list of import / export containers, vessel berthing, etc. An application has been implemented to digitalize operational, administrative and financial processes in the port, leading to all sorts of efficiency, reliability and environmental benefits. Other examples presented concern: electronic warehouse management system, use of Artificial Intelligence for Q&As on port operation procedures; digitizing of promotion and marketing tools; seaport security monitoring system; electronic office system; intelligent reporting system; and the 5G-based Oracle Transportation Management (OTM) to provide a single platform for companies to manage all transportation activities throughout their supply chains.

In terms of digital strategy, SNP builds upon the existing digital tools in place to further develop the digital ecosystem eSNP: electronic system that helps with connecting a network of port organizations. The system will simplify, standardize and speed up information exchange among various sides, which will enhance interacting efficiency among customs, maritime and port authorities, with the aim to optimize management, automate processes, improve service quality and reduce operational cost in the port and logistics services. Also, a pilot study is done to look into automated handling facilities.

In the implementation of their digital strategy, SNP faces some challenges, which relate the need to change behaviour and awareness for more efficient digital processes; the need to upskill port and logistics staff in digital tools and autonomous processes; seamless connection between systems; consensus from management level to employees; security to withstand cyber-attacks. SNP concluded the presentation by making a few recommendations how the APEC Secretariat could support port digitalization in the region:

1. Study to research the introduction of blockchain technology in the community of ports, logistics, shipping lines, shippers and consignees.
2. Workshop on the application of industry 4.0 technologies to seaport operations, smart port and port automation.
3. Support the development of guidelines to protect port systems against cyber-attacks.
4. Explore financing opportunities for developing economies to facilitate them in their port digital transformation.
5. Support with the development of standardized training courses for upgrading the skills of human capital on management and operational level.

Discussion

At the time of the workshop, the comprehensive presentation of SNP did not lead to any questions.

Closing Remarks by Chair of Workshop

In the closing remarks, the Chair thanks everyone for participating in the event. The online workshop today has shown that despite challenges, ports in the APEC region show interest and dedication in their digitalization journey. Presentation and discussions in the workshop have illustrated both challenges and recommendations to accelerate the port digitalization efforts in the APEC region. Out of all recommendations, the Chair emphasizes the need for improving the knowledge infrastructure within the APEC region on this topic, which could play a key role in addressing challenges ahead to foster the needs for both small and larger ports in APEC economies.

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