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D8.5 – Pixel external evaluation and proof of concept report

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Version	1.0	**Status**	*Final*
Description	This document will summarize the external assessment on PIXEL's proof of concept and future R&D potential. It will be a reference document both for the goodness of the project and for use in dissemination and communication activities.		
Work Package	WP8		

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30-Jul-2021	0.3	Added R&R section and first parts of section 4
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21-Sept-2021	0.7	Added section for the Port of Trieste (other ports).
24-Sept-2021	0.8	Added section for the Port of Quebec and VIGIE Ports
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Key Data

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Abstract

This deliverable, associated with task T8.4, intends to show all efforts performed by the PIXEL Consortium in order to **widen the assessment scope** beyond the technical and business realms carried out in other WP8 related tasks. Once the PIXEL platform, models and algorithms have been tested in the four pilot ports, there is a certain need for further **testing in external ports** to assess transferability and get additional feedback.

Initially, the PIXEL Consortium committed to go **beyond** the Proof-of-Concept and perform a **full transferability analysis** in external ports, tracking the work performed by the **CSA DTF**, especially that related to transferability; however, the **unexpected delays** experienced during the pilot due to COVID-19 pandemic effects as well as the **increased focus from external ports to more compelling matters** (such as pure operational/economic subsistence) represented a great barrier. PIXEL partners approached up to **13 candidate external ports**, ranging from small to big-sized ports, and sometimes even from an early stage. Although the approach was very welcome by all the ports, who **showed interest**, most of them were not in the position to commit to a scale demonstration of PIXEL. On the one hand, due to the late delivery of the platform in PIXEL pilots (end of WP7 at M39) and, on the other hand, due to administrative issues (permissions, data availability, slow decision making procedures), time constraints and summer holidays were some other factors leading to the previous. To cope with this situation, it was agreed that a thorough explanation of the platform (and its possibilities) was to be made and a Letter of Intent (LoI) would be signed by the ports. In that regard, teleconferences were conducted, arrangements were made and LoIs were signed by up to 5 ports. These LoIs are interpreted by PIXEL partners as an open window to explore actual full-scale deployment of the solution in those ports via the PIXEL Association.

The situation described beforehand somehow restricted the margin of manoeuvre and the PIXEL partners concentrated therefore on the analysis and development of a **transferability methodology** which was already drafted in a previous deliverable (D8.1), but **needed an update from:**

- **Internal outcomes from PIXEL pilots**: the testing in our four different ports, together with some alignment from the exploitation perspective, allowed to **consolidate the different PIXEL assets** to be tested in external ports. Moreover, not until they were tested in the ports were we in the position to specify a thoroughly list of requirements, which had sometimes been asked from external ports during our initial contacts.
- **The progress in CSA DTF**: Not until the beginning of 2021 could we find the last deliverables from the CSA DTF related to the **Transferability Analysis**; unfortunately, the amount of items to be potentially evaluated had been increasing from the earlier versions of such deliverable, expanding the **complexity** and impracticability to obtain all data from external ports. Anyway, the team strived to to **align this analysis with PIXEL's methodology** and even tried to provide CSA DTF quantitative values, such as the **TA-score** and the **TA-index**.

Besides conducting Proof-of-concepts in external ports, this deliverable also performed an **in-depth study** about the **identification of future research directions**. The study is presented in easy-to-read summary tables that cover various timeframes:

- **Background period (until 2015):** this period allowed us to set the roots about how the different research lines appeared in port environments. The literature here was quite **homogenous** and it was possible to identify common research areas and research topics, sometimes giving a relevance quantitative value.
- **Current state (2015-2020)**: this period covers approximately the last 5 years. The increase in port activity and explosion of IT technologies resulted in a disparity of research areas/topics **difficult to aggregate and categorize**. Some *research areas* refer to: environment, sustainability, IoT, etc. whereas some *research topics* are: green shipping, port capacity, multimodal transportation, supply chain management, sustainable development, climate and energy, port-city interaction
- **Future trends (2020-2030)**: here it has been quite challenging to get homogeneous information, as the documentation is limited and the divergence huge. The used documents cover future views from relevant bodies or organizations (WPSP, UNO SDGs, AIVP, etc.). Whenever the terminology found

was more industry- than research-oriented, alignment with the documentation available from the CSA DTF network was performed.

Statement of originality

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List of acronyms

Acronym	Explanation
AB	Advisory Board
API	Application Programming Interface
CBA	Cost-Benefit Analysis
CPU	Central Processing Unit
CSA	Coordination and Support Action
DoW	Description of Work
DSS	Decision Support System
EC	European Commission
ESPO	European Sea Ports Organisation
FESTA	Field opErational teSt supporT Action
FOT	Field Operational Test
FVG	Friuli Venezia Giulia Region
GA	Grant Agreement
GCS	Gate Control System
GHG	GreenHouse Gases
GPMB	Grand Port Maritime de Bordeaux - Port of Bordeaux
GUI	Graphic User Interface
ISO	International Organization for Standardization
IoT	Internet of Things
KPI	Key Performance Indicator
LoI	Letter of Intent
MC	Mobility Case
MS	Milestone
OS	Operating System
PA	Predictive Algorithm
PCT	Port City Terminal
PCS	Port Community System
PEI	Port Environmental Index
PIXEL	Port IoT for Environmental Leverage
PoC	Proof of Concept
PoF	Port of The Future
PPA	Piraeus Port Authority SA
PQM	Product Quality Model

Acronym	Explanation
RAM	Random Access Memory
RIA	Research and Integrated Action
SQUARE	Software Quality Requirements and Evaluation
ThPA	Thessaloniki Port Authority
TEN-T	Trans-European Transport Networks
TMC	Traffic Management Centre
UC	Use Case
WCAG	Web Content Accessibility Guidelines
WP	Work Package

1. About this document

This deliverable aims to provide a final detailed description about the interaction of PIXEL with the "outside world" after its pilots. In other terms, PIXEL is not just a standalone project, although it needed a certain amount of time to be born as a useful set of tools and functionalities, well tested and documented. As a non-isolated project, PIXEL grew within the Ports of the Future network, interacting and collaborating with other RIAs and the CSA DTF. After the different tests (pilots) in the four different ports according to the Use Cases, the maturity of the developments achieved a certain confidence level so that they could be tested (transferred) to other external ports. This will allow further testing as well as getting more feedback to develop the final PIXEL products (WP9).

Besides the transferability to external ports, research contributions and directions are also analysed and provided in this document. Fundamentally, the impact on research is described in the context of ports considering their chronological developments in main and specific areas.

This document is one of the main outputs of the PIXEL project because it targets directly external users who are interested in transferring part of the PIXEL offer to their ports. Furthermore, researchers in the area of ports can get a good status about current and future trends in ports and how PIXEL is contributing to.

1.1. Rationale of the deliverable

D8.5 is the last deliverable of WP8. It does not extend a previous deliverable, though a previous plan was drafted in deliverable D8.1 (August 2019). At that time, we could not anticipate all the results within the PIXEL project and how they could be transferred to external ports, so this deliverable will try to follow the initial plan drafted once with some adaptations to the current status and provide more details as well and interesting findings.

This document is released at the end of the project. The PIXEL Consortium, based on the results provided in the pilots and/or Use Cases, worked together in order to provide the following information to external ports interested in a Proof-of-Concept:

- **Methodology**: the transferability process follows a step-by-step methodology to describe the scope, the requirements needed and the evaluation to be performed.
- **Transferability sheets**: identification of the potential "pre-products" or assets within PIXEL to be described in terms of dependencies, requirements (hardware, software, other) and licenses. The concept of pre-product refers to the fact that at the final definition of the PIXEL product comes afterwards and is part of WP9 (business and innovation).
- **Description of the use-cases and scenarios**: external ports may check the Use Cases defined in PIXEL. Technical and Business assessment are part of WP8 (tasks T8.2 and T8.3) and represent an additional interesting input for external ports, but according to the general time plan, final results from these tasks will be provided at the end of the project; therefore, only partial information can be given to external ports.
- **Documentation**: A lot of software was released in PIXEL and therefore there was a need to provide not only offline documentation, but also online updated documentation via *readthedocs* as well as access to *GitHub* and *Dockerhub*.

These items of information will allow external ports (mainly port authorities) deploying and testing the different PIXEL assets. We tried to be as descriptive as possible so that any port could perform its own transferability process without our intervention, although support from the PIXEL Consortium was provided.

Additionally, this deliverable includes an analysis about past, current and future research directions in ports, linked to the (academic) contributions that PIXEL has provided throughout its lifetime.

1.2. Deliverable context

Table 1. Deliverable context

Keywords	Description
Objectives	*Objective 1: Enable the IoT-based connection of port resources, transport agents and city sensor networks* External ports will start testing the PIXEL assets by installing the PIXEL IoT platform, as basis or infrastructure to support their own data network, or later aggregate additional high-level PIXEL models or predictive algorithms. *Objective 2: Achieve an automatic aggregation, homogenization and semantic annotation of multi-source heterogeneous data from different internal and external actors* By installing the IoT platform including the Information Hub as well as the Data Acquisition Layer, which are closely linked to fulfil this objective, external ports are able to define data models (PIXEL already proposes and extends many from the FIWARE data model approach). Once the data are in the Information Hub, external ports can build their own models or use the ones offered by PIXEL to target their specific goals. *Objective 3: Develop an operational management dashboard to enable a quicker, more accurate and in-depth knowledge of port operations* The PIXEL IoT platform already includes a Dashboard able to manage data, models and predictive algorithms. This includes the publication of models/predictive algorithms and their output visualization. *Objective 4: Model and simulate port-operations processes for automated optimisation* Besides the IoT platform, various models (e.g. PAS, PEI) are part of the PIXEL offer to be tested in external ports. In fact, part of the PAS and PEI user interfaces are coupled within the Dashboard to facilitate the user experience. *Objective 5: Develop predictive algorithms* Various predictive algorithms have been developed within PIXEL and can be tested in external ports (e.g. traffic prediction algorithm). The algorithms, as much as possible, were developed with core parts, so that it could later be extended or adapted for external ports (e.g. in the form of regressors plugins) *Objective 6: Develop a methodology for quantifying, validating, interpreting and integrating all environmental impacts of port activities into a single metric called the Port Environmental Index (PEI)*

	The most important model developed within PIXEL is the PEI and was also available and tested in external ports.
Exploitable results	The results of any of the assets ("pre-products") tested in external ports can be considered an interesting input highly relevant for the exploitation in PIXEL, as it will allow the final specification of products.
Work plan	This deliverable integrates the final work done in T8.4. It is a crucial document because it will feed WP9 to define the final PIXEL offer and products. Furthermore, it instructs external ports about the process to follow in order to test successfully any of the PIXEL assets.
Milestones	MS10: Final Evaluation. D8.3, D8.4 and D8.5 released.
Deliverables	Detected inputs (indeed many as we are dealing with transferability and a lot of potentially transferable work was done within the project): • D3.4: Use cases and scenarios manual v2. D3.4 extends and completes the previous version (D3.3) with more detailed information on the target use cases and scenarios. • D4.2: PIXEL models v2. Description of all models developed in PIXEL. It represents the core part for theoretical information and analysis, whereas the implementation was part of WP7. • D4.4: Predictive Algorithms v2. Description of all predictive algorithms developed in PIXEL. It represents the core part for theoretical information and analysis, whereas the implementation was part of WP7. • D5.3: PEI Definition and Algorithms v2. Final definition of the PEI and how it is calculated and implemented. • D5.4: PEI Manual for adoption in ports and guidelines for environment and society. Recommendations about using the PEI as well as how to understand the report made by the PEI model. • D6.2: PIXEL Information system architecture and design v2. Description of the PIXEL architecture • D6.5: APIs and documentation for software extension. Documentation in case some extension is needed in any of the PIXEL core components. This is really unlikely to be used, though (PIXEL already provides a global all-in-one installation of the PIXEL platform to facilitate deployment) • D7.2: Integration Report v2. Describes how all components in PIXEL have been integrated and tested in the different pilots. • D7.3: Pilots and Cross Pilot Collaboration Report. Before transferring PIXEL models to external ports, they were first transferred to other internal ports. • D8.1: Evaluation Plan. Initial plan drafted for all T8.X tasks, therefore including T8.4

	• D8.3: Technical Evaluation v2. Final technical evaluation of PIXEL. This will show external ports how PIXEL has been technically evaluated. • D8.4: Business and economic assessment report. Final business evaluation of PIXEL. This will show external ports how they could potentially obtain business benefit from PIXEL. Detected outputs: • D9.5: Report on dissemination activities and Update of the Dissemination Plan v2. Transferability results represent an important part for disseminating results at the end and after the project. • D9.8: Business and Exploitation Plan v2: Transferability results will help better define/refine the final PIXEL products and the way they can be better exploited.
Risks	The participation of external ports in transferability tasks is out of the control of the project Consortium, though we contacted some in advance to guarantee a reasonable participation. This relates to ***Risk 19*** in the GA. This deliverable includes the results from transferability tests in external ports; therefore, it is tightly coupled with in-time results from the pilots in internal PIXEL ports. Delays in WP7 (among other factors) have reduced the time to contact external ports and offer them already tested assets developed in PIXEL. This relates to ***Risk 20*** in the GA and the granted project extension helped dealing with this risk.

2. Introduction

As stated in the Grant Agreement, WP8 intends to use PIXEL use cases and involved stakeholders to assess its impacts in technical, business and economic terms. Task 8.4 has widen the assessment scope by taking into account wider user community requirements that exist today or are emerging, and has inquired if the PIXEL concept can cover those as well. The extended requirements come as a result of the Task 3.1 and will be validated/enhanced with the help of external to the project stakeholders, being experts from the business community. Moreover, Task 8.4 has identified some future research directions that can become feasible as a result of the implementation of the PIXEL concept. Members of the research community will be the main stakeholders involved in that. This task has also looked for proof of concept and real deployment in external ports (ports out of the PIXEL consortium) in order to demonstrate the validity of the general approach in PIXEL, spreading the use of the PEI and the PIXEL technologies towards a major European and Global uptake of the results. This activity has been mainly driven by participant industries, leveraging the wide contact and customer network.

In summary, there are two main aspects that have been undertaken in Task T8.4:

- **Identify future research directions**: PIXEL being a research project, it is important to present the output of the project from a research perspective, analysing the two main areas where PIXEL is contributing to: technical and environmental (even sometimes coupled). On each of them, PIXEL specific research lines will be specified (e.g. IoT architectures, energy management, etc.) and will be put in context regarding general research directions for ports (Port of the Future) with the main aim of highlighting the main impacts from PIXEL to the port community.
- **Extend the assessment/evaluation by building a proof-of-concept (PoC) in external ports**: use cases tested and validated in PIXEL should be as much as possible transferred to other external ports in order to increase its usefulness. The PEI use case, being a transversal one, is more prone to be easily transferred to and tested in other ports, as there will be a specific methodology to collect and develop the data. Regarding the other use cases, which can be somehow coupled with pilot ports, at least part of the developed technology may be tested. The PoC should be performed in strong collaboration with external stakeholders, mainly with the business community, who should suggest additional requirements that will make their transferred use case more attractive to the port community in terms of exploitation opportunities.

3. Future R&D potential

3.1. Introduction

In order to evaluate the potential of future research lines which may become feasible through the implementation of the PIXEL project, it is important to establish a proper framework and categorise the different areas and scopes PIXEL is targeting.

In this context, the approach which will be followed includes initially the understanding of the evolution of research in the port sector through the collection of data from published papers with respect to the main research areas and topics covered for a period extending from the past to the present.

Three periods were selected for the categorisation of the collected data. The first period (until 2015) aims to provide a comprehensive view of the main research interests in the past while the second deals with the current trends in research including the research areas which emerged during the last five years. The third period, which concerns the future, aims to provide an indication of where the research is heading. Regarding the analysis of the collected information, an attempt to provide quantitative data will be made whenever this is possible.

Following the process of capturing the evolution of research in the port sector, the contribution of the PIXEL project to specific research areas and topics through publications and the participation to conferences will be presented.

Finally, a top-down approach will be used to define the potential future research lines which the PIXEL has the potential to create or contribute to, starting from the main research areas, then the general research areas for ports and finally linking them with the specific areas covered in PIXEL.

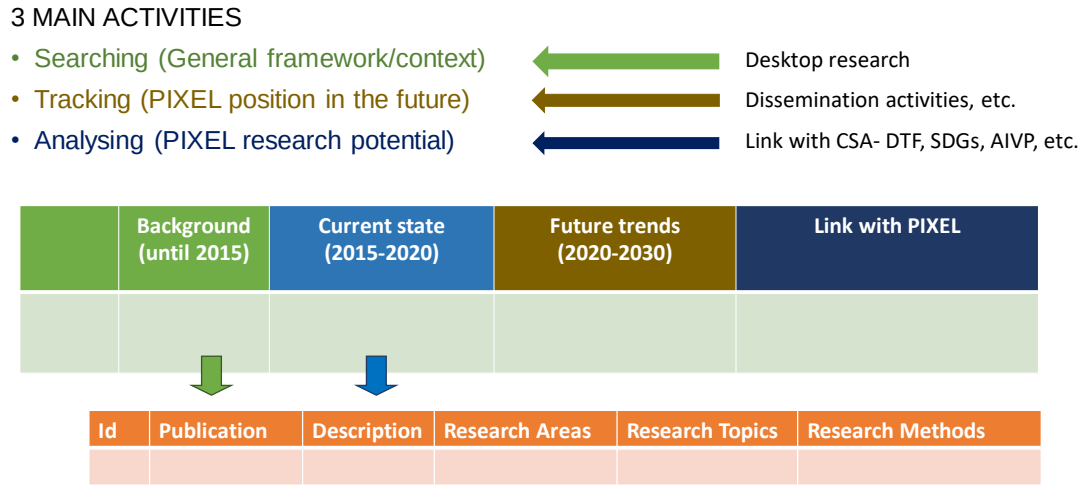

Figure 1. General overview of the methodological approach

3.2. Background period (until 2015)

For the first period of reference, a collection of review papers was made through desktop research in popular journal databases, covering the period from the past until 2015. More specifically, the articles considered included the review of papers covering a period starting from 1956 until 2014. The main issue that emerged during the process of data is related to the fact that the papers did not have a common way of presenting the

statistical data of the reviewed papers thus making it difficult to draw robust conclusions for the entire period based on quantitative data.

Having said the above, with regard to the outcomes of the analysis, it appears that the three main research interests in the period until 2015 were largely related to:

1. the governance aspect of ports and the port policy (including the regulations, privatization of ports etc.);

2. the management of port operations and the corresponding aspects (performance, efficiency, competition etc.)

3. the port planning in terms of port development, spatial planning, networks and port clustering.

Other issues equally important but without as high frequency as the aforementioned include terminal studies, the position of ports in the supply chains and the port choice. The environmental sustainability and digitalisation which are the main research interests related to PIXEL, were not included in the most frequent topics during this period. This fact is aligned to the status in the port industry during this period as it is reflected in the findings of the analysis performed in the context of D3.1 (stakeholders and market analysis report). In the stakeholders and market analysis report one main conclusion is that while solutions exist in order to increase the efficiency and connectivity of ports and create local value and social integration of ports to the cities, there is not any widely recognized platforms that operate taking into account the environmental factor and the interoperability between the port and the surrounding communities. This lack of focus placed by the industry to the development of solutions to reliably monitor the environmental performance of ports leveraging the available technologies is also reflected to the main research areas during this period where a lack of relevant topics was observed.

Table 2: Port research overview (until 2015)

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
1.	SHI, W. & LI, K. (2017) Themes and tools of maritime transport research during 2000-2014, Maritime Policy & Management, 44 (2), pp.151-169	Based on a review of papers published in 19 transportation journals over the period 2000–2014 (1,292 papers reviewed)	-	• Terminal studies, berth allocation (22%) • Ports in transport & supply chain (6%) • Port governance, port policy, regulation, & legal issues (13%) • Port planning, development, cluster, network, & economic impact (18%) • Port management, service, performance, efficiency, & competitiveness (33%) • Port choice (5%) • Port risk & security (2%) Other: spatial analysis, employment, academic research, etc. (1%)	• Survey, interview, questionnaire, & observation • Economic modelling • Mathematical, econometric, & statistical analysis • Case study • Conceptual, content, comparative, & qualitative analysis • Literature review • Simulation

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
2.	TALLEY, W. (2013) Maritime Transport Research: Topics and Methodologies, Maritime Policy & Management, 40 (7), pp.709-725	Based on a review of all papers published in the Maritime Policy & Management and Maritime Economics and Logistics journals over the period 2001–2012	• Port governance/ privatization (15%) • Port performance (44,5%) • Maritime/port clusters (7,5%) • Port state control (2,5%) • Port competition (12,5%) • Port choice (12%) • Marine terminal concessions (6%)	-	• Institutional Research • Statistical inference • Optimisation • Survey • Simulation • Proposition • Other (AHP, Linkage analysis, Fuzzy model, Performance index, Econometric model, Growth model, Emissions model, Game theory, Forecasting, Factor analysis, Benchmarking, DEA, Queuing network model, Heuristic & iterative algorithms, Gravity model, Markov theory, Stochastic frontier, Principal eigenvector)
3.	WOO, S. et al (2013) Evolution of research themes in Maritime Policy & Management 1973–2012, *Maritime Policy & Management*, 40 (3), pp.200-225	Based on a review of all papers published in the Maritime Policy & Management journal over the period 1973–2012 (984 papers reviewed). Two main areas: shipping and ports (here focus only on ports)	-	• Port policy (12%) • Governance & reform (11%) • Management & strategy (20%) • Competition & performance (21.5%) • Planning & development (19%) • Ports in supply chains (4%) • Spatial analysis (8%) • Terminal operations (4%) Follows Woo et al, 2012 (see row item 6)	• Survey • Interview • Economic analysis • Mathematic analysis • Statistical analysis • Case study • Conceptual work (modelling & descriptive studies) • Observation • Review & content analysis • Archival
4.	NG, A. (2013) The Evolution and Research	Based on a review of port geography articles published in 26 geography	Foreland & maritime space (global)	Port system (16,5%) • Port hierarchy	-

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
	Trends of Port Geography, *The Professional Geographer*, 65 (1), pp.65-86	journals over the period 1956–2011 (155 papers reviewed)		• Port clustering; • Development of continental/ national port ranges <u>Port connectedness</u> (4%) • Connections of ports with foreign markets <u>Port choice, competition, and cooperation</u> (8%) • Port attractiveness • Port competition & cooperation <u>Port's place in shipping strategies & networks</u> (7%) • Concentration & de-concentration • Hub development • Impacts of technological improvements on ports • Relation between ships & ports • Impacts of shipping lines & shipowner strategies on ports	
			Hinterland (regional/ national)	<u>Catchment areas & supply chain linkages</u> (2%) • Shrinking hinterland • Evolution over time <u>Port, intermodal transportation, & supply chain</u> (11%) • The role of ports in the development of multimodal transportation and logistics • Port's inland connection • Relation between port & cargo sources/shippers <u>Inland/satellite terminal</u> (4%) • Functions & operation of inland terminals, and their relations with ports	

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
				Port & regional development (9%) • Feasibility studies, impact assessments of port projects and intermodal facilities on regional & non-urban surroundings, including port development, climate change & environment issues • Port & international trade • Impacts of economic development on ports	
			The port (local)	History & location (5%) • Geographical characteristics • Cost–benefit analysis in port site selection • History of port international trade Evolution over time (6,5%) • Composition of the port community • Stages of port development • Port morphology Port operation (1%) • Berth allocation • Port planning & marketing • Port performance, efficiency, service quality • Port pricing • Safety & security issues • Information for port planning & operation Port–city relation (17%) • Port and urban development • Waterfront re-development • Port–urban land use conflicts	

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
				• Port & transport labour issues	
			Management, policy, & governance (8%)	• Politics, policies and the institutional system of port management & governance, including deregulation, devolution, privatization, public–private partnership • Strategies of terminal operators • Maritime organizations & port management and governance	
			Philosophy & epistemology (1%)	• Definition, meaning, & understanding of ports geography • The problem of taxonomy • Analysis of port research trends • Identity of port geographers & their relation with other (non)geography subdisciplines	
5.	NOTTEBOOM, T. et al (2013) Advances in Port Studies: The Contribution of 40 Years Maritime Policy & Management, *Maritime Policy & Management*, 40 (7), pp.636–653	Based on a review of all port studies published in the Maritime Policy & Management journal over the period 1973–2012 (267 papers reviewed)	Terminal studies (9%)	• Terminal productivity and efficiency • Terminal capacity & size • Strategies of terminal operating companies • Optimisation of terminal operations	-
			Ports in transport & supply chains (10%)	• Theorising the role of ports in supply chains • Changing logistics strategies of terminal operating companies and shipping lines and impact on ports • Role of seaport terminals • Hinterland access & supply chains • Local pressures on ports • Supply chains and liner service networks • Role of IT	
			Port governance (20%)	• Theorising the context of port governance	

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
				• Comparative analysis of port governance models • Port governance reforms at a national scale-results • Port governance reforms at a national scale-potential • Industrial Relations in ports • Role of Port Authorities in contemporary port governance • Port community, cooperation in seaports • Port governance through cooperation between seaports	
			Port planning & development (19%)	• Port planning • Impact studies • Port development • Tendering–Concessions	
			Port policy & regulations (18%)	• Market access • Pricing mechanisms • Financing • Environment • Safety & security	
			Port competition & competitiveness (18%)	• Port choice • Port competitiveness • Modelling port competition • Theoretical advances • Descriptive analysis	
			Spatial analysis (6%)	• Port city development • Port system development • Interaction between port system & hinterland networks • Modelling optimal port location & optimal port system configuration	
6.	WOO, S. et al (2012) Seaport Research: A Decadal Analysis of Trends and	Based on a review of papers published in 125 journals over the period 1980–2009	Port policy (9%)	• Supranational port policy (13%) • National port policy (22%) • Regulation & market (33%)	• Survey • Interview • Economic modelling

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
	Themes since the 1980s, *Transport Reviews*, 32 (3), pp.351–377 and WOO, S. et al (2011) Seaport Research: A structured literature review on methodological issues since the 1980s, *Transportation Research Part A*, 45 (7), pp.667–685	(840 papers reviewed)		• Public involvement (16%) • Safety & security regulation (1%) • Environmental regulation (14%)	• Mathematical modelling • Simulation • Case study • Conceptual work • Archival analysis • Content analysis
			Governance & reform (10%)	• Port governance model (20%) • Port governance reform (50%) • Port labour reform (30%)	
			Management & strategy (20%)	• Port strategy (24%) • Human resources management (13%) • Information & knowledge management (7%) • Safety & security management (10%) • Environmental management (15%) • Port pricing (19%) • Terminal Operating Company strategy (12%)	
			Competition & performance (19%)	• Port competition (15%) • Port selection (15%) • Port performance (11%) • Port efficiency (32%) • Port competitiveness (27%)	
			Ports in supply chains (5%)	• Redefining ports in supply chain context (34%) • Integration along supply chain (30%) • Land-side logistics (36%)	
			Planning & development (15%)	• Demand analysis (21%) • Supply analysis (22%) • Financing, risk, and project appraisal (13%) • Economic impact studies (25%) • Strategic planning & decision-making (6%)	

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
				• Development cases (13%)	
			Terminal operation (11%)	• Review and methodology (8%) • Terminal as a whole (19%) • Seaside operation (38%) • Yard operation (32%) • Landside operation (3%)	
			Spatial analysis (11%)	• Port system (55%) • Network analysis (19%) • Port–city relationships (26%)	

3.3. Current state (2015-2020)

For the period between 2015-2020 a summary table has been prepared based on desktop research and documents found covering this time frame. The main research areas are the following: environment, sustainability, IoT, risk and security, supply chain management and logistics and digital transformation. The amount of research topics is huge, but the most important/cited ones are: green shipping, distribution flows, port capacity, multimodal transportation, international trade, supply chain management, sustainable development, climate and energy, port-city interaction, digitalization and technology.

It has been a research challenge to homogenize the heterogeneous topics available in the literature due to several reasons: (i) different terminology, (ii) difficulty to cover only a 5-year period instead of a longer one, and (iii) different categorizations for research areas and topics. The result tried therefore to follow the same structure as the previous section.

Moreover, and whenever possible, the research topics have been ranked according to their relevance, so that some topics are more interesting to the research community than others (and probably also to the port market industry).

Table 3. Port research overview (2015-2020)

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
1.	WENMING SHI, YI XIAO, ZHUO CHEN, HEATHER MCLAUGHLIN & KEVIN X. LI (2018) Evolution of green shipping research: themes and methods, Maritime Policy & Management, 45:7, pp.863-876	Based on a review of papers published in transportation journals over the period 1988-2017	Environment	• Green shipping practice taken to reduce pollution (37.1%) • Green policy and green port performance assessment (26.8%), • Evaluating relationships between environmental and economic performance (20.2%), • Emissions calculation (10.8%), • Reviews about green shipping (5.2%).	• Mathematic and statistical analysis (39.57%) • Economic modelling (15.32%) • Case study (12.34%) • Literature review (9.36%) • Bottom-up/ top-down/ activity-based approach (6.81%) • Scenario (4.26%) • Sesitivity analysis (2.98%) • Survey (2.98%) • Simulation (12.34 %)
2.	PAUL TAE-WOO LEE, ZHI-HUA HU, SANG-JEONG LEE, KYOUNG-SUK CHOI & SUNG-HO SHIN (2018) Research trends and agenda on the Belt and Road (B&R) initiative with a focus on maritime transport, Maritime Policy & Management, 45:3, pp.282-300	Based on a review of 47 papers published in CSSI journals between 2015 and 2016	Supply chain management and logistics	• Capabilities, • Distribution flows • Network • Strategy	• Case study • Document review method • Interview and survey • Policy approach • Scenario analysis • Statistical statement • Strategy analysis • Text mining
			Shipping and ports	• Shipping market, vessel speed, • Fleet management, • Port cluster, • Port competition, • Hub ports, • Container repositioning • Port capacity	
			Connectivity, transport, and routing	• Maritime network, • Hub-and-spoke network,	

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
				• Transport network • Transport resilience • Multimodal transportation • Trans-China Railway, • Trans- Siberian Railway • Artic Sea route	
			Industry development and investment	• Industry (e.g. cruise, wine, and tourism) development) in association with the B&R; • Public–private partnership, • Strategic investment behaviours	
			Trade and cross-border	• International trade • Trade liberalization, • Cross-border e-commerce • Cross-border network	
			Infrastructure and Internet of Things (IoT)	-	
			Safety and risk	• Risk management • Passage safety • Supply chain security • Supply chain risk	
3.	XIWEN BAI & XIUNIAN ZHANG & KEVIN X. LIM & YAOMING ZHOU & KUM FAI YUEN (2021) Research topics and trends in the maritime transport: A	Based on an analysis of 3199 articles published between 1991 and 2020	• Port management • Container Operations • Liner Shipping Management • Maritime Policy and Law • Intermodal Transport • Maritime Cluster and Regional Development • Environment Performance • Terminal Operations	-	• Data collection • Text processing • Topic number selection • Knowledge discovery

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
	structural topic model pp.16-20				
4.	NERGIS ÖZISPA & GAMZE ARABELEN (2018) Sustainability issues in ports: content analysis and review of the literature (1987- 2017) pp.10-11	Based on an analysis of 53 studies published between 1998 and 2017	Sustainability	• Sustainable Development (20,75 %) • Sustainability Performance (16,98%) • Sustainable Management (15,09%) • Port Construction (13,21%) • Environmental Sustainability (9,43%) • Sustainability Indicators (7,55%) • Sustainability Policy (3,77%)	-
5.	WPSP (2020) World ports sustainability report 2020 pp.7	Based on the content analysis of the WPSP Project Portfolio between 2018 and 2019	Sustainability	• Resilient Infrastructure (21,2%) • Climate and Energy (24%) • Community outreach and Port city dialogue (37,9%) • Safety and Security Governance and Ethics (10,6%)	
6.	Markus Vejvar & Kee-Hung Lai & Chris K. Y. Lo (2020) A citation network analysis of	Based on an analysis of 253 related papers from 1967 to 2016	Shipping performance	• Shipping strategy and network • Scheduling and optimization • Multiple objective management	• Citation network analysis • Literature review

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
	sustainability development in liner shipping management: a review of the literature and policy implications, Maritime Policy & Management, 47:1, 1-26		Port selection and management	-	
			Shipping markets	-	
			Environmental dimension	-	
7.	Ying Zheng & Jingzhu Zhao & Guofan Shao (2020) Port City Sustainability: A Review of Its Research Trends pp. 10-11	Based on the review of 103 articles between 2000 and 2020	Sustainability	• The impact of ports and cities interaction on sustainability of port cities (15%) • The evaluation of sustainable performance (plans, policies and programs) with port cities (15%) • The impact of stakeholders on sustainability of port cities (10%) • The problems facing the sustainable development of port cities (20%) • Technologies, methods and measures to promote sustainability of port cities (41%)	

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
8.	SUNG-WOO LEE & SUNG-HO SHIN (2019) A Review of Port Research using Computational Text Analysis: A Comparison of Korean and International Journals	Based on the review of 2113 research articles in international journals and Korean journals between 2000 and 2018	• Port Management • Liner Shipping Management • Environmental Performance • Emission • Optimization (2015-2018)		• Case study • Document review method • Scenario analysis • Strategy analysis • Text mining
9.	Ziaul Haque Munim, Mariia Dushenko, Veronica Jaramillo Jimenez, Mohammad Hassan Shakil & Marius Imset (2020) Big data and artificial intelligence in the maritime industry: a bibliometric review and future research directions, Maritime Policy & Management, 47:5, 577-597	Bibliometric review of 279 studies from 1995 to 2019 on the applications of big data and artificial intelligence (AI) in the maritime industry	Digital transformation Applications from big data from Automatic Identification Systems (AIS) Energy efficiency Predictive analytics	• Digitalisation in maritime transport • Port Community Systems • Innovation in maritime transport • Maritime surveillance • Environmental and economic sustainability • Speed optimization • Route and crane planning • Vessel performance • Visual surveillance system	

3.4. Future trends (2020-2030)

For the period between 2015-2020 a summary table has been prepared based on desktop research and documents found covering this time frame. The research areas can be summarized as follows: Digital transformation, Energy efficiency, Port infrastructure & management, Integration in supply chain & synchro modality, Environmental concerns, Sustainability, Safety and security, Digitalization, Port-city relation, and Port governance. The amount of research topics is huge, but the most important/cited ones are: digitalisation and

PCS, environmental and economic sustainability, energy and logistics optimization, TENT-T networks, multi- and synchro-modality, cybersecurity, port cooperation –other ports and cities-, and IoT.

It has been a research challenge to get homogeneous information about this current and future period due to several reasons: (i) reduced amount of documents from the research community, and (ii), divergence in the classifications of the research areas. The result tried therefore to follow the same structure as the previous sections.

Unfortunately, the research topics could not be ranked according to their relevance, as research citations refer to past document not covering this period. As it mainly refers to the future directions, most guiding documents encompass future visions from relevant bodies or organizations, such as WPSP, UNO SDGs, AIVP, etc. Considering that sometimes the vision provided is more industry- than research-oriented, the conclusions (terminology, classification) in this section have been aligned with the documentation available from the DocksTheFuture (DTF) network.

Table 4. Port research overview (future trends)

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
1.	ZIAUL HAQUE MUNIM & MARIIA DUSHENKO & VERONICA JARAMILLO JIMENEZ & MOHAM-MAD HASSAN SHAKIL & MARIUS IMSET (2020) Big data and artificial intelligence in the maritime industry: a bibliometric review and future research directions, Maritime Policy & Management, 47:5, 577-597	Based on the review of 279 studies between 1995 to 2019.	• Digital transformation	• Digitalisation in maritime transport • Port Community Systems • Innovation in maritime transport	-
			• Applications from big data from Automatic Identification Systems (AIS)	• Maritime surveillance • Environmental and economic sustainability	
			• Energy efficiency	• Speed optimization • Route and crane planning	
			• Predictive analytics	• Vessel performance • Visual surveillance system • Other applications	

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
2.	ALEXIO PICCO & BEATRICCE DAURIA (2018) D1.5 Port of the Future concepts, topics and projects - draft for experts' validation	Based on the European lines and projects for the port of the future	• Port infrastructure & management	• Infrastructure • Sea side infrastructure • Maritime terminals • Other port infrastructure • Hinterland connections • Roads • Railroads • Inland waterways • Logistic areas • Industrial areas • Means of transport • Sea-going vessels	• Survey • Interview • Observation • Analysis of macro-trends and perspectives • Collected data about recent traffic volumes and how they will evolve.
			• Accessibility and fulfilment of EU standards.	• Accessibility • TENT-T networks • Smart traffic management • Standards and legal instruments	
			• Integration in supply chain & synchro modality.	• Multi and synchro modality • Integration in the supply chain	
			• Environmental concerns	• Alternative fuel • Power supply • Pollution prevention, reduction and elimination	
			• Sustainability	• Environmental sustainability • Economic sustainability • Social sustainability	
			• Safety and security	• Physical security • Cybersecurity	

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
			• Digitalization	• Business processes • Data sharing • B2B • System integration	
			• Port-city relation		
			• Port governance	• Financing and funding • Communication • Corporate social responsibility • Non-financial reporting	
			• Human element	• Labour market • Education and training	
			• Relation with neighbouring countries.	• Mediterranean and other neighbouring partner countries • Cooperation between ports	
3.	ERICCSON (June 2020) Port of the future. Addressing efficiency and sustainability at the Port of Livorno with 5G	Based on the evaluation of the operations at the Port of Livorno	• Automation • Transport and logistics • Environmental sustainability • Safety and security • Cybersecurity • Port-city relation		• Identify relevant SDGs • Identify port processes • Technology assessment
4.	HILDE MEERSMAN & EDDY VAN DE VOORDE & THIERRY VANELSLANDER	Based on scientifically validated instrument that helps in measuring impacts.	• Environmental concerns • Digitalization • Integration in supply chain • Transport and logistics	-	-

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
	(2016) Port competitiveness now and in the future : what are the issues and challenges?		• Port infrastructure • Port governance • Automation		
5.	INDRA VONCK, RUBEN CAMPHUIJSEN & SJORS BERNS (2020) Global Port Trends 2030 The future port landscape	Document based on scenarios developed over the past years by Deloitte Port Advisory.	• Port governance	• Use of alternative trade routes • Tilt in Asia • Increased protectionism • Strategic investment programs	
			• Digital transformation		
			• Sustainability	• Environmental sustainability • Social sustainability	
			• Safety and security	• Cybersecurity	
			• Relation with neighbouring countries.	• Collaboration between carriers • Collaboration at port	
			• Port infrastructure	-	
6.	RICARDO J. SANCHEZ & LARA MOUFTIER (2016) Reflections on the future of ports: from current strains to the changes	Based on the review of 9 studies between 2011 and 2016	• Environmental concerns	• Alternative fuel • Pollution prevention, reduction, and elimination	
			• Climate change	-	

	Publication	Description	Research areas (ranking, if available)	Research topics and ranking (if available)	Research methods
	and innovation of the future.		• Port governance	-	
			• Human element	• Labour relations • Culture change	
			• Accessibility and fulfilment of standards.	• Accessibility • Standards and legal instruments	
			• Port infrastructure & management	• Hinterland connections • Port relocation	
			• Digitalization	• IoT • Automation and robotics • Cybersecurity	
			• Sustainability	-	
7.	EDWIN VAN SPEN (2020) Port of the future, 7 building blocks	Based on Sustainable Development Goals formulated by the United Nations in 2015.	• Port infrastructure & management • Digitalization • Environmental concerns • Sustainability		

3.5. Main contributions from the PIXEL project

The PIXEL project targets especially small and medium ports, offering them the possibility to measure, control and reduce environmental impact by monitoring real-time data.

The objectives are:

- Reduction of environmental impact of port activities.
- Increase of renewable energy uptake in use-cases at small, medium and large port.
- Adoption of a Port Environmental Index as a global quantitative measure to monitor and act on own environmental footprint.
- Reduction of operational infrastructural costs with better Port-city integrations.
- Improvement of logistics through data analytics over waiting time for vessels, on-time performance.
- Heterogeneous information hub tailored for the interoperability in building over the limited data interchange of Port Community Systems.

Following this set of purposes, a summary table is shown below for all publications and conferences where PIXEL has participated, highlighting the main research areas and topics according to the ones listed in previous sections. As can be observed, all of them refer in one way or the other to a way of tackling the research objectives of the project. For each subsection, we have also quantified the involvement in each research area.

3.5.1. Publications

Table 5. Port research overview (publications)

	Publication	Research Areas	Research Topics
1.	JOAO PITA COSTA & IGNACIO LACALLE & MIGUEL A. LLORENTE & OLIVIER LE BRUN, ET AL (2021) Advantage of a Green and Smart Port of the Future	• Digitalization	• System integration
		• Environmental concerns	• Pollution prevention, reduction and elimination • Alternative fuel • Power supply
		• Port infrastructure & management	• Hinterland connections • Infrastructure
2.	MATIJA ŠIROKA & STJEPAN PILIČIĆ & TEODORA MILOŠEVIĆ & IGNACIO LACALLE & LUKA TRAVEN (2021) A novel approach for assessing the ports'	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability

	Publication	Research Areas	Research Topics
	environmental impacts in real time – The IoT based port environmental index.	• Digitalization	• Data sharing
2.	DEJAN ŠTEPEC & TOMAŽ MARTINČIČ & FABRICE KLEIN & DANIEL VLADUŠIČ & JOAO PITA COSTA (2020) Machine Learning based System for Vessel Turnaround Time Prediction.	• Digitalization	• System integration
4.	STJEPAN PILIČIĆ & LUKA TRAVEN & TEODORA MILOŠEVIĆ & IGOR KEGALJ & ANTE SKOBLAR (2020) Noise Pollution – Introduction to the State of the Research and the Implementation in the Horizon 2020 Project Pixel	• Environmental concerns	• Pollution prevention, reduction, and elimination
		• Sustainability	• Environmental sustainability
5.	TEODORA MILOŠEVIĆ & LADO KRANJČEVIĆ & STJEPAN PILIČIĆ & MARKO ČAVRAK & IGOR KEGALJ & LUKA TRAVEN (2020) Air Pollution Dispersion Modelling in Port Areas	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
6.	D. SARABIA-JÁCOME & C. E. PALAU & M. ESTEVE & F. BORONAT (2020) Seaport Data Space for Improving Logistic Maritime Operations	• Digitalization	• Data sharing • System integration
		• Relation with neighbouring countries.	• Mediterranean and other neighbouring partner countries • Cooperation between ports
7.	E. SIMON & CH. GARNIER & I. LACALLE & J. PITA COSTA & C.E. PALAU (2020) Small and medium ports' activities modelling:	• Digitalization	• Data sharing • System integration

	Publication	Research Areas	Research Topics
	introduction to the PIXEL approach		
8.	D. SARABIA-JACOME & I. LACALLE & C.E. PALAU & M. ESTEVE (2020) Enabling Industrial Data Space Architecture for Seaport Scenario	• Digitalization	• Data sharing • System integration
9.	D. YACCHIREMA & R. GONZALEZ-USACH & M. ESTEVE & C.E. PALAU (2018) Interoperability of IoT Platforms applied to the transport and logistics domain	• Port infrastructure & management	• Roads • Means of transport
		• Sustainability	• Environmental sustainability • Economic sustainability
		• Digitalization	• Data sharing
10.	A. BELSA & D. SARABIA-JACOME & C. E. PALAU & M. ESTEVE (2018) Flow-Based Programming Interoperability Solution for IoT Platform Applications	-	-

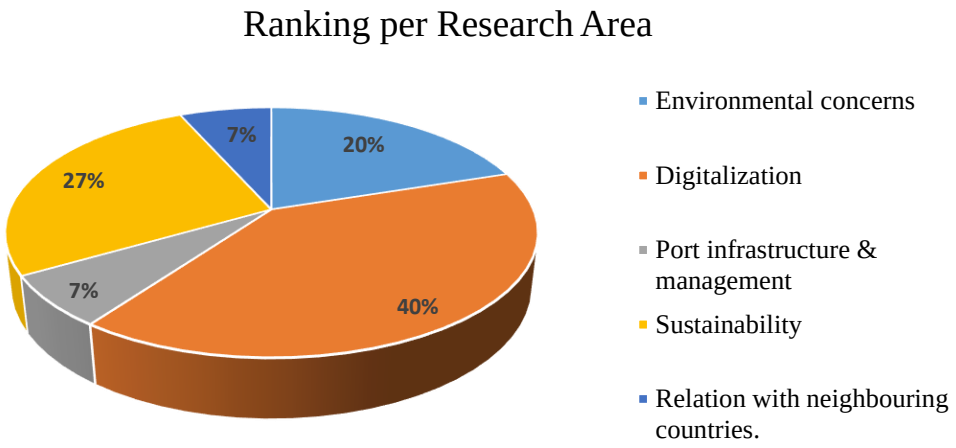

Figure 2. Publications- ranking per research area

3.5.2. Conferences

Table 6. Port research overview (conferences)

	Conference	Research Areas	Research Topics
1.	TEODORA MILOŠEVIĆ & STJEPAN PILČIĆ (MEDRI) & NACHO LACALLE (UPV) & ORESTIS TSOLAKIS (CERTH/HIT) (2021) 1st July-2021. PIXEL Webinar 4. Port Environmental Index (PEI)	• Environmental concerns	• Pollution prevention, reduction, and elimination
		• Digitalization	• Data sharing • System integration
		• Sustainability	• Environmental sustainability
2.	MARC DESPLAND (ORANGE) & ISMAEL TORRES (PRO) & ANDREU BELSA (UPV-INVITED GUEST) (2021) 17th June-2021. PIXEL Webinar 3. The PIXEL platform	• Digitalization	• Data sharing • System integration
3.	NACHO LACALLE (UPV) (2021) 16/18th June-2021. UMT - 27th International Conference on Urban and Maritime Transport and the Environment (ONLINE)	• Environmental concerns	• Pollution prevention, reduction, and elimination
		• Digitalization	• Data sharing • System integration
4.	RAFAEL VAÑO (UPV) (2021) 14th June - 31st June-2021. IEEE 7th World Forum on Internet of Things (HYBRID)	• Digitalization	• Data sharing • System integration
		• Environmental concerns	• Pollution prevention, reduction, and elimination

	Conference	Research Areas	Research Topics
5.	CHARLES GARNIER (CATIE) (2021) 14/16th June-2021. IPIC - International Physical Internet Conference (ONLINE)	• Digitalization	• Data sharing • System integration
6.	MARC DESPLAND (ORANGE) (2021) 8/10th June-2021. FIWARE Smart Fest (ONLINE)	• Digitalization	• Data sharing • System integration
		• Environmental concerns	• Pollution prevention, reduction, and elimination
		• Sustainability	• Environmental sustainability
7.	FABRICE KLEIN (GPMB) (2021) 2/4th June-2021. Green Tech (ONLINE)	• Environmental concerns	• Alternative fuel • Pollution prevention, reduction, and elimination
		• Sustainability	• Environmental sustainability
		• Digitalization	• Data sharing • System integration
		• Port infrastructure & management	• Hinterland connections • Infrastructure • Vessel retrofitting
8.	CARLOS PALAU (UPV) (2021) 27th May-2021. BIG DATA VALUE Dataweek (ONLINE)	• Digitalization	• System integration

	Conference	Research Areas	Research Topics
9.	CARLOS PALAU (UPV) (2021) 23rd April-2021. COREALIS Final Conference (ONLINE)	• Digitalization	• System integration
10.	DR. GEORGIA AYFANTOPOULOU (CERTH) (2021) 24-26 March- Huawei Industrial Digital Transformation Conference (ONLINE)	• Environmental concerns	• Alternative fuel • Power supply • Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
		• Digitalization	• Data sharing • System integration
		• Port infrastructure & management	• Hinterland connections • Infrastructure • Inland waterways
		• Integration in supply chain & synchro modality.	• Multi and synchro modality
11.	MARC DESPLAND (ORANGE) & FABRICE KLEIN (GPMB) (2021) 24 March- Salon de la Recherche (ONLINE)	• Environmental concerns	• Pollution prevention, reduction, and elimination
		• Sustainability	• Environmental sustainability
		• Port-city relation	-
12.	LEONIDAS PITSIKAS (PEOPLE) & CHARLES GARNIER (CATIE) (2021) 10 February- PIXEL Webinar 2. Technical presentation of user stories, models and algorithms	• Environmental concerns	• Pollution prevention, reduction, and elimination
		• Sustainability	• Environmental sustainability
		• Digitalization	• Data sharing • System integration

	Conference	Research Areas	Research Topics
13.	CARLOS E. PALAU (UPV) & MIGUEL ANGEL LLORENTE (PRO) (2021) 12 January- PIXEL Webinar 1. PIXEL Presentation	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
		• Port-city relation	-
		• Integration in supply chain & synchro modality.	• Multi and synchro modality
14.	IGNACIO LACALLE (UPV) (2020) 24 November- 2020.DocksTheFuture Digital Conference (ONLINE)	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
15.	TOMAŽ MARTINČIČ (XLAB) (2020) 5/30th October- 2020. OCEANS 2020 (ONLINE)	• Digitalization	• Data sharing • System integration
16.	ERWAN SIMON (CATIE) (2020) 15 September- 2020. The Operational Research Society – Sustainable Maritime Operations Stream (ONLINE)	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
		• Digitalization	• Data sharing
17.	CHARLES GARNIER (CATIE) (2020) 2/4 September- 2020. Virtual MariMatch - International Maritime Event (ONLINE)	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
18.	MARC DESPLAND (ORANGE) (2020) 23 July- 2020. FIWARE Green Economy DAY (ONLINE)	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability • Economic sustainability

	Conference	Research Areas	Research Topics
		• Digitalization	• Data sharing
19.	TOMAŽ MARTINČIČ (XLAB) (2020) 30 June - 3 July- 2020. The 21st IEEE International Conference on Mobile Data Management. Versailles, France (ONLINE)	• Digitalization	• System integration
20.	IGNACIO LACALLE (UPV) (2020) 23 June 2020. The Future of the Ports: a vision for 2030 at TRA Helsinki (ONLINE)	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
21.	DEBORAH MILLE (CREO) (2020) 4/6 February-2020. Euromaritime. Marseille, France	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
22.	STJEPAN PILICIC & TEODORA MILOSEVIC (MEDRI) (2019) 9/14 December-2019. Annual Faculty of Medicine Celebration Days. Rijeka, Croatia	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
23.	LUKA TRAVEN (MEDRI) (2019) 28 November-2019. 39 Scientific Symposium: Recent scientific achievements of the Teaching institute of public health. Rijeka, Croatia	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
24.	STJEPAN PILICIC & TODORA MILOSEVIC (MEDRI) (2019) 15/16 November-2019. 8th Conference on Marine Technology. Rijeka, Croatia	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability

	Conference	Research Areas	Research Topics
25.	DEJAN STEPEC (XLAB) (2019) 27-31 October-2019. OCEANS Conference and Exposition. Seattle, USA	• Digitalization	-
26.	LEONIDAS PITSIKAS (PEOPLE) (2019) 16/17 October-2019. BILOG- Logistics and Maritime Forum. La Spezia, Italy	Environmental concerns	• Alternative fuel • Power supply Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
		• Digitalization	• Data sharing • System integration
		• Port infrastructure & management	• Hinterland connections • Infrastructure • Inland waterways
		• Integration in supply chain & synchro modality.	• Multi and synchro modality
27.	IGNACIO LACALLE (UPV) (2019) 10/12 October-2019. International Conference on Internet and Distributed Computing Systems (IDCS). Napoli, Italy	• Digitalization	• System Integration
28.	OLIVIER LE BRUN (CREO) (2019) 1/2 October-2019. Blue Med Mediterranean Days. Toulon, France	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
29.	CHARLES GARNIER (CATIE) (2019) 17/19-September-2019. ITS4C Congress 2019. Bordeaux, France	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability

	Conference	Research Areas	Research Topics
30.	ERWAN SIMON (CATIE) (2019) 10/12-September-2019. Maritime Transport 2019. Rome, Italy	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
		• Digitalization	
31.	ARISTOS HALATSIS (CERTH) (2019) 4/6-September-2019. Baltic Port Conference. Stockholm, Sweden	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
32.	STEFANO BEVILACQUA (ASPM) & GILDA DE MARCO (INSIEL) (2019) 9/11-July-2019. 8th Black Sea Ports & Shipping. Constanta, Romania	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
		• Port-city relation	-
		• Digitalization	• System integration
33.	STEFANO BEVILACQUA (ASPM) & GILDA DE MARCO (INSIEL) (2019) 25/27-June-2019. 7th Mediterranean Ports & Shipping. Casablanca, Morocco	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
		• Port-city relation	-
		• Digitalization	• System integration
34.	GEORGIA AYFANTOPOULOU (CERTH)	• Environmental concerns	• Pollution prevention, reduction and elimination

	Conference	Research Areas	Research Topics
	(2019) 13-June-2019. Export Summit VII. Thessaloniki, Greece	• Sustainability	• Environmental sustainability
		• Digitalization	• System integration
35.	JOAO COSTA (XLAB) (2019) 16/17-May-2019. European Maritime Days. Lisbon, Portugal	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
		• Port-city relation	-
36.	CARLOS PALAU (UPV) (2019) 15/18-April-2019. IEEE 5th World Forum on Internet of Things. Limerick, Ireland	• Digitalization	• Data sharing • System integration
37.	BENJAMIN MOLINA (UPV) & JOAO COSTA (XLAB) & FLAVIO FUART (XLAB) & DEJAN STEPEC (XLAB) & STEFANO BEVILACQUA (ASPM) & TAMARA COSANO (SDAG) & MANUEL DEVESCOVI (INSIEL) (2019) 3/4-April-2019. CSA Mid-Term Conference. Trieste, Italy	• Environmental concerns	• Pollution prevention, reduction and elimination •
		• Sustainability	• Environmental sustainability
38.	IGNACIO LACALLE (UPV) & MICHEL LE VAN KIEM (GPMB) (2019)	• Environmental concerns	• Pollution prevention, reduction and elimination

	Conference	Research Areas	Research Topics
	6/7-March-2019. TEN-T Atlantic Corridor Working Group meeting. Lisbon, Portugal	• Sustainability	• Environmental sustainability
		• Digitalization	• Data sharing • System integration
		• Port infrastructure & management	• Hinterland connections • Infrastructure • Inland waterways
		• Integration in supply chain & synchro modality.	• Multi and synchro modality
39.	Luka Traven (MEDRI) (2018) 10-15 Dec-2018. Annual Faculty of Medicine Celebration Days	• Digitalization	• System Integration
40.	MARC DESPLAND (ORANGE) (2018) 27/28-Nov-2018. FIWARE Global Summit. Malaga, Spain	• Digitalization	• System Integration
41.	IGNACIO LACALLE (UPV) (2018) 6-Nov-2018. CID ALICE - New Global Routes: OBOR. Athens	• Environmental concerns	• Pollution prevention, reduction and elimination
		• Sustainability	• Environmental sustainability
		• Digitalization	• Data sharing • System integration
		• Port infrastructure & management	• Hinterland connections • Infrastructure • Inland waterways

	Conference	Research Areas	Research Topics
		• Integration in supply chain & synchro modality.	• Multi and synchro modality

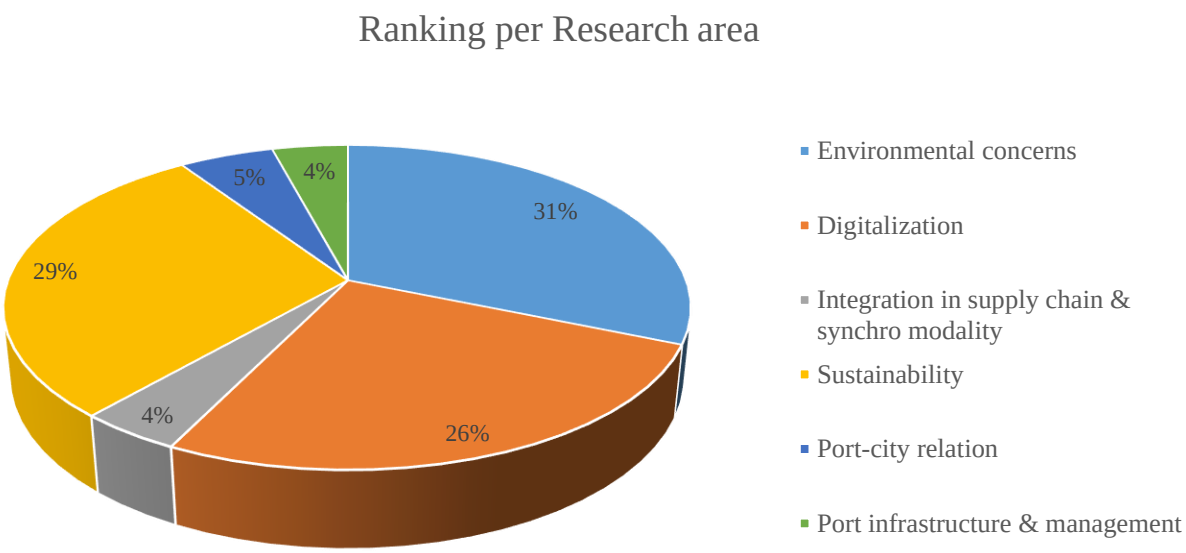

Figure 3. Conferences - ranking per research area

3.6. Summary

Analysing the data on the main research areas in the last five years and considering also the future trends in research compared to the past, it becomes obvious that the digitalisation of transport and the environmental sustainability are two areas that have recently gained focus from the research community. This trend is fully aligned to global efforts for environmental protection and towards the sustainability in all sectors of the economy which are further facilitated by the efficiency gains from the implementation of innovative technological solutions.

Therefore, the PIXEL project having developed a solution mainly designed to bring the ports environmental monitoring and digitalisation of processes in the port area, can contribute significantly to the evolution of the port related research in these areas.

4. Proof of Concept

4.1. Introduction and scope

The Proof-of-Concept (PoC) is typically a small exercise to test a design or an assumption in order to demonstrate or verify its practical functionality. In the literature, sometimes this concept is differentiated from Prototype. Whereas the first one is the first step and is related to technology and feasibility, the latter one represents a second step and is more related to the user and its desirability.

In the context of PIXEL, **PoC tries to go beyond this notion and refers to a complete transferability attempt** towards external ports. The main path is described through the following key aspects:

- An integration development was already done in WP6, mainly related to the core architecture and its core modules. Strictly speaking, this already supposes a **PoC** and an **initial prototype**.
- A **deployment scenario** was created in four different ports to test various models and predictive algorithms, as part of WP7
- Furthermore, some models and predictive algorithms that were initially conceived for one port were also ported to other ports, as part of the last task within WP7. This can be considered a **first transferability activity.**
- In WP8, besides the assessment of the pilot ports, we extend the transferability of PIXEL assets (in task T8.4) to **external ports** to further check their usefulness and, at the same time, gather additional feedback, specially from a business perspective.
- The transferability carried out in WP8 will provide **relevant insights** to adapt the PIXEL offer and its exploitation approach in WP9, in order to consolidate the **Key Exploitable Results**.

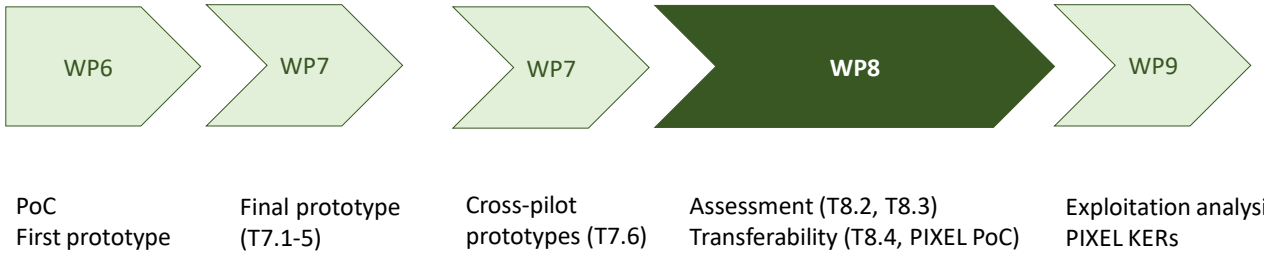

Figure 4. Transferability process in PIXEL

Transferability is really an **ambitious** task within research projects due to various reasons. First, requirements identified in the project were mainly obtained from (end user) partners, thus it is not clear whether our generic approach will target specific needs of external ports. Although PIXEL was designed with scalability and extrapolation in mind, ports vary widely among countries and even regions, therefore we have recognised there might not be possible to deliver a one-size-fits-all solution in this realm. Second, those external ports are typically interested in following the research, but it is really difficult to engage them in some sort of on-premises testing mainly due to time constraints, administrative issues like nested permissions or slow decision making procedures and technical like data availability. Third, the COVID-19 situation has arisen a lot of concerns and many ports have only focussed on core first-priority activities, thus the margin for research and tests has been significantly reduced.

In order to accomplish transferability successfully, three main sequential goals or subtasks were identified. They will be outlined below, but will be further described in following sections:

- **Step 1. PIXEL asset list (WHAT)**: The aim of this action was to have a clear vision of the PIXEL offer before being able to transfer it to external entities. This had two main dependencies:

- ***On the one hand, the business perspective from WP9.*** We should be able to simplify and export the current work performed in WP9 related with the product info and with the help of our Innovation and Exploitation Manager.
- ***On the other hand, the technical perspective from WP7.*** We should be able to list a set of requirements needed per infrastructure (machine, sensors), models and predictive algorithms; it should also include an estimated time to install, deploy and test selected items. Furthermore, a minimal set of documentation is needed to guide external entities/staff in the process.

- **Step 2. Ports engagement (WHERE/WHO):** The goal here was to identify and engage potential candidate ports. Some ports showed initial interest after first contacts; however, most of them wanted a formal letter with clear intentions, scope and requirements. The candidate list of ports had to be prioritised in terms of target ports and models to test, considered the timing requirements and the needed resources during WP7.
- **Step 3. Methodology (HOW):** The objective here was to follow a common methodology to facilitate both the transfer process and the assessment and retrieval of feedback. A first approach, based on the TIDE methodology, was already established in deliverable D8.1 (M16). At this stage of the project (M39) some adaptations and/or links might have to be performed:
  - ***CSA DocksTheFuture.*** This project within the PoF network produced a deliverable (D5.3 – Transferability Analysis) that can be somehow aligned with PIXEL. The analysis there is possibly too formal and complicated; it is intended more for an internal analysis to the PIXEL Consortium (or any other project in the PoF network) rather than to an external port. Anyway, we have tried to simplify the process to make it more useful and practical, and will be commented in further sections.
  - ***Evaluation.*** The evaluation in external ports could potentially be influenced by the technical (task T8.2) and business (task T8.3) evaluation performed in WP8. When deliverable D8.1 was released, there were no results from these tasks. Note also, that the tree tasks in WP8 will end at the end of the project (M41), so it is not possible to wait for the final results, but to try to work with intermediate ones.
  - ***Support and documentation.*** Related to the first task, external ports will require a lot of documentation and even support, above all if external ports are small and have limited resources. A documentation platform was already established in *ReadtheDocs* (https://pixel-ports.readthedocs.io/en/latest) for the core architecture, but required extra inputs related to models and predictive algorithms. Additionally, as part of WP9, we uploaded quite a lot of videos in our YouTube channel including our PIXEL webinars.

4.2. Link with CSA DTF and Transferability analysis

The CSA DocksTheFuture performed a macro study of past projects in order to gain substantial knowledge and provide insights about the Port of the Future Vision 2030. In their work, which was shared and disseminated across the PoF network in form of workshops and webinars, they produced a number of key outcomes, such as:

- The **DTF Project Common Index** (PCI), a synthetic index aiming at providing information of the achievement of strategic KPIs by all relevant projects.
- The **DTF Transferability Analysis** (TA), an assessment of the capability of successfully transfer initiatives from one port to others.
- The **DTF Decision Support System** (DSS), a flexible tool to guide port planning with the aim of simplify decision making process, assuring the achievement of long term goals.

Though they are somehow connected, we have focused only on the Transferability Analysis aspect, which will be briefly summarised, starting from various important terms, such as:

- **Innovative Concepts** (ICc), which somehow quantified the innovation component of the PoF concept in the form of an **I-score** (see deliverable D3.2 of DTF for more information [1])

- **Potential Contribution for Transferability** (PCT), a high-level assessment intended to measure the potential impact on target ports, and quantified by means of a **TA-score** (see deliverable D3.4 of DTF for more information [2])
- **Ease of Transferability** (EoT) refers to the process of qualifying and quantifying transfer objectives, risks, challenges and constraints. It goes a step further than the TA-score (high-level perception) and it is expressed through a **TA-index**.

According to DTF, the managed transferability can have different scenarios for purpose and promotion:

- **Multi-port participation projects:** based on collaboration in living labs or pilots. This is the typical scenario in PIXEL, where we had 4 different pilot ports.
- **"CHAMPION" approach**: proven port projects can provide their expertise and experience as *donor port* (offered or requested) to assist/guide an *adaptor port*. This would be an ideal follow-up in PIXEL, in case any of the four pilot ports guides an external ports adopting a certain platform, technology or model. However, this situation typically occurs after a transferable item has been tested during a large period of time to be considered sufficiently mature. This is a barrier for PIXEL as the pilots have not been largely tested.
- **Port peering**: (voluntary) collaborative engagement between ports to combine its resources during the (entire) life cycle of a project development and deployment. No peering strategy was performed between any of the PIXEL pilot ports and the other ports participating in the PoF network (COREALIS, PORTFORWARD), thus the transfer process will focus on purely external ports. However, some of the ports in the PoF network showed initial interest in parts of PIXEL (e.g. Port of Valencia).

CSA DTF tried to offer a thorough **Transferability Analysis** (see deliverable D5.3 of DTF for further information [3]) in order to allow multiple ports to collaborate as well as to assist adaptor ports scaling their solutions to other ports considering risk management, barriers and constraints.

The **first step** of the *Transferability Analysis (TA)* refers to the **Transferability Score (TA-score)**, a high-level anticipation on the *Potential Contribution towards Transferability* (PCT), independent from innovativeness, expressed as the number of targeted ports for which a specific project 'fits' or may fit and is reflected in the DTF **Project Common Index** (see deliverable D3.3 of DTF for more information [4]). This value can be provided at earlier stages of a project without the need to wait for results, and it encompasses one dimension for innovativeness and another for objectives.

PCT of a new solution = contribution in a pilot port x number of ports in which the solution will be used x probability (potential) of ports in which the solution can be used

Note that for single-port projects (no innovativeness), TA-score =0. Related to objectives, they refer to the 17 DTF High-level strategic objectives.

Figure 5. DTF High-level objectives. Source: CSA DocksTheFuture

As for deliverable D5.3 [3], the PCT/TA-score provides for a 5-band scale for evaluation, as shown in the Table below

Table 7. Scale for the TA-score. Source: DocksTheFuture

scale	PCT	
0	ZERO-weight	NOT measured: **single port**, OR **similar solution**(s) already exist AND/OR has no horizontal applicability (no efforts undertaken to peering or champion solution in potential adaptor ports)
1	LOW	**No to low support or high constraint for transferability**: project supports an IC, but no barriers/constraints considered or investigated OR transferability has high risk
2	MEDIUM	**Modest support for transferability**: project supports an IC, applicable to targeted ports, constraints/barriers & resolutions suggested, but NO peering resources to implement solution
3	HIGH	**Limited potential for transferability**: project supports an IC, applicable at **some (1 to 4) targeted ports**, constraints/barriers & resolutions suggested, AND peered resources across a minimum of 3 ports to implement (through port-peering and/or Champion approach)
4	STRONG	**wide support for transferability**: project supports an IC, applicable at **multiple (5 or more)** targeted ports, constraints/barriers & resolutions + risk management provisions established or anticipated AND has peered resources across various ports (3 or more) to implement solution simultaneous (through port peering and/or Champion approach)

The **second step** of the *Transferability Analysis (TA)* delivers a methodology to facilitate the 'transfer'-process and is based on a proven methodology developed by **POLIS**, known as the **NICHES+ 6-step methodology** [5], aligned to the specific needs of Port of the Future projects, referred to as the **PoF TA Methodology**. This process should be run periodically during the project and/or at the end, and it mainly implies two aspects:

- **TA Risk Assessment and Management Provisions** using PoF TA Methodology to evaluate the *Ease of Transferability* (EoT): identified strategic and operational objectives, evaluated barriers/constraints, recognised success factors and measured performance indicators (target and actuals), resulting in a project management script for transferring a solution from one port to another.
- **Transferability Index (TA-index)**: is the outcome of the full Transferability Analysis, using the recommended methodology, reflecting the ease of transferability in the **TA-index** which ranks the transferability suitability according to the table below.

Table 8. TA-index score

Score	Description
+2	strong support for transferability
+1	modest support for transferability
0	neutral
-1	modest constraint for transferability
-2	strong constraint for transferability

The assessment methodology is not simple and can only be performed by people involved in the project, preferably experts in such an evaluation, with the needed project management experience, and also with a deep knowledge of the overall project strategic objectives as well as the detailed performance indicators associated to each of the deliverables and the implemented solutions.

The PoF TA Methodology places a big focus on both the success factors and barriers to implementation, trying to estimate whether it is feasible to transfer an IC from one port to another given a different context. The success depends on various factors, some related to the project planning, implementation and operation of the concept, while others relate more to the context (physical, organisational and institutional aspects).

The PoF TA Methodology follows 6 basic steps adapted from the NICHES+ as depicted in the Table below. A more in depth description of each step should be found in deliverable D5.3 of DTF [3].

Table 9. Niches+ 6-step approach for transferability assessment. Source: DocksTheFuture

# Step	Description
1	Clarify the **impacts and measures** of the IC
2	Identify if **up- or down-scaling** is required and take into account subsequently as appropriate
3	Identify the **main components of IC** and its relevancy towards the **TA context**
4	Identify **relevant characteristics** and its **achievement in the current context** to be aligned to the **adaptor port**(s) situation (consider both alignment of port operations as well as adapting the solution to fit the specific port environment + adapting the implementation approach and integration with other existing systems and data)
5	**Assess** the **ease of transferability or difficulty** in achieving the required level of importance of the characteristic in a receiving i.e. adopter port
6	Consider the **set of values across the characteristics** and assess the likely potential for transferability and conditions that may be required

The **first 4 steps** of the previous Table define the potentials for transferability of an innovative project. **Steps 5 and 6** can only be confirmed after the previous commented two aspects are targeted: TA Risk Assessment and Management Provisions, and an understanding on how the TA-index is achieved for a project.

TA Risk Assessment & Management Provisions include the **definition**, **assessment** and **agreement** among the project owners and their prime or key stakeholders, towards:

- Identification of **expectations** from all or at least key stakeholders to the projects
- Adapt a **common Project Management & Reporting system** among project owners and primary stakeholders.
- **Knowledge & skills** available across the engaged ports and partners to provide guidance and assistance
- Obtain **insights & recommendations** from stakeholders
- Define and agree a **detailed planning of ALL resources** across project participants
- Identify the **barriers & constraints** in the new environment
- Identified the **risks or barriers** at development, deployment and integration (data, business models, operations, …)
- Define/agree **costs & benefits** for ALL parties involved
- Engage into **stakeholder dialogue**
- Set a **well-defined quantifiable** and **realistic SMART specified KPIs**

After this process, the PoF TA Methodology recommends building a full transferability assessment table comprising two parts:

- **The scope of the Innovative Concept and its context, with impacts and measure of success towards contributing to the DtF KPI-set, DtF PCI and DtF TA**, such as: efficiency, safety, environment, accessibility, use in ports, measured KPIs, benefits, etc.

- **The components, their characteristics, ease of achieving level and contributions required to successful implementation**, completed from the appropriate perspectives of strategies/policies, services offered, target users, geographical coverage, legal/contractual/technical requirements, etc.

After that, the last two steps of Table 9 can be completed:

- Step 5 uses **Table 8** to perform the (subjective) assessment
- Step 6 intends to **draw general conclusions** about the potential for transferability through consideration of the factors identified and the assessment values, also using Table 8.

In summary, the CSAT DTF provided a complex Excel file with multiple tabs to be filled (Figure 6 intends to showcase this overwhelming complexity –at the cost of readability-). Such complexity was extremely difficult to understand and, in some cases, some parameters could not be properly estimated. Even though some webinars were held within the PoF network, the RIA projects found it in general only partially useful for internal usage within each consortium, but rather impractical for contacting external ports. The PIXEL consortium, especially the project coordinator and the innovation manager, made a great effort to provide some results during these webinars related with the project in general and the PEI in particular. However, those results were partial (PIXEL pilots were still under test) and the DTF Excel file were even enriched during the last months of the CSA DTF project.

Anyway, we appreciated the work done and the methodology employed. In fact, in deliverable D8.1 of PIXEL, a similar methodology (TIDE) was identified - also based on the Niches+ one - by the time the first plan was drafted; therefore, the update of the methodology has been partially enriched/aligned with the work done by the CSA DTF. Furthermore, we have tried to assess the most important quantitative parameters (Ta-score, TA-index) from the CSA DTF for the target external ports. We will point to this work in the following sections.

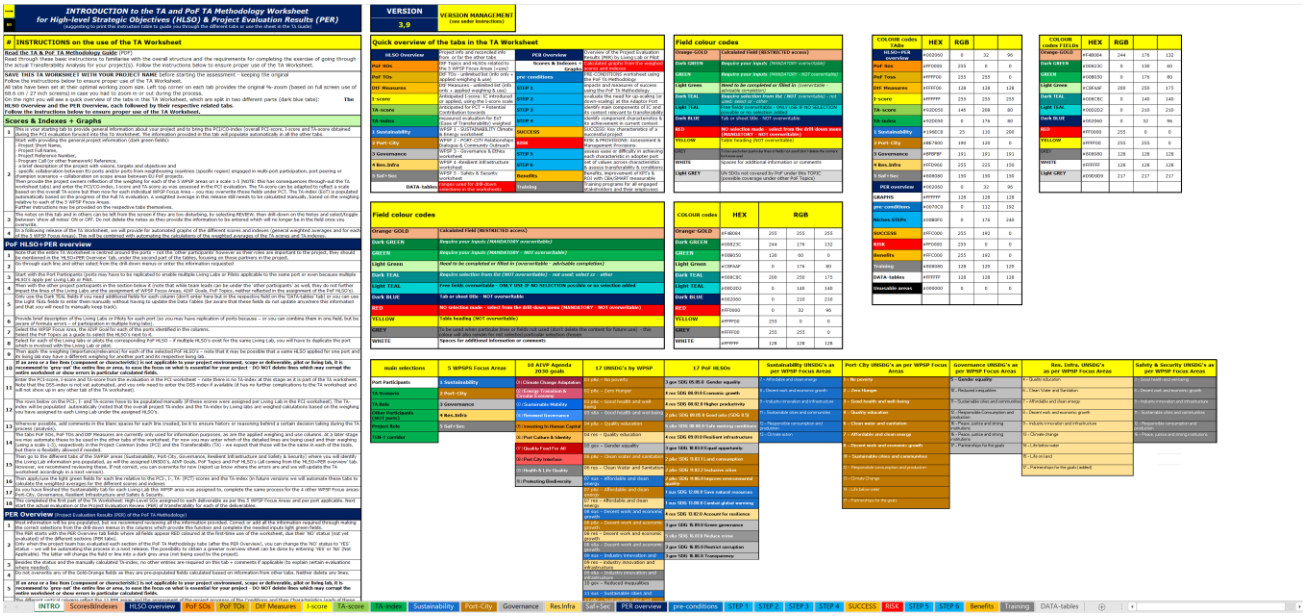

Figure 6. CSA DTF TA Analysis Excel sheet overview. Source: DocksTheFuture

4.3. PIXEL asset list

The **first step** before transferring anything requires an awareness exercise about what we have available and its potential to be transferred. This directly links with task T9.4 (exploitation), where PIXEL is analysed from a business perspective. However, the distinction must be highlighted for a better understanding:

- From **WP9 perspective**, the main focus is the **exploitation**, and the **commercial/business analysis** here identified what is called Key Exploitable Results (KERs), which refer to a list of assets subject to be exploited in one way or another. More information about this can be read in deliverable D9.8.
- From **WP8 perspective**, the main focus is **transferability**, i.e. the additional testing of PIXEL assets to get further (mainly business) feedback; thus these assets can be referred as **pre-products** and the categorization is slightly different as in WP9. For example, T8.4 in WP8 considers the PIXEL platform as a single asset to be tested in external ports (even for simplicity, as otherwise it might imply additional integration tasks). Furthermore, we have also **assigned priorities** to those assets according to our intention to further test PIXEL (or some assets) in external ports. For the consortium, **testing the PIXEL platform as an IoT platform as well as testing the PEI is of highest priority**, as they probably represent the most significant contribution of the project. Other models and predictive algorithms developed in PIXEL are also useful but come to another level of priority and simplicity, because they require the PIXEL platform to be tested and/or they need additional integration steps. Anyway, this is our initial intention, but in the end it will mostly depend on the target port to decide which PIXEL assets they would like to test according to their needs and expectations.

The table below shows the relationship between WP9 and WP8 assets, including the assigned priorities.

Table 10. Relationship between WP9 KERs and WP8 PIXEL assets

KER	Name	KER Type	Results Platform	T8.4 Assets in Analysis	T8.4 Priority
KER1	Port Environmental Index	Core	Port Environmental Index	**PEI**	max
KER2	PAS	Core	Port Activity Scenario	**PAS**	med
KER3	Maritime Data Analytics	Core	Maritime Data Analytics	**Maritime Data Analytics (former "ETD")**	min
KER4	Energy Demand Model	Core	Port Activity Scenario	**PAS**	med
KER5	Environmental Pollution Model	Core	Port Activity Scenario	**PAS (extended)**	min
KER6	Multimodal Transport Analytics (Hintermodal Transportation + Traffic PAs)	Core	Maritime Data Analytics	**Multimodal Transport (+ Traffic PAs)**	min
KER7	PIXEL Information Hub	Enabler	Big Data Engine	**PIXEL Platform**	max
KER8	Data Acquisition w/ agents	Enabler	Big Data Engine	**PIXEL Platform**	max
KER9	Operational Tools	Enabler	Big Data Engine	**PIXEL Platform**	max
KER10	Dashboard & Integrations	Enabler	Big Data Engine	**PIXEL Platform**	max
KER11	COVID-19 Pilot	Core	Port Activity Scenario	**PAS (extended)**	min

According to the list of PIXEL assets, we generated a common template for each one, so that we have a summary description useful for various reasons: (i) everybody within the PIXEL consortium will share a common view of the asset, how does it work and what it requires –this information came as feedback from WP7-, and (ii) external ports will also get a uniform description of each asset, so that they can compare and decide which one(s) they are interested in.

Table 11. PIXEL WP8 assets template

Item	*Sub-Items (if any)*	*Comments*
General description		*Explain in a short paragraph what the pre-product/component does. Try to include a picture (building blocks) if it facilitates the understanding*
Business perspective		*Explain in a short paragraph why the usage of this pre-product/component might bring business profit to the port (link WP9 → KERs)*
Involved PIXEL ports		*Make a reference to the involved ports/use cases/pilots in PIXEL*
Requirements	Hardware	*List/Explain needed hardware to run the component. This can be in terms of servers or needed sensors (this can be linked to data requirements)*
	Software - General	*List/Explain needed software to run the component. For each needed software, indicate license, or at least if it is open source or commercial*
	Software - PIXEL dependencies	*Indicate whether this pre-product can be run standalone or it needs other PIXEL pre-products (e.g. every model will require the PIXEL platform, the PEI might require the PAS, the PIXEL platform requires the whole architecture modules, etc.)*
	Data requirements	*List/Explain all needed input data to run the pre-product (for models/PAs). Map data needs with Data Models, and the need of (NGSI) Agents to process them*
	Code Adaptation	*List/Explain if the pre-product requires some code adaptation for each port (e.g. traffic PA may require additional regressors)*
	Staff Skills	*List/Explain all needed skills to be able to install/deploy/use the pre-product (e.g. technical skills to manage software, knowledge skills to understand the data or results, just user skills to manage the dashboard, etc.)*
	Timing	*Try to provide an estimation of the amount of time needed to: * install the pre-product/component * install and configure the needed data * do a basic test to check the pre-product/component * any additional analysis of (historical) data to provide valid input*
Source code		*Link to github repository (OPEN) or gitpixel (PRIVATE)*
License		*Type of license*
Documentation	Installation Manual	*Link to github or readthedocs. Include Youtube videos (if any)*
	User manual	*Link to github or readthedocs. Include Youtube videos (if any)*
	Other manuals & tutorials	*Link to github or readthedocs (e.g. NGSI Cookbook) and/or Youtube videos*
Support		*Contact person (e-mail) Explain the plan to provide support (e.g. e-mail, phone. github, etc.)*

The description of the PIXEL assets is provided in the Appendix section.

4.4. Port engagement

Once the list of PIXEL assets is clear and well defined, the **second step** refers basically to disseminating this information to external ports and asking them for their potential participation and engagement. However, we have realised that this is **not an easy task, e**specially during the period that we have been living the last few months of the project (pandemic outbreak, mobility restrictions, focus of activities from external ports to operational/economic subsistence rather than to explore innovation-related conversations with research projects). Although we have considered that our outcomes and pre-products are worthwhile and valuable for ports, approaching an external port and ask for their time and resources is really hard. There is a great deal between awaking interest and reaching engagement. Final engagement presents further barriers beyond the contact and establishment of telcos and informal commitments, mainly due to time constraints, administrative issues like nested permissions or slow decision making procedures and technical like data availability.

The CSA DocksTheFuture also identified such difficulty and suggested a way to profile a project as an Innovative Concept or a port as a Champion: *concepts should be illustrated with good practice examples, key benefits, decision criteria for implementation and useful references*. In PIXEL, this directly links with our Use Cases and the next section.

4.4.1. Further analysis and considerations

In order to be successful in this step and really engage a port, the PIXEL asset list is not enough, the PIXEL consortium needs to do an **extra internal analysis** to provide additional clear information about its work and **use cases** it to identify candidate ports with higher probabilities of accepting and engaging. This step was already pre-identified in deliverable D8.1 and had two main objectives:

- Establish some sort of **reference potential and candidate port profile** according to our use cases. The main idea is to align the PIXEL asset offer and the interest of the candidate external port, so that we mainly focus on the assets with more potential impact on the target port.
- Identify some **preliminary KPIs or objectives** that can be considered as natural extension from the KPIs already defined in each pilot port. This is related to getting feedback and measuring potential (business) impact from external port. Ideally, this exercise goes somehow **in line with task T8.3**, where every pilot is evaluated from a business perspective; analysing the business impact on a pilot should serve as hint or indicator to approach an external port, explain to them how a specific PIXEL asset might contribute and get further feedback from them. KPIs are just possible ways of evaluating such impact, in case they can be identified beforehand.

The **PEI use case** is considered as a **transversal one**, here we can extract commonalities for the four ports, the PEI also had a Work Package dedicated to it including (environmental) questionnaires to external ports from which useful information could be extracted. According to deliverable D5.4 a significant part of European ports is already **environmentally aware**, recognising their responsibility towards society and thus putting effort in complying with the EU policy for the protection of the environment. Therefore, we firmly thing that the PEI is an attractive PIXEL asset.

Table 12. UC internal analysis schema for transferability purposes

Use case	Objectives	Impact	Potential (business) KPIs	Analysis questions
Energy/ Transport/ Port-city	From D3.4	From D3.4	From T8.3	Does another port work in a similar way and benefit from this UC? → Profiling What alternative objectives/KPIs might be of interest for a port? → Extension
PEI	From D3.4	From D3.4	From T8.3	Extract commonalities from the 4 ports and find similar or dissimilar ports according to some eKPIs, to widen the range of the best and worst case scenarios

4.4.2. Candidate ports

During the project, the PIXEL consortium established links with other ports, and different possibilities were already pre-identified in deliverable D8.1:

- Through the **PoF network** (CSA), PIXEL joined a cluster of research projects related to defining the Port of the Future, thus potentially interested in exchanging ideas and participating.
- Some of the partners within the PIXEL Consortium are port authorities and have **close connections with other ports** of the same or different country to be exploited. Most ports tend to build internal networks to face common problems and know therefore similarities and dissimilarities among them, which will help better identify candidate ports.
- The PIXEL **Advisory Board (AB)** might also suggest candidate ports where PIXEL outputs (assets) may potentially fit.

Though PIXEL is primarily intended for **small** and **medium ports**, it is important to consider also **big ports** as candidates. This will also help assessing the transferability at various scopes (small, medium and big ports).

The potential candidate ports initially identified are listed in the Table below. We included a set of additional info (contact points, output from bilateral telcos, etc.) to track the status of each port (not listed in the Table).

Table 13. List of potential candidate ports

#	Port	Identified by
1	Port of Valencia	UPV
2	Port of Gijon	PRO
3	Port of Malta	PRO
4	Ports of Balearic Islands	PRO
5	Port of Trieste	INSIEL
7	Port of Le Havre	ORANGE
8	Port of Rijeka	MEDRI
9	Port of Algeciras	UPV/AB
10	Green Marine (association) – Port of Quebec	GPMB
11	VIGIE Ports (association) – Port of La Rochelle, Port of Bayonne	GPMB
12	Port of Trelleborg	XLAB
13	Port of Cartagena	UPV

The selection criteria were also established in deliverable D8.1:

- **Real willingness of the candidate port**. Real commitment from ports will help (i) solving problems or accelerating the solution when they appear, and (ii) promoting the results to society. A possible indicator to measure this is the availability of a clear administrative contact point as well as a clear technical contact point with real authority in the port.
- **Feasibility** from ports' point of view. External ports should provide basic initial feedback showing the main objectives and resources, considering the given PIXEL asset list. The PIXEL Consortium will then evaluate the technical, administrative and legal difficulties to reach the expectations (e.g. access to data, access to servers, etc.)
- **Internal PIXEL's priorities**. The PIXEL consortium prioritises some assets from others, as commented in previous sections. The consortium will also decide if the assets are really providing impact to the selected port and they can benefit from it.

A **Letter of Intent (LoI)** was created to be distributed among candidate or selected ports and can be find as Annex 1.

In summary, **engagement of external ports** is really crucial as without real involvement of ports there is nothing to do. This implies contacting external port representatives, explaining the PIXEL project and our use cases and how they can benefit from the PIXEL assets. This process typically takes time as **several bilateral telcos** with external ports are needed before they provide a definitive answer.

4.5. Methodology overview

This section briefly describes the methodology and the main steps to follow in the transferability process.

4.5.1. Initial methodology. TIDE methodology and PIXEL adaptations

As described in deliverable D8.1, the **initial methodology identified** to be adapted and used in PIXEL is **extracted from the TIDE project** [6] and basically tries to answer the following question to external ports: *What are the steps to follow if I want to transfer successfully any of the PIXEL assets in my port?* The schema, extracted from the TIDE project, is presented in Figure 7, and covers several steps, which are somehow translated into PIXEL as described in Table 14 .

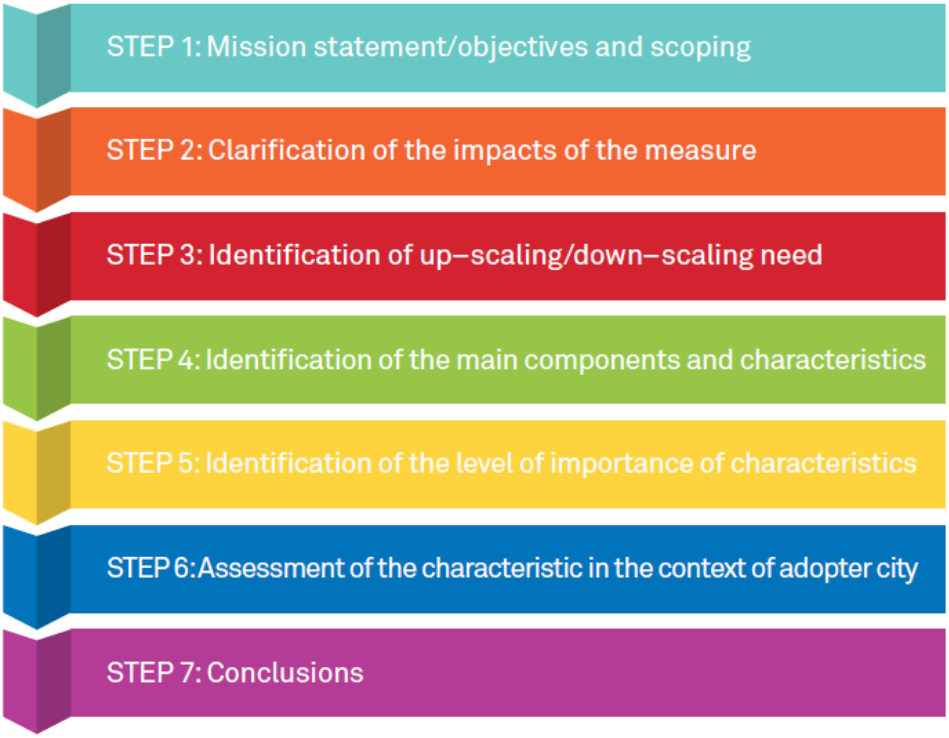

Figure 7: TIDE methodology schema. Source: TIDE [6]

Table 14. PIXEL initial methodology extracted from TIDE

#	TIDE step	PIXEL step (adaptation, if needed)
1	Mission statement, objectives and scope	**Aim and scope** - Write down (e.g. bullet points) the reason for testing one or more PIXEL assets and the specific objectives to fulfil. - Set the scope in a realistic way, initial abstract ideas during the contact phase with external ports must now become concrete. - Check if the user story (use case) in the target port is different from the ones already from PIXEL
2	Impacts	**Expected impacts** - List the (potential) impacts of adopting the selected PIXEL asset - Check if they are the same of different from the ones in PIXEL
3	Up-scaling/Down-scaling	**Not applicable in PIXEL** - In the context of PIXEL, the testing of the PIXEL asset will mainly require a single port and its area
4	Identification of components and characteristics	**Deployment requirements** - Requirements from the external port (infrastructure, data, sensors, services) - Requirements from PIXEL (other PIXEL assets) - Other requirements (missing components, extra development and integration, legal issues, etc.)
5	Relevance	**Limitations** - If the previous list of requirements is too large, it will need to be classified/prioritised - Data availability limitations - Legal limitation - Timing constraints
6	Assessment	**Evaluation results** - Define how you are going to evaluate the transferability process (e.g. similar to D8.3) - Assessment scenario - Identify KPIs to evaluate, if any, or other indicators/questionnaires to assess the level of transferability - Data collection and results
7	Conclusion	**Conclusions** - Main conclusions from the assessment (key success factors and barriers) - How useful do external ports find the PIXEL asset? Would they recommend it to another port? - Is any additional requirement identified not listed in deliverable D3.2 that might benefit the PIXEL asset? - Any other (free) feedback from the external port?

4.5.2. Final methodology and CSA DTF Considerations

During the project the PIXEL transferability methodology has been **influenced by the interaction with the PoF**, and mainly by the TA-Analysis performed by the CSA DocksTheFuture. Even if their approach is too broad and complex and hard to fully implement in practical terms, we recognize that some aspects are useful to consider and, in fact, goes in line with basic project management (e.g. PMI and PM2). Furthermore, the methodology followed by them was based on the **Niches 6 steps methodology** [5], which represented the roots for the TIDE methodology. Thus, there is already an implicit alignment in PIXEL and CSA DTF.

The result of the adaptation from the initial PIXEL methodology into the final one is summarized in Table 15 introducing additional considerations/enrichments from CSA DTF – some of them were already there due to the initial alignment . Note also that it should **not been considered as a strict methodology**, but rather as a step-by-step guidelines **open to flexibility** and some changes; this will be primarily dependent on the target port and how they want to proceed with the transfer. If the target port is a big port, they might have their own way of testing assets; on the other hand, for small and medium ports, this methodology will probably be of practical use.

Table 15. PIXEL final methodology

#	PIXEL step (adaptation, if needed)
1	**Aim and scope** - Write down (e.g. bullet points) the reason for testing one or more PIXEL assets and the specific objectives to fulfil. - Set the scope in a realistic way, initial abstract ideas during the contact phase with external ports must now become concrete. - Highlight the innovate aspect for the target port - Check if the user story (use case) in the target port is different from the ones already from PIXEL. In case of a donor/adaptor port scenario, check differences between ports (operational, infrastructure, financial) that may my impact the expected result - Related projects and experience from the target port (useful references)
2	**Expected impacts** - List the (potential) impacts of adopting the selected PIXEL asset - Check if they are the same of different from the ones in PIXEL - Can additional port stakeholders be impacted? Are there any expectations for them?
3	**Deployment requirements** - Requirements from the external port (infrastructure, data, sensors, services, staff) - Requirements from PIXEL (other PIXEL assets) - Training requirements - Other requirements (missing components, external data, extra development and integration, legal issues, etc.)
4	**Limitations** - If the previous list of requirements is too large, it will need to be classified/prioritised - Data availability limitations - Legal limitation. Is the local/national/international legal framework limiting somehow? - Timing constraints - Overall risk management approach
5	**Evaluation results**

	- Define how you are going to evaluate the transferability process (e.g. similar to D8.3, but from a business perspective). - Describe the assessment scenario - Identify KPIs to evaluate, if any, or other indicators/questionnaires to assess the level of transferability. - Can the benefits be quantified or qualified? Qualified measures only run the risk of not resulting in comparable measures. Try to ensure quantification of the benefits (better information, improved, safety, improved traffic flow, reduced environmental, impact, etc. - Identify if other port stakeholders need to be properly informed for a smooth test. Contact points need to be clear during the transfer, and any change should be handled - Can the target port help disseminate the results/benefits broadly? - Degree of compatibility with current strategies and policies, including pollution reduction, transport modes, accessibility and sustainability - Data collection and results
6	**Conclusions** - Main conclusions from the assessment. Key benefits, key success factors and barriers. - Cost of adoption, if possible (further investments needed to deploy the tested PIXEL asset at full size) - How useful do external ports find the PIXEL asset? Would they recommend it to another port? - Is any additional requirement identified not listed in deliverable D3.2 that might benefit the PIXEL asset? - Is there any example of good practice to be extracted? - Any other (free) feedback from the external port?

4.6. Port of Valencia

4.6.1. Introduction and approach to PIXEL

The **Valenciaport Foundation** for Research, Promotion and Commercial Studies of the Valencia region (Valenciaport Foundation) is a private non-profit research centre created in 2004 through an agreement between the most representative associations and companies of the Valencia logistics-ports community and various institutions of the Valencia region, all of which are involved in logistics and maritime transport. The Valenciaport Foundation team is composed of R&D&I specialists and engineers in the fields of **digital transformation, ICT, industrial, maritime and intermodal transport, logistics and transport economics**. The Valenciaport Foundation manifests an R&D&I centre of excellence that not only undertakes its own academic research but also serves as a tool at the service of all agents involved in the **transport and logistics chain** and particularly within the **maritime, port and transport domains**, these being key competitive elements buttressing the internationalisation process of Spanish companies. On top of the activities linked to research and training, the Valenciaport Foundation also carries out international cooperation projects focused on the optimal and integrated development of transport, logistics and ports located in third countries.

Figure 8. Port of Valencia

The Port of Valencia showed interest in the **Port Environmental Index (PEI)** from an early stage of the project; they are really active contributors in multiple European projects and are placing relevant efforts on **digital transformation**, **port-city integration** and **sustainability and energy transition**, among others. Therefore, they were an excellent candidate to test PIXEL outcomes. Furthermore, through the **Fundación Valenciaport (FVP)**, they have participated in another PoF project (**COREALIS**); this facilitated the exchange of information among projects at an early stage during the **CSA DocksThefuture events** (some of the face-to-face, before the lockdown). UPV was the responsible contact point from PIXEL, who also arranged some specific telcos with relevant roles from the Port of Valencia, such as:

- *Chief of Security, Environment and Infrastructure of the Port Authority* (APV)
- *Managing Director* at FVP
- *Innovation & Port Cluster Development Director* at FVP
- *Project Managers and technical staff* for the specific details

During the telcos, the **general overview of PIXEL** was presented (platform, models and algorithms) with a special **focus on the PEI**, as this was the main interest of the Port of Valencia.

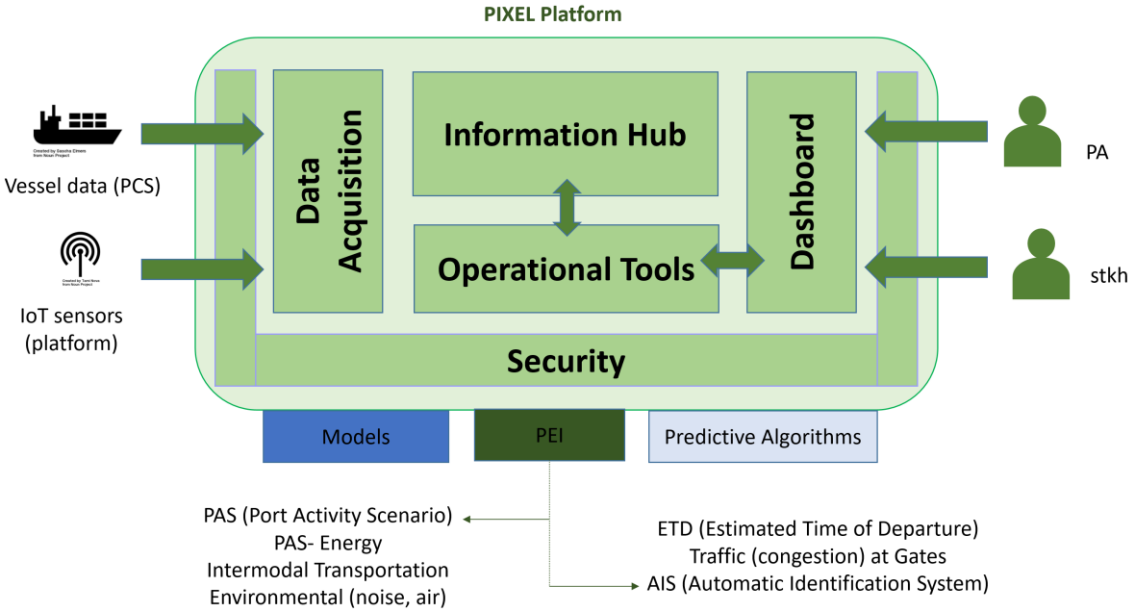

Figure 9. Overview of PIXEL presented with the different potential components to be potentially transferred.

Besides the telcos, they were invited to the **PIXEL webinars** that were held during the last months of the project, being one of them exclusively dedicated to the **PEI**, where the PIXEL Consortium presented both the

background theoretical basis and the implemented approach by showing a PEI example through the PIXEL Dashboard.

4.6.2. Aim and scope

The Port of Valencia is dedicated to **improve the environmental performance** and therefore intends to **test the PEI** on their premises. More specifically, the reasons for testing are:

- Better **understand the environmental variables** and how they should be considered to **measure the** (environmental) **impact**. The PEI is based on an analysis of relevant environmental variables and how they should be grouped and managed.
- Include a **system and methodology to collect and store** all needed measurements from the environmental variables. The PEI is a model running *natively* on the **PIXEL platform**, able to collect and store the data.
- **Visual monitoring tool** to show the results in *various ways*. The PIXEL platform, through its **Dashboard**, *natively* includes the visualization of the results of the PEI.
- **Reports and recommendations.** Based on the calculation (environmental impact), the reporting of data in a document and some initial recommendation is appreciated by any public entity managing a large organization, such as a port. The PEI is able to perform such task.

Some initial remarks were identified to shape the scope in a realistic way:

- The Port of Valencia already has its own technological infrastructure and the usage of a second platform (PIXEL platform) appears to be an *initial burden* for a final integration.
- The identification of the needed data for the PEI, how to collect and store them, follows an individual process by each port (see Figure 10) and can take *significant time* to list all data sources and properly integrate them in a proper format.

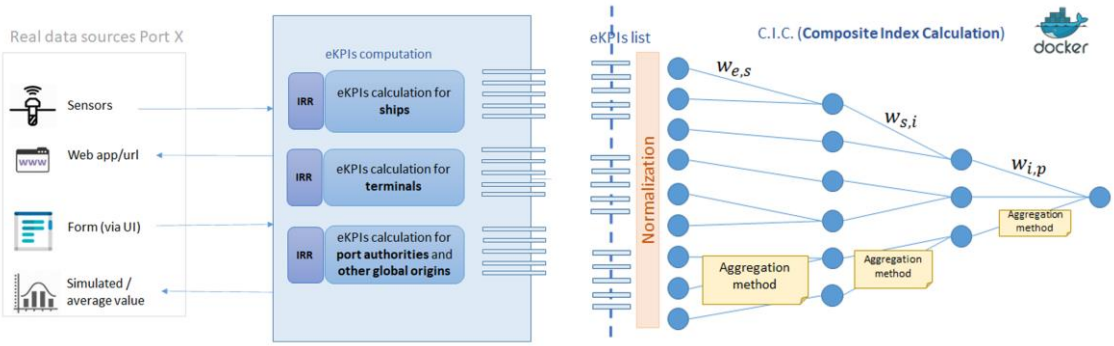

Figure 10. PEI general process

- Even if the PEI has its own (general) recommendations, the PIXEL platform already allows to monitor data and define alerts based on several criteria (e.g., thresholds), so that specific policies can be triggered based on environmental eKPIs. Though this is possible, it is unlikely to be tested in the Port of Valencia: only a small test in terms of time will be done, and the generation of relevant alerts would require more testing time to properly understand the overall process on each specific port in order to be able to set alarms.

The main **innovation** by testing the PEI in the Port of Valencia is not different than in the other ports in PIXEL, as there is no other **quantitative composed indicator** to measure the environmental impact. In fact, the Port of Valencia is part of **EcoPorts** (https://www.ecoports.com/). This European port sector initiative includes some tools, such as the Self Diagnosis Method (SDM) and the Port Environmental Review System (PERS), but the approach is significantly different.

4.6.3. Expected impacts

The Port of Valencia expects the following impacts by testing and further using the PEI:

- To **consolidate its position** as one of the **top Smart Ports** in Spain and in Europe. According to [7], the **Port of Valencia led the ranking** of Smart Ports in Spain in 2020, considering several criteria. Though not leading all criteria, the Port of Valencia significantly **outperforms other ports in terms of environmental score**, and the PEI might help as a tool to enhance the monitoring of the environmental impact.

TOP10 smart port	Port	Global score [0-400]	Environmental score [0-100]	Economic Operational score [0-120]	Social score [0-100]	Political institutional score [0-80]	Digitalization degree [0-100]
1º	Valencia	299,47	67,73	88,83	82,24	60,67	70,26
2º	Barcelona	282,04	52,27	93,92	67,76	68,08	77,45
3º	Bilbao	244,13	50,64	72,01	61,39	60,09	45,55
4º	Vigo	234,37	48,57	54,78	77,83	53,19	65,36
5º	Algeciras	228,78	31,59	79,90	70,24	47,04	79,80
6º	Huelva	192,78	58,44	34,89	50,10	49,35	32,37
7º	Tarragona	189,63	57,01	32,73	60,27	39,62	63,98
8º	Gijón	177,57	44,88	42,20	58,10	32,39	63,21
9º	Cartagena	165,21	48,43	38,17	38,41	40,19	47,33
10º	Las Palmas	151,54	36,33	42,40	38,51	34,30	64,27

Figure 11. Top 10 of Spanish Smart Ports. Source [7]

- To **increase its transparency index** in various dimensions, especially in **communication and Open Data**. According to a global dynamic transparency index tool [8], the Port Authority of Valencia is *well positioned* in the area of communication, e-administration and Open Data. The PEI is not only a tool that allows the global environmental monitoring of a port, but also promotes the **sharing** of such information across multiple ports to foster **best practices**. Considering that the Port Authority of Valencia is **committed to zero emissions by 2030**, the PEI as a tool for monitoring and cross-collaboration might be useful; note that the PEI tool also provides **recommendations** based on the values of the environmental Key Performance Indicators (eKPIs).

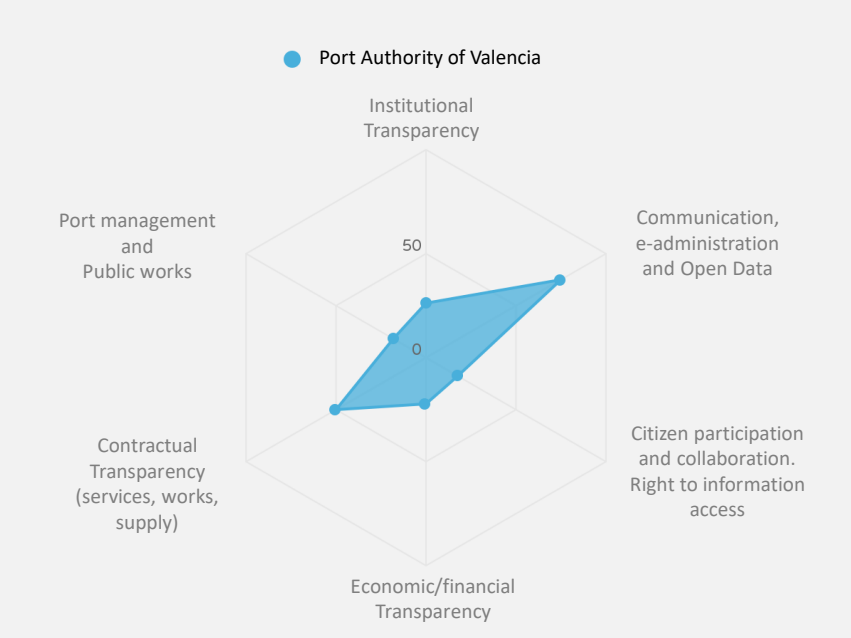

Figure 12. Dynamic Transparency Index. Source [8]

- To **further investigate** on the PEI as a **quantitative indicator.** The PEI is a quantitative indicator offered by the PIXEL project as its main outcome, and it went through a deep analysis about how to aggregate, normalize and quantify the multiple different eKPIs. Following a common criterion allows to compare numbers (PEI, SEI, eKPIs, etc.) across multiple ports. However, there is also room for improvement and the criteria could be further tested. The Port Authority of Valencia has been investigating its own environmental index for years and therefore they could potentially adapt their own conclusions within the PEI algorithm.

4.6.4. Deployment requirements

4.6.4.1. PIXEL Platform

In order to deploy the PEI as a service, a PIXEL platform needs to be ready as previous requirement. This requires 2 virtual machines (VMs), CORE and PUBLIC:

- **Server 1 = VM 1** = we will name it as **PUBLIC**. It will provide access from the outside, if the port wants this feature. In this case, a public IP address or an equivalent mechanism (NAT access) will be required
- **Server 2** = **VM 2** = we will name it as **CORE**. It will include most of the PIXEL core components according to its architecture

The servers/VMs are expected to have the following (virtualized) hardware:

- **4 cores**
- **16 GB RAM**:
- **HD 300-500 GB**

The servers/VMs are expected to have the following software installed:

- **Ubuntu server 18.04 LTS**: Ubuntu is the preferred Linux distribution where the PIXEL platform has been mostly tested. However, any Linux distribution with Docker support should be able to allow the installation.
- **OpenSSH server**: this will allow access for the server to proceed with the installation.

The port is supposed to provide access to both servers/VMs during the installation process, typically in form of **VPN access**. Once logged in, both servers are accessible via **SSH** through their internal (local) IP address. An **admin account for each server** MUST also be provided by ports.

As the amount of installed services will be basically the PEI (no PAS or predictive algorithms), these requirements might be reduced depending of resources availability on VPF premises, especially for the disk space, which given the reduced time frame for testing can be significantly reduced. However, the CORE VM includes an Elasticsearch Docker, which requires at least 8 GB of RAM to function properly (thus 16 GB of RAM for the whole VM).

For the Port of Valencia installation, we propose:

- VM1 (CORE) = 4 cores,16 GB RAM, 120 GB HDD,
- VM2 (PUBLIC) = 4 cores, 8 GB RAM, 120 GB HDD

Important Note: Outgoing traffic should be allowed for HTTP (TCP 80), HTTPS (443) and GIT (9418) in both servers.

4.6.4.2. Data requirements

The PEI requires a minimum amount of **data available in the platform** to proceed with the calculations. How this data is collected is **port specific** and is fully described in PIXEL deliverable D5.3. For the given data there is a need for the creation and integration of enough **NGSI agents** to connect the available data sources to PIXEL's context broker (in the DAL) in the form of eKPIs.

For the port of Valencia, a similar approach was used as for the Port in Thessaloniki (considering the possibility of gathering only a subset to focus on one PEI sub-index), and the following data were identified:

Table 16. Data needed for the Port of Valencia to test the PEI

Data	General comments for NGSI agents
Air Emission - SHIPS	The agent **must run monthly/yearly** and will **encapsulate the data per month**
Waste and wastewater - SHIPS	The agent **must run monthly/yearly** and will **encapsulate the data per month**
Air Emissions - TERM	The agent **must run monthly/yearly** and will **encapsulate the data per month**
Waste - TERM	The agent **must run monthly/yearly** and will **encapsulate the data per month**
Noise GLOBAL	Data is provided through yearly reports; it is unlikely the presence of sensor stations recording values historically. NGSI might potentially also simulate the data from external sources (as done for the Port of Thessaloniki for some years when there was no data) The agent **must run monthly/yearly** and will **encapsulate the data per month**
Light GLOBAL	Data is provided through yearly reports; it is unlikely the presence of sensor stations recording values historically. NGSI might potentially also simulate the data from external sources (as done for the Port of Thessaloniki for some years when there was no data) The agent **must run monthly/yearly** and will **encapsulate the data per month**
Ship calls	Ship calls are needed for the timeframe when the other items (waste, air Emissions, etc. are calculated). This data is typically provided in (near) real-time, including access to historical data.

Once the data has been identified, and without digging in the format, what is important is to check whether the provided information has the relevant items to perform the calculations. For this, UPV provided some examples for each item, as shown in the table below.

Table 17. Data breakdown to identify specific data items

Data Item	Requirements
terminalWaste	1) **List all terminal items by category. Example**: *ENUM_WASTEITEMS = ["end-of-life tyres", "Oils", "mxd municip waste", "Lamps", "Electr.", "Toner", "Sludges", "Oily water", "Batteries", "cherki", "Wooden pack", "Lead Batt", "Absorbents", "Filters", "Scrap ",*

	"Cables","paper pack", "elec. Equip", "mxd pack","Organic", "cont. oil", "waste+oil", "org. chems"] **2) Make the corresponding mapping to general category. Currently used:** *•Non-Hazardous waste: "end-of-life-tyres" (0),"mxd municip waste" (2),"Electr." (4),"Toner" (5),"cherki" (9),"Wooden pack" (10), "Scrap" (14), "Cables" (15) NEW: "paper pack" (16), "elec. Equip" (17), "mxd pack" (18)* *•Hazardous waste: "Oils" (1),"Lamps" (3),"Sludges"(6),"Oily water" (7),"Batteries" (8),"Lead Batt" (11),"Absorbents" (12),"Filters" (13) NEW: "Organic" (19), "cont. oil"(20), "waste+oil" (21), "org. chems" (22)* **3) Provide the corresponding waste quantity (kg, l) by month** *ENUM_MONTHS = ["January", "February", "March", "April", "May", "June", "July", "August", "September", "October", "November", "December"]* 4) **ShipCalls are needed for the needed timeframe (month). Example (in bold needed fields):** *{* *"**imo_code**":" 8918344",* *"**ship_type_category**":"GENERAL CARGO NON SPECIALIZED",* *"**ship_type_class**":"MULTI-DECKER",* *"ship_descr":"IZMAIL ",* *"**date_katapl**":"Dec 19 2019 03:45:00:000PM",* *"date_apopl":null,* *"**time_prosdesi**":"Dec 20 2019 07:35:00:000AM",* *"start_work":"Dec 20 2019 08:40:00:000AM",* *"end_work":"Dec 20 2019 11:00:00:000AM",* *"**time_apodesi**":"Dec 20 2019 02:30:00:000PM",* *"**departure_date**":"Dec 20 2019 02:50:00:000PM",* *"work_descr":" ",* *"work_latin_descr":"DEMBARKATION-UNLOADING ",* *"empr_descr":" ",* *"empor_latin_descr":"COILS-IRON RINGS ",* *"cf_empty":"0",* *"cf_emforta":"0",* *"cf_value":643,* *"**cf_tonnage**":643* *}* *The Port of Valencia already has an online service for historical vessel call at https://www.valenciaportpcs.net/portcalls/search/historic , but it does not provide all needed information (IMO,category, type, timing values)*
shipsWaste	1) **List all ships waste items. Sometimes it is divided in Container Terminal (CT) and Container Cargo Terminal (CCT). Most info should come from MARPOL Annexes** **2) List the used categories. Example:** *ENUM_WASTEITEMS = ["Plastics", "Food waste","Domestic waste", "Cooking oil", "Incinerator ashes", "Operational waste", "Animal carcass-*

	es","Fishing gear","E-waste","Cargo residues -harmful-","Cargo residues - non-harmful-", "Passively fished waste", "Other substances"] *ENUM_WASTEWATERITEMS = ["Oily bilge water","Oily residues -sludge-","Oily tank washings", "Dirty ballast water","Scale and sludge from tank cleaning","Other - oil","NLS - type X","NLS - type Y","NLS - type Z","NLS - other","Sewage"]* **3) Provide the corresponding waste quantity (kg, l) by month** *ENUM_MONTHS = ["January", "February", "March", "April", "May", "June", "July", "August", "September", "October", "November", "December"]* 4) **ShipCalls are needed for the needed timeframe.** *See example as in terminalWaste*
shipsAirEmissions	***1)*** **ShipCalls are needed for the needed timeframe.** *See example as in terminalWaste* **2) Emission factors will be set (automatically) according to various pollutants by category and class** *ENUM_EKPIS = ['CO2', 'NOX', 'PM10', 'PM2.5', 'SO2', 'HC', 'CO', 'N2O', 'CH4']*
terminalAirEmissions	Ports do not typically provide direct information about the terminalAirEmissions, but should be calculated from 1) **Electricity usage (total consumption in kWh) by month**. 2) **Gas usage** (**total consumption in kWh) by month** 3) **ShipCalls are needed for the needed timeframe to get the total tonnage. Example (in bold needed fields)**: *See example as in terminalWaste* For every month, we have a set of eKPIs to consider (twice, one for electricity and another for gas) *ENUM_EKPIS = ['CO2', 'NOX', 'PM10', 'PM2.5', 'SO2', 'HC', 'CO', 'N2O', 'CH4']* Each eKPI is estimated based on a relationship with the following types: *ENUM_EQ_TYPES = ['Straddle carrier', 'Front lift container', 'Large loader', 'Small loader', 'Excavator', 'Forklift', 'Passenger vehicle', 'Tractor', 'Sweeper']*
light	This depends whether the target port has stations to monitor and record values or not. If not, data can be somehow simulated from *[lightpollutionmap.info - World Atlas 2015 record]*
noise	This depends whether the target port has stations to monitor and record values or not. This is typically simulated from annual reports, extending the real calculated values (e.g. of a week) to a whole year.

Based on these data, different NGSI agents were identified to be developed, following a similar methodology as for the Port of Thessaloniki (see deliverable D7.2). They are listed below in form of a summary table.

Table 18. NGSI Agents for Port of Valencia-PEI (I)

Data sources-Agents	PEI - Agents	PEI - Agents
Data source name	**terminalWaste**	**shipsWaste**
Comments	* data ready for **years 2019/2020** * VPF provides data **monthly** * **3 EKPIS** = [ekpi-municipal-solid-waste-terminal, ekpi-inert-waste-terminal, ekpi-hazardous-waste-terminal] * granularity at insertion in **Orion/Elastic** = monthly	* data ready for **years 2019/2020** * VPF provides data **monthly** * **14 EKPIS** =[ekpi-e-waste-ships, ekpi-cargo-residues--harmful--ships, ekpi-passively-fished-waste-ships, ekpi-oily-bilge-water-ships, ekpi-oily-residues--sludge--ships, ekpi-oily-tank-washings-ships, ekpi-dirty-ballast-water-ships, ekpi-scale-and-sludge-from-tank-cleaning-ships, ekpi-other-oil-ships, ekpi-nls-type-x-ships, ekpi-nls-type-y-ships, ekpi-nls-type-z-ships, ekpi-nls-other-ships, ekpi-sewage-ships] * granularity at insertion in **Orion/Elastic** = monthly
SourcePort	SourcePort: **TE**	SourcePort: **SH**

Table 19. NGSI Agents for Port of Valencia-PEI (II)

Data sources-Agents	PEI - Agents	PEI - Agents
Data source name	**shipsAirEmission**	**terminalAirEmission**
Comments	[data inferred from vessel calls] * data ready for **years 2019/2020** * VPF provides data **monthly** * **9 EKPIS** =[ekpi-CO2-ships,ekpi-NOX-ships,ekpi-PM10-ships,ekpi-PM2.5-ships,ekpi-SO2-ship,ekpi-HC-ships,ekpi-CO-ships, ekpi-N2O-ships, ekpi-CH4-ships] * granularity at insertion in **Orion/Elastic** = monthly	[data inferred from gas, electricity consumption, vessel calls] * data ready for **years 2019/2020** * VPF provides data **monthly** * **9 EKPIS** =[ekpi-CO2-terminal, ekpi-NOX-terminal, ekpi-PM10-terminal, ekpi-PM2.5-terminal, ekpi-SO2-terminal, ekpi-HC-terminal, ekpi-CO-terminal, ekpi-N2O-terminal, ekpi-CH4-terminal] * granularity at insertion in **Orion/Elastic** = monthly
SourcePort	SourcePort: **SH**	SourcePort: **TE**

Table 20. NGSI Agents for Port of Valencia-PEI (III)

Data sources-Agents	PEI - Agents	PEI - Agents
Data source name	Light	Noise
Comments	[Based on lightpollutionmap.info - World Atlas 2015 record] * data ready for **years XXX** * VPF provides data **monthly/yearly** * **1 EKPIS** =[ekpi-light-pollution-global] * granularity at insertion in **Orion/Elastic** = inserts eKPIs **every day/month/year**, given a whole year	[simulated from annual reports] * data ready for **years XXX** * VPF provides data **monthly/yearly** * **2 EKPIS** =[ekpi-noise-pollution-lden-global,ekpi-noise-pollution-lnight-global] * granularity at insertion in **Orion/Elastic** = inserts eKPIs **every day/month/year**
SourcePort	SourcePort: **GL**	SourcePort: **GL**

4.6.5. Limitations

For the port of Valencia, after the first contacts with them and once the results in the PIXEL pilots were available, an initial estimation of tasks for transferring the PEI was drafted. The following estimation should be considered tentative as it depends on previous experience, reusability of code and staff dedicated to accomplish the different needed tasks.

1) **Install the PIXEL platform** (**5 days**). Although the installation can be performed in one day, it needs previously allocation of infrastructure resources. If the target company (here Port of Valencia) already has a cloud environment, this time could be reduced. Alternatively, the PIXEL Consortium can share temporarily a testing platform.
2) **Analyse data origins, data available, schema of considered eKPIs (7 days**). Checking the correct data, formats, frequency, etc. is really important and takes some time. If the target company (here Port of Valencia) already has an IoT platform to provide all data in a digital format via an API, this time can be reduced.
3) **Develop NGSI agents (1-2 months**). Depending on the selected data, the format, and the way it is provided, the implementation of NGSI agents may take a considerable amount of time. If already existing agents can be reused from other pilots, this time can be reduced. This is unlikely to happen due to port specifics and the way they provide their data.
4) **Integrate agents into PIXEL DAL and IH (7-15 days)**. Once NGSI agents are implemented and tested locally, they should be deployed in the DAL. Afterwards, one needs to check if the data is arriving properly to the IH (no parsing errors). If already existing agents can be reused from other pilots, this time can be reduced. Once again, this is unlikely to happen and the reusability percentage is typically low according to our experience in the four pilot ports.
5) **Install the PEI model, run or schedule it through the Operational Tools and configure the PEI UI tool (1-3 days)**.

Considering that the final results from WP7 were delayed for various reasons, it was practically impossible to transfer the PEI to an external port until August-September. These were really bad times due to holiday seasons.

With these timing limitations, the transferability process was split into two steps in order to approach realistic results:

- **Initial Proof-of-Concept**: Merge the data of each needed source from a whole year in different files (e.g., JSON files) that will be imported from NGSI agents into the PIXEL platform in the proper format, split by month. The rationale behind this is the **reduction in time needed to perform the integration**, otherwise it seems impossible to provide results on time according to the estimations presented beforehand. The *transferability team* will start collecting data from year 2020 and then, if possible, data from year 2019 to have some internal comparison/evolution for the port of Valencia. Note that the **simplification in this process does not affect nor impact the result of the PEI**, as the data inserted in the PIXEL Platform (Information Hub) to be used by the PEI algorithm will be same.
- **Final Proof-of-Concept**: based on the results of the previous step, the testing platform is extended to include living (real time) data, and NGSI agents can be scheduled properly to collect the data as they are being produced. Additional data sources might be included if they were not available in the previous step (in case they had been simulated or a newly purchased sensor station had been deployed in port's premises)

4.6.6. Evaluation results

At the time of finalising this deliverable we were not given the **minimal amount of data** from the Port of Valencia to adapt the code and provide initial results for the initial Proof-of-Concept. Unfortunately, there has been **much more delay than expected** from the Port of Valencia to provide all data. By the time we get the data, we will perform the calculations and update this section in the future. The new release will be available in the project's website (Deliverables section).

Anyway, some results can be listed below:

- **Analysis study and DTF links.** Early studies from PIXEL ports as well as early contacts with the Port of Valencia allowed to:
  - Better identify **what is available and what not** for the target port. Cross-checking this information with our four ports serves as a new iteration in the way the process could be **changed/adapted/enhanced** to facilitate the transferability for this and future ports.
  - Provide some **score values** according to the **DTF-TA**, considering the limitations. This information is reflected in the Table below.

Table 21. Port of Valencia results. Link with DTF-TA

DTF-TA Concept	Comments
TA-score	**Initial value: 4 (STRONG)** **Final value: 3 (HIGH)** **Rationale:** Though the PEI is potentially applicable to any port, the experience during the four pilots, confirmed with the Port of Valencia, clearly shows a significant number of constraints and barriers detected, even for big ports. **Note:** *The number of constraints/barriers grew during the pilot trials and were likely to be similar to external ports*
EoT/TA-index	**Initial value: +2 (strong support for transferability)** **Final Value: +1 (modest support for transferability)** **Rationale:** *The DTF-TA analysis makes a distinction between TA-index and EoT (Easy of Transferability). The latter is somehow a qualitative value that leads to a quantitative impact on the TA-score. Considering the status on the test in the Port of*

	Valencia, still unfinished, we anticipate, at least, a reduction of one step in the score scale.

- **FAQ**. Through the exchange of viewpoints in the different teleconferences and e-mails with the port of Valencia, we were able to identify some Frequently Asked Questions that might apply to other ports and would facilitate understanding the PEI. They are listed in the Appendix.

4.6.7. Conclusions

Even if the final results are not ready at the time of writing this deliverable, **a lot of work** has been devoted to contacting the Port of Valencia, explaining the pros and cons of the PEI, defining the needed information to be gathered and planning the Proof-of-Concept process. Therefore, some conclusions can be drawn:

- The Port of Valencia is a **big port**, they have their own business calendar and it is really **difficult to catch their attention**. Therefore, it is vital to send a **clear message**, easily understandable by port decision makers and with **real (measurable) value** for them.
- Be careful with the **timing periods**. Due to the previous point, the interest in the PEI might vary throughout time if you start communication too early. Shortening the time is definitely risky, but you should find a **balance to preserve the interest and commitment** during the whole transferability process.
- Sometimes big ports have some sort of **R&D department** *outsourced*, which might act as intermediary and facilitator to engage the port. This was somehow the case here with the ValenciaPort Foundation; they **facilitated the communication** between the port and UPV and could also make the appropriate link in the Port of the Future cluster, as they were members of the COREALIS project.
- **Do not underestimate the time analysing the data provided by ports**, how they provide them, why they provide them in such format and periodicity, and so on. This is never wasted time and will facilitate later the development of code (NGSI agents).
- **Big ports** already have their **own infrastructure** and a way of integrating sensors, thus the PIXEL platform is not perceived as a valuable asset. Depending on the success of PIXEL, the PIXEL platform may evolve to focus on **interoperability** with other (IoT) platforms.

The letter of intent is attached in Annex 2.

4.7. Port of Quebec

4.7.1. Introduction

GPMB collaborates with the Port of Quebec about innovative environmental activities in ports. Indeed, the Port of Quebec is involved **in Green Marine** program and has done several works in the PIXEL context:

- Environmental assessment of the activities of the Port of Bordeaux
- Comparison of the different **environmental LABELS**
- Promotion of PIXEL to **Green Marine**

Obviously, this collaboration allowed the Port of Quebec to discover PIXEL activities and aims for green Ports.

Figure 13. Port of Quebec

The Port of Quebec showed interest during the PIXEL project to this global **quantitative** approach which could be of interest as a beneficial addition to the Green Marine program. Thus the Port Environmental Index (**PEI**) is particularly interesting for the port of Quebec to develop an innovative program with indicators able to show improvements of ports and allow to compare them.

4.7.2. Aim and scope

The Port of Quebec, the oldest port in Canada and the 2nd biggest port, is a real opportunity for **large-scale** PIXEL testing. Then, at the end of the Green Marine discussions during the project, meetings were organized by **GPMB** and **UPV** as soon as PIXEL's GPMB platform was fully operational (June 21, and July 21 for the PEI) to show the benefits of this innovative tool and the facility to use it.

Then two demonstrations were made to the Director of the Environmental Department of Port of Quebec. The aim of the project and details to determine a composite PEI was explained. Answers were given to many technical questions, as well as more global ones regarding efforts and actions to implement PIXEL focussing on the PEI.

4.7.3. Expected impacts

The Port of Quebec expects the followings impacts by testing and using the **PEI**:

- To improve their Green Marine program (Port of Quebec is a founding member of this program) by adding a complementary approach; a quantitative score. This will allow to challenge ports between them to improve the environmental efforts towards excellence.
- To consolidate their position as port leader in innovative projects for the benefit of the environment.

Indeed, the interest of PIXEL is to provide a score based on **physical measurements**, while Green Marine determines its score from levels of **environmental approaches**.

4.7.4. Deployment requirements

The choice of the virtualization of the infrastructure used for PIXEL offers easy replication possibilities to carry out tests quickly; the hosted virtual infrastructure of the GPMB is made up of:

- Server 1: 4 vCPU 16 GB RAM, 150 GB HDD
- Server 2: 8 vCPU 32 GB RAM, 300 GB HDD

Indeed, it's possible **to clone simply** these servers by subscribing new resources to our host, and personalise them to have an infrastructure ready to drive tests for the Port of Quebec.

Then, in a view to have a **minimal scope** of test, some data streams need to be outputted from the PCS of the port of Quebec to PIXEL regarding ship and cargo traffic:

- Agent pixel MVP_DONE (ships arrived and gone)
- Agent pixel MARPOL (ships' waste)

This part was studied, discussed with the Port of Quebec but not developed due to the short time available in September.

Other data sources seemed easier to be entered in forms as part of the assessment test rather than automatically implemented from their PCS.

4.7.5. Limitations

After the second demonstration (July 21), the Port of Quebec was ready to discuss about PIXEL tests to assess their PEI in order to concretely touch the PIXEL interest for them. But the August holidays and the end of PIXEL in September did not make it possible to carry out these tests within the port on time. According to the representative of Port of Quebec, a Proof of Concept deployment can start from October 4th on. Although PIXEL team is motivated and delighted to deliver such an action, it has not been able to be reported through this document. Results will be updated via the website in the next months.

Moreover, a few additional forms must be developed to simplify the implementation of PIXEL for quick and minimalist testing purposes, and thus avoid the implementation of automated information exchange from the PCS of the port of Quebec which would require more time and resources for them.

4.7.6. Conclusions

The Port of Quebec offers a great opportunity to evaluate PIXEL at a larger scale in a port of North America. Moreover, the weight of this port in Green Marine and their interest in regards to the PEI offers real opportunities to convince other ports, members of Green Marine, to adopt PIXEL. Indeed, the PIXEL quantitative solution is a crystal clear complement to the qualitative approach of Green Marine.

However, performing such tests requires at least a few months to define scope and mobilize resources. Unfortunately, Port of Quebec was focused (during the pandemic outbreak) on more compelling actions and, by the time the arrangements were accelerated, PIXEL project time was missing to implement it and October was set as the potential period to carry out the Proof of Concept.

A rapid implementation, on a small perimeter, was therefore studied to easily implement PIXEL for first PEI tests in a record short time: a minimum of few weeks is needed with the team of the Port of Quebec to coordinate implementation and other weeks are needed to implement it before starting evaluation.

The **letter of intent** is attached in Annex 3.

4.8. Vigie Ports (Bayonne and La Rochelle)

4.8.1. Introduction

Figure 14. EIG VIGIE and the French Port Community System VIGIEsip

EIG VIGIE was initiated by GPMB to develop and commercialise the Port Community System VigieSip for small and medium Ports.

The port information system VIGIEsip was initially developed with a view to dematerializing all administrative formalities for the port passage of goods, respecting the European single window directive while managing port rights. Innovative through its ability to adapt quickly to a new environment and to offer tailor-made services to encourage maritime trade, VIGIEsip now equips 20 ports participating in the EIG VIGIE ports and a river port.

EIG VIGIE thus offers a great development opportunity to PIXEL for small and medium French Ports. And even if for the moment PIXEL still seems a little avant-garde for ports of EIG VIGIE, the GPMB succeeded in convincing the nearest regional ports of the interest of PIXEL's PEI in particular in view to acceptance port-city.

GPMB and VIGIEsip Team explored an original way to accelerate and simplify PIXEL tests in others ports using PCS VIGIEsip. Indeed, the virtualisation platform chosen by GPMB to host PIXEL and the management of IT VIGIEsip facilitate the replication of a solution, in particular to interface both.

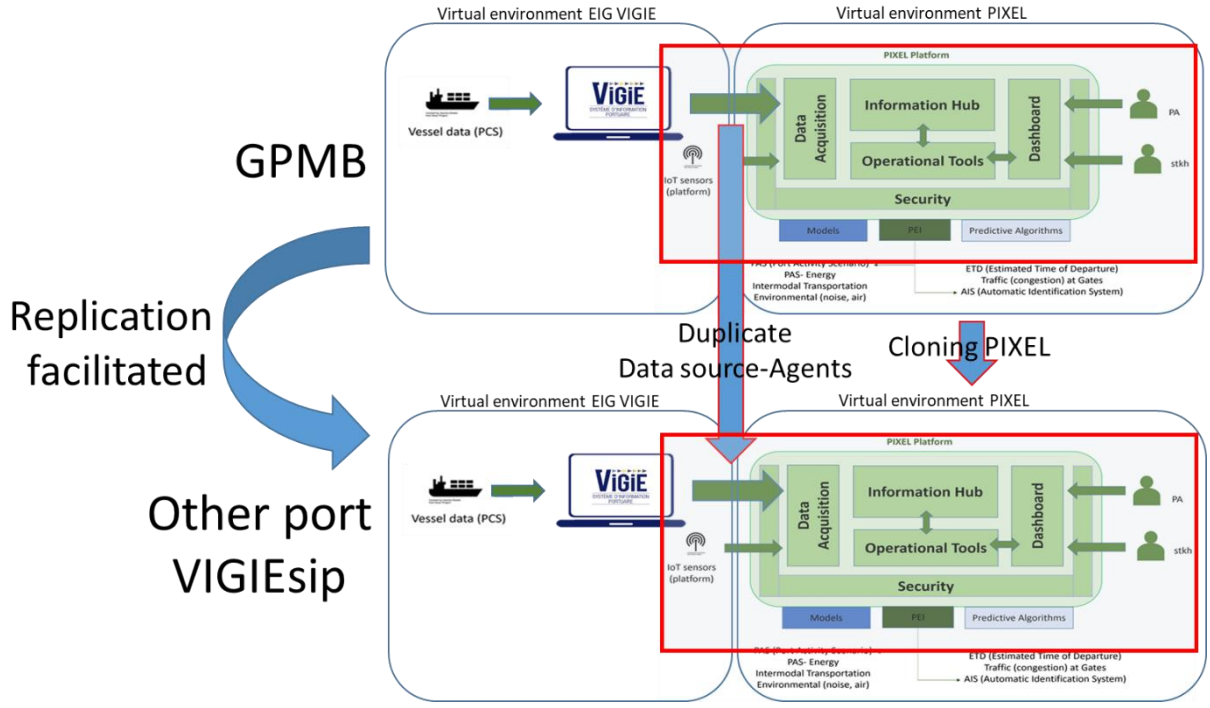

Figure 15. Schema of cloning PIXEL, and duplicate data source-agents

4.8.2. Port of Bayonne

The port of Bayonne, member of the GIE VIGIE, is a regional and cross-border port managed by the Chamber of Commerce and Industry of 3 municipalities of Bayonne. It is ranked 9th among French commercial ports and mainly deals with bulk.

Figure 16. Port of Bayonne

The case of the port of Bayonne is interesting because it is involved in environmental actions. It's the first French port to be triple QSE certified: Quality ISO 9001, OHSAS 18001 for Safety and ISO 14001.

4.8.3. Expected impacts (Bayonne)

The Port of Bayonne is particularly interested in the PEI and expects the following impacts by testing and further using it:

- To consolidate its position of a regional top environmental port
- To have a tool with indicators in order to measure its performance and to be able to benchmark other ports

Moreover, the port is also interested in the energy use case of GPMB, as a decision tool, and wants to continue the discussion about our use of it.

4.8.4. Port of La Rochelle

The Port of La Rochelle is the 6th major maritime port with a traffic of 10 million tonnes. Its activity is mainly composed of petroleum products, forestry and agricultural bulk

Figure 17. Port of La Rochelle

4.8.5. Expected impacts (La Rochelle)

The Port of Bayonne expects the following impacts by testing and further using the PEI:

- To consolidate its position as a port involved in environmental actions
- To have a tool with indicators in order to measure its performance

4.8.6. Deployment requirements to test PEI

The Ports of Bayonne and La Rochelle are members of EIG VIGIE and both use VIGIEsip. Thus, the replication of developments carried out for the GPMB pilot are simplified because the VIGIEsip database (structure) of other ports is the same as the one of GPMB for basic activities.

4.8.7. Limitations

GPMB and the VIGIEsip team studied an initial estimation of efforts to easily test PIXEL's PEI in other ports members of EIG VIGIE. This approach explored mainly possibilities of cloning the virtual platform of PIXEL and replicating data source-agents of VIGIE in order to simplify tests. This approach is not as relevant as an installation of PIXEL accompanied by developments tailored of NGSI agents; however, this in situ testing solution on the same perimeter of the GPMB has the great advantage of being the **fastest way to deploy**; a very good compromise between much reduced installation efforts and an acceptable operational perimeter for evaluation tests in a new port. Indeed, discussions with other ports show that they have real difficulties in mobilizing time and coordinating the various functional and technical teams necessary for carrying out the tests.

The following tentative time plan was drafted:

- **Duplicate PIXEL** and **VIGIEsip** platform (1 day)
- **Personalize PIXEL** and **VIGIEsip** platform (2 days), in particular data source-agents:
    - Agent pixel TIDE (tide level each minute – if available and needed)
    - Agent VIGIEsip MVP_PLANNED (ships planned)
    - Agent VIGIEsip MVP_DONE (ships arrived and gone)
    - Agent VIGIEsip MARPOL (ships' waste)
- **Analyse** data available and schema of considering eKPIs (5 days)
- **Install sensors** (same as GPMB - 3 days)
- **Develop input forms** for data not already present in VIGIE (5 days)
- **Adjust the PEI model, run or schedule** it through the Operational Tools and configure the PEI UI tool (1-3 days).

Encountered difficulties have been lack of time between the moment where the GPMB platform was fully operational (June 21 and July 21 for the PEI) and the end of PIXEL program in September 21. Indeed, the rapid deployment solution still requires time for discussions with the other ports to explain the process, understand the expectations and prepare the actions.

Other meetings are planned for October in order to continue the process and prepare for future tests, but by the moment of closing this deliverable no actual PoC deployment could be carried out within the framework of the PIXEL program despite all the efforts of the GPMB.

4.8.8. Conclusions

The EIG VIGIE network of ports opens an interesting door to reach the small and medium-sized ports which benefit from few resources and which wish to benefit from the innovation work carried out by the GPMB. And

if the PIXEL program did not make it possible to have a demonstrator sufficiently early to make demonstrations and consider tests in other ports, the message nevertheless passed to the ports, and the use case of Bordeaux has been shown. The interest it has arisen in the first two ports has been real both in its innovation approach and in concrete terms with the results of the GPMB's PEI.

Therefore, some conclusions can be drawn:

- **Awareness of the interest** of the PIXEL program among small and medium-sized ports requires taking the step of a forward-thinking solution. In fact, the majority of ports are concentrated on operations and daily life. Significant prior awareness raising work is required.
- Small and medium ports **have issues to mobilize time and their teams** for exploration actions (PIXEL tests); then it seems important to provide a **very simple and rapid deployment** solution to make tests in order to facilitate acceptance of experience (PIXEL deployment and tests).
- The **PEI** appears to be the **focal point of interest of PIXEL**. It can be strategic to put it forward so as not to confuse the message of too many functionalities.
- Small and medium ports have little or no human and technical resources. **Significant support** is expected.
- The great **uniformity of VIGIE** installations facilitate the **replication** of the **PIXEL** solution in other ports, in particular thanks to the facilitated replication of NGSI agents

The letter of intent is attached in Annex 4 (Port of La Rochelle).

The letter of intent is attached in Annex 5 (Port of Bayonne).

4.9. Other ports

4.9.1. Generalization to Spanish port

4.9.1.1. Port of Algeciras

The Port of Algeciras Bay is the largest urban area on the Bay of Gibraltar. The Port of Algeciras Bay is the one of the busiest port in Spain and Top 20 port in the world. Located 20 kilometers north of the southernmost town in the Iberian Peninsula, the Port of Algeciras Bay is an industrial center, transportation hub, and the focal point for ships going to Tangier, Morocco, and the Canary Islands. The port is managed by the Algeciras Bay Port Authority (APBA by its name in Spanish).

Figure 18. Port of Algeciras

PIXEL staff contacted APBA environmental and IT projects departments and arranged a series of meetings to explain the work done during the H2020 project and exploring the possibilities of extending the concepts according APBA strategic plan and short or mid-term needs.

The meetings had as a result great expectation by the target customers and a overall approval of the topics, techniques and methods addressed in the project. As a first integration experience, PIXEL staff prepared an integration with APBA's PCS data plus a PAS model created with the advise of the APBA projects department staff, with these data sources, it could be established a working version of the PEI, with the logical limitations of a tight timetable, and access to data (as for instance no access to terminals' data).

One special interest manifested by APBA was the modelling of energy production/consumption prediction models. The port is switching to greener energies as much as possible (considering that due to reasons of yard space is not possible to generate 100% green energy withing the port area), and this is a strategic priority. The port is strongly investing in the adaptation of the docks and berthing areas to electrify and modernize all the supplies, so they showed special interest in having a way to estimate the supply of energy in advance, to improve planning and adapt the production accordingly. In addition, APBA was considerably interested in testing PEI (or at least a sub-set of the indicators that are provided by the tool), for which some sample data was explored and discussed and a proof of concept will be tackled in the forthcoming months.

Potential further activities will also be analysed under the scope of PIXEL Association.

4.9.1.2. Port of Vigo

The Port of Vigo is one of Europe's most important fishing ports. Located in the Province of Galicia on the Vigo Inlet off the Atlantic Ocean and just over 20 miles north of Spain's border with Portugal, it is Spain's largest non-capital city. In 2007, almost 300 thousand people lived in the Port of Vigo. The management entity for the Port of Vigo is the Vigo Port Authority (APV)

Figure 19. Port of Vigo

PIXEL members contacted with the APV once the results of the project were successfully assessed in the participant ports' pilots. Interestingly, Port of Vigo is a partner of PIXEL's sistering project PortForward. The first meeting with APV representatives (coming from R&D projects and environmental actions departments), revealed the multiple synergies between PIXEL actions and APV activities inside and outside PortForward. As a first initiative, PIXEL staff agreed to participate as research consultant in forthcoming activities of the project, bringing expertise in IoT sensing devices and the PEI calculation, during the remaining period of execution of PortForward (until April 2022). The idea is to integrate PEI, PAS and vessel calls- related models within the PortForward platform so APV can benefit and assess the synergies of the two projects.

On the other hand, APV also was strongly interested in the energy production/consumption prediction algorithms for similar reasons as described by APBA. They are betting heavily on clean energy production and there is a need on estimating the consumption in advance to 1) dimension the needed equipment and 2) adapt the daily operations to the new energy supply methods.

At the time of the release of this deliverable, PIXEL staff keeps in contact with both Port Authorities in order to improve the collaboration and make the most of the PIXEL results on their respective ports. Any advancements due beyond this date will be reported on the Final Review meeting.

4.9.2. External testing in the Port of Trieste

During the development of PIXEL, in order to fulfil the provision of T8.4, ASPM got in touch with the Port Network Authority of the Eastern Adriatic Sea - Port of Trieste to introduce them to the PIXEL project.

At that time, the ASPM was a public equivalent body that was established by the Chamber of Commerce, Industry, Handicrafts and Agriculture of Gorizia as its technical branch to promote the Port of Monfalcone and its activities. The ASPM, thanks to specific procurements from the Regional Government, had the responsibility of important tasks as the managing of the port security system and the maintenance of some specific port areas. The ASPM was the owner of the 38% of the port area equipped with sheds and warehouses, directional buildings and public services. Thank to this role the ASPM well represented the port of Monfalcone inside PIXEL Consortium and had been capable to provide the data, procedures and IoT connections needed to implement the PIXEL platform in the Port of Monfalcone.

The Port Network Authority of the Eastern Adriatic Sea - Port of Trieste expressed a general interest over the main activities of the project, therefore the ASPM - with the help of INSIEL, its technical partner in PIXEL - went deeper in describing to the IT department of the Port the modelling activities that were ongoing, pointing out the two pilot actions in which the Port of Monfalcone was directly involved: the intermodal pilot and the PEI pilot.

The IT Department confirmed the interest to follow the project activities and evaluate the possibility to test a specific model in their port, but PIXEL, at that time, was still in an early stage.

In the meanwhile, the Port Network Authority of the Eastern Adriatic Sea extended its competence to the Port of Monfalcone and started discussing with the ASPM in order to acquire its assets. On the 29th of October 2020, the assets of the ASPM have been sold by the Chamber of Commerce of Venezia Giulia to the Port Network Authority of the Eastern Adriatic Sea. The act became effective from the 1st of November. The contract refers to nearly the 100% of the agency (buildings, areas and personnel) -PIXEL participation included-.

Therefore, the Port Network Authority of the Eastern Adriatic Sea became part of the PIXEL consortium as “PP16 -APT”.

The Port Network Authority of the Eastern Adriatic Sea is a public body having as its primary task to direct, plan, coordinate, promote and control port operations and commercial and industrial activities in the ports of Trieste and Monfalcone.

Since November 2020, APT has been involved in PIXEL activities and went deeper in the evaluation of the models that could have been tested in Trieste.

Typically, to test one of the PIXEL models in an external organization, the following path should be implemented:

(i) PIXEL technical partners develop a platform and several models/Port Activity Scenarios;
(ii) PIXEL ports test both and learn how to use them;
(iii) PIXEL ports try to test/transfer it in external ports, typically in any port from their cluster or regional network.

Due to COVID pandemic consequences, and extension of the project time plan, a delay on the full integration and testing of the platform in the port occurred. Although the interest of the Port of Trieste was active during this period, the efforts of the personnel devoted to the project were focused on polishing functional and usability issues that were being experienced during the las months of WP7 (till July 2021) and also during the evaluation of the whole tool in the port (W^P8 till September 2021). Unfortunately, the resources that could be allocated to such action were rather limited and the time constraint was a decisive factor to decide dropping the PoC tentative of PIXEL-Port of Trieste. The Port of Monfalcone should be consulted.

Despite the fact that the two ports are currently under the control of the same Port Network Authority, the sites are completely different, both in terms of dimensions, port organization and PCS: the port activities of the Port of Monfalcone are executed on a public berth of 1.5 km while the port of Trieste has 12 km of berths divided into terminals; the port of Monfalcone has no port community system while in Trieste we can find a high level of digitalisation in all procedures, thanks to a state of the art PCS.

To elaborate the previous, after all those facts and their effect over the testing phase have been evaluated, the IT Department of the Port of Trieste highlighted the lack of time, personnel and resources to start testing any of the PIXEL models in an IT environment far more complex than the one present in the Port of Monfalcone, in a such tight time.

Unfortunately, these facts, represented by the Port of Trieste, highlighted the scenario already described as “Risk 19” in the GA: the participation of external ports in transferability tasks is out of the control of the project Consortium. This risk is more critical where the complexity of the proposed system grows and the time available to test it decreases. This risk management action will be properly reported in the Project Final Report to be delivered before the Final Review of the project.

Conclusions

This document describes in detail the **transferability methodology** to be used when any of the PIXEL assets (PIXEL platform, PEI, PAS, Maritime Analytics, Traffic Prediction) is to be tested in an external port. The methodology is somehow **aligned with the CSA DTF TA-Analysis**, but is more simple, practical and useful. Instead of complex aspects proposed by the CSA, the methodology clearly points out simple and direct aspects to be covered in each step of the transferability process (*aim and scope, expected impacts, deployment requirements, limitations, evaluation results and conclusions*) that are easy to understand and provide by a given external port.

The **methodology** is intended to be able to be performed by a port, with (almost) no support from the PIXEL Consortium, as the PIXEL assets are already available and described in terms of requirements (infrastructure, technical). However, in order to reach such **goal of independence**, some external trials need to be performed in advance with the PIXEL assistance. The PIXEL Consortium approached **13 ports**, but due to administrative issues (permissions, data availability, slow decision making procedures) and time constraints, it has not been possible to perform full-scale deployments of PIXEL in external ports. However, case studies, methodology, requirements, equipment and time needed were discussed with 5 ports, which led the team to obtain promising letters of intent. Nonetheless, some of the previous actions have redounded in actual commitments of deployment that will conclude them soon as soon as the (external) ports **provide all needed data**. Note that for the PIXEL assets to be tested, it takes some time to collect all data.

Future research directions were also analysed in-depth in this deliverable, covering three periods and identifying research areas and research topics for each one:

- **Background period** (until 2015)
- **Current state** (2015-2020)
- **Future trends** (2020-2030)

A **summary table** is provided for each period, as well as the **contributions of PIXEL** (*publications and conferences*) for the identified research areas/topics.

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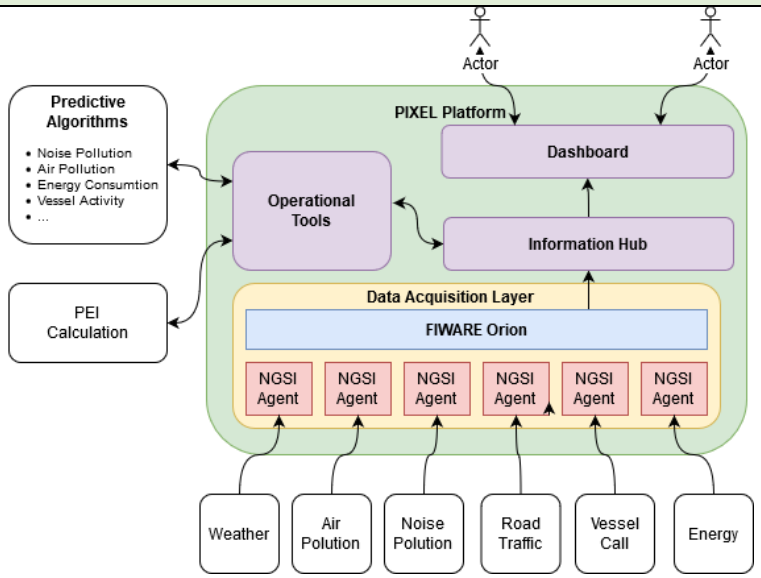
Appendix 1. PIXEL Platform asset

Item	*Sub-Items (if any)*	*Comments*
General description		 *The Pixel platform is a complete data IoT management platform that provides all the features needed to run the PIXEL project. The platform allows to collect data from heterogeneous data sources like IoT, IoT Platforms, Port ICT and other external API providers. The data is stored in a flexible data hub and is accessible to all the models and algorithms deployed in the platform. The platform also provides a complete dashboard to visualize and manage all the features.*
Business perspective		*The PIXEL platform provides the full features needed to run the different Models developed for PIXEL. It provides a ready to run solution to collect data and run those models. It is a quick and flexible solution to benefits of the PIXEL Models even if the port already has a data management platform.*
Involved PIXEL ports		*GPMB, PPA, THPA, APT*
Requirements	Hardware	*PIXEL as a whole (all modules and configurations included) requires the following:* *• 2 virtual machines (VM), CORE and PUBLIC. Each of them must have:* *o 4 cores* *o 16GB RAM* *o HD 300-500 GB* *Depending on the quantity of inputs (number of vessels calls) the PAS model takes more time to run (between 1 min to 5 min (for a year of data))*

	Software - General	*To run just PAS as a model, Docker (and enough HW resources would be enough). As it has been said, it is considered to be run using PIXEL, therefore the software requirements are:* *• OpenSSH* *• FIWARE ORION (included in DAL)* *• ELK stack (Elasticsearch, Logstash, Kibana), Apache Kafka and Zookeeper (included in Information Hub)* *• FIWARE KeyRock and Wilma (included in the PIXEL Security module)* *• Vue.js, Apache eCharts, FIWARE ElastAlert (included in the Dashboard)* *• Nagios and MySQL* *For running the agents, again Docker + Data Acquisition Layer should be enough. If it is selected to run agents isolatedly, then a compiler/executor of the language used must exist (in general, Python). If the pyngsi library (developed by ORANGE for facilitating the development of NGSI agents) is used, it also must be installed*
	Software - PIXEL dependencies	*PIXEL Platform is a full features platform. But to be able to use all of those features, you need to deploy NGSI Agents to collect your Data Sources and deploy the different Models like PAS or PEI useful for your use-case*
	Data requirements	*The PIXEL don't need specific data sources. You have to deploy the NGSI Agent needed for the different models you want to run*
	Code Adaptation	*The deployment might need to be adapted to match the infrastructure capabilities like for INSIEL/Monfalcone that manage their own Reverse Proxy. But most of the adaptation refers to deploying NGSI Agents and models*
	Staff Skills	*The PIXEL Platform is a complex micro services like platform deployed using docker-compose. In order to be able to manage a PIXEL platform you need a good understanding of the PIXEL Architecture and the docker management.* *A good understanding of the roles of each components is also mandatory for troubleshooting*
	Timing	*The installation of the full PIXEL platform using docker-compose takes less than half a day for the first installation. After that updating the platform take less than 15 minutes.* *Deployment of NGSI Agents or Models could take between 15 minutes to 1 hour depending of its integration status*
Source code		*The Installation process is here https://gitpixel.satrdlab.upv.es/marc.despland/Installation with all the files needed to perform the installation using docker-compose*
License		
Documentation	Installation Manual	https://gitpixel.satrdlab.upv.es/marc.despland/Installation
	User manual	https://pixel-ports.readthedocs.io/en/latest/
	Other manuals & tutorials	*https://github.com/pixel-ports/docs-hub-dal/blob/master/docs/ngsiagent_cookbook.md* https://youtu.be/EA57OY3hDWU
Support		*Marc Despland (marc.despland@orange.com)*

Appendix 2. PIXEL PEI asset

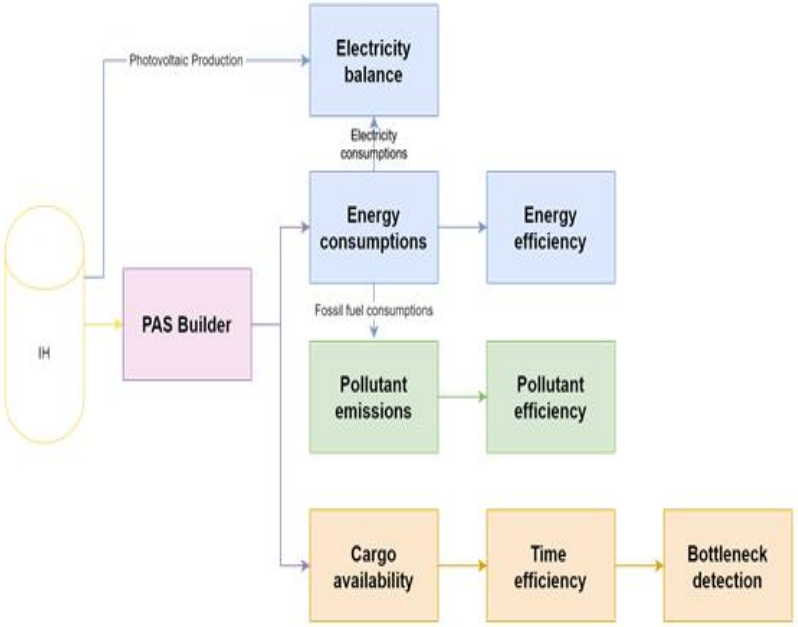
Item	*Sub-Items (if any)*	*Comments*
General description		*This pre-product represents in a user-friendly, joint view the environmental impact of the port based on the methodology established in PIXEL. The methodology roots in the acquisition of different data (from varying sources) related to several environmental domains (air pollution, waste, wastewater, noise, light and odour) and the application of a series of mathematical operations (sub-indexing, normalization, weighting and aggregation). The results are a series of individual indicators (so-called eKPIS - environmental KPIs) that, after such combination, redound on a single composite index: the PEI (Port Environmental Index).*
Business perspective		*PEI is a global quantitative environmental index fed on a variety of data types (including real-time), allowing ports to access the progress of their own environmental performance. This method enables flexibility and scalability in monitoring environmental performance in real-time through the IoT infrastructure at the port.* *(1) Ports can have a reliable measure of their environmental footprint and so they can plan actions to reduce it to the desired levels* *(2) The environmental efficiency in PEI is segmented by different categories of emissions and pollutants and can be monitored per category* *(3) The measurements are valid across ports of all sizes and data infrastructure capabilities, allowing to increment accuracy with better data input*
Involved PIXEL ports		*GPMB, APT, PPA, THPA.*
Requirements	Hardware	*PIXEL as a whole (all modules and configurations included) requires the following:* *• 2 virtual machines (VM), CORE and PUBLIC. Each of them must have:* *o 4 cores* *o 16GB RAM* *o HD 300-500 GB* *According to the tests conducted in the context of D8.3, the PEI model can be represented (in terms of HW resources consumption):* *• Mean CPU usage: 16.35% (if PEI scheduled monthly), 17.2% (if PEI scheduled yearly)* *• Mean memory usage: 23 MB (monthly), 35.4 MB (yearly)* *Finally, the PEI also requires the execution of a series of NGSI agents (normally, between 4 and 10) that will also run in the same server (PUBLIC virtual machine). It is expected that the requirements stated above will be enough to run such agents.*

	Software - General	*To run just PEI as a model, Docker (and enough HW resources would be enough). As it has been said, it is considered to be run using PIXEL, therefore the software requirements are:* *• OpenSSH* *• FIWARE ORION (included in DAL)* *• ELK stack (Elasticsearch, Logstash, Kibana), Apache Kafka and Zookeeper (included in Information Hub)* *• FIWARE KeyRock and Wilma (included in the PIXEL Security module)* *• Vue.js, Apache eCharts, FIWARE ElastAlert (included in the Dashboard)* *• Nagios and MySQL* *For running the agents, again Docker + Data Acquisition Layer should be enough. If it is selected to run agents isolatedly, then a compiler/executor of the language used must exist (in general, Python). If the pyngsi library (developed by ORANGE for facilitating the development of NGSI agents) is used, it also must be installed*
	Software - PIXEL dependencies	*Being part of the PIXEL project, the PEI has been developed making use of its basic components, then relying on Data Acquisition Layer, Information Hub, etc. Although the PEI as a model has been conceived to be used standalone (outside of PIXEL), in this table it is assumed that PEI will also be used by a port upon PIXEL basic infrastructure. In addition, the PEI may make use of the following PIXEL products (models):* *• PAS model, as the tool for estimating Air Pollution associated to the activities of the port terminal. If this option is selected, an additional agent is needed.* *• PARES model, to make use of AIS data to obtain berthing and manoeuvring time per vessel. This has not been tested in PIXEL as no pilot needed it. This would also need a special agent and, of course, data obtained from AIS technology (via AIS antenna or via subscription to external services such as MarineTraffic or VesselTracker)*
	Data requirements	*Data related to ship-calls (arrival and departure time, cargo type, etc.), waste at ships and terminals, light pollution, etc. As the way data is collected, we encourage you to check the section 1 of deliverable D5.3: https://pixel-ports.eu/wp-content/uploads/2020/07/D5.3-PEI-Definition-and-Algorithms-v2.pdf* *It explains clearly how data is identified and collected for 4 different ports.*

	Code Adaptation	*The PEI as a model does not need to be adapted. It will be used as a Docker image (model) loaded from the Operational Tools and scheduled through them.* *The only code adaptation (actually, pure development) needed is the creation and integration of enough NGSI agents to connect the data sources to PIXEL's context broker (in the DAL) in the form of eKPIs.* *What a port will need to do before tackling the development of agents is:* *• Analysing which of the eKPIs apply to their case* *• Analysing which of the "data origins" apply to their case (e.g., dropping the "terminal" eKPIs as the user will only be the Port Authority).* *• Obtaining, from the previous, a final list of eKPIs to be feeding the PEI.* *• Analysing which data is needed to obtain those eKPIs.* *• Identifying (some consultancy action may be needed from PIXEL partners here) which must be the proper process in each case to convert from raw data to eKPIs (involving units, pre-processing, associated reliability rating – check deliverable D5.3).* *Only then the agents can be coded. A guide on how to create agents can be found here. Some examples have been developed in PIXEL and may be provided by partners if (and only if) the exploitation analysis (on-going, WP9) agrees on their publication.* *Afterwards, the agents must be connected to PIXEL infrastructure and integrated into the IH. A guide for doing so is here:.* *https://github.com/pixel-ports/docs-hub-dal/blob/master/docs/ngsiagent_cookbook.md* *To check whether the data is being properly retrieved and stored, the responsible for the deployment in the port should check the Information Hub registries (e.g via Kibana).*
	Staff Skills	*- Development responsible: Knowledge of implementing IoT agents, preferably Python and familiar with pyngsi (most agents in PIXEL have been implemented using this library)* *- Deployment responsible: Knowledge of UNIX systems (preferably LINUX) and basic IT deployment skills, including networking.* *- Environmental Manager (or responsible for the PEI configuration): Knowledge on environmental procedures, such as the current relevant eKPIs for the port and which normalization (and other editable mathematical operations) should be applied.* *- Port Manager (or end-user): Skills to manage the UI and interpret the results for the port.*

	Timing	*The following estimation should be considered for guidance only as it depends on previous experience, reusability of code and staff dedicated to accomplish the different needed tasks* *1a. Install the PIXEL platform (5 days). Although the installation can be performed in one day, it needs previously allocation of infrastructure resources. If your company already has a cloud environment, this time can be reduced.* *1b. Analyse data origins, data available, schema of considered eKPIs (7 days). Checking the correct data, formats, frequency, etc. is really important and takes some time. If your company already has an IoT platform to provide all data in a digital format via an API, this time can be reduced.* *2. Develop NGSI agents (1-2 months). Depending on the selected data, the format, and the way it is provided, the implementation of NGSI agents may take a considerable amount of time. If you can re-use already existing agents, this time can be reduced.* *3. Integrate agents into PIXEL DAL and IH (7-15 days). Once NGSI agents are implemented and tested locally, they should be deployed in the DAL. Afterwards, one needs to check if the data is arriving properly to the IH (no parsing errors). If you can re-use already existing agents, this time can be reduced.* *4. Install the PEI model, run or schedule Operational Tools and configure the PEI UI tool (1-3 days).*
Source code		*Currently the code (PEI model, NGSI agents) is available under a private repository (external companies will need to have credentials or be assisted by PIXEL partners)* *The Docker instance for the PEI model is available at pixelh2020/pei:1.0 (this is common for all ports)* *The Docker instances of several NGSI agents are also available in the pixelh2020 dockerhub repository, but they are specific to each port (code needs to be adapted for re-use)*
License		*Apache 2.0*
Documentation	Installation Manual	*The PEI model is installed as any other model and prediction algorithm through the Dashboard and/or Operational Tools: https://docs-hub-dashboard.readthedocs.io/en/latest/user_guide/#operational-tools*
	User manual	*Currently there is no online documentation yet, but you can check deliverable D7.2 (PEI section)* *PEI description (YouTube): https://youtu.be/Vmmiv71XKOE* *PEI webinar (YouTube): https://youtu.be/-M-Au5DW9fw*
	Other manuals & tutorials	*Installation of the platform: https://gitpixel.satrdlab.upv.es/marc.despland/Installation* *Deployment of NGSI agents: https://github.com/pixel-ports/docs-hub-dal/blob/master/docs/ngsiagent_cookbook.md* *General documentation https://pixel-ports.readthedocs.io/en/latest/*
Support		*Contact person: Ignacio Lacalle (UPV)* *Email: iglaub@upv.es (preferred channel).*

Appendix 3. PIXEL PAS asset

Item	*Sub-Items (if any)*	*Comments*
General description		 *The Port Activities Scenario (PAS), combined with the energy model and emission factors, is a transferable and applicable tool for small and medium European ports that allows to model port supply chains.). The knowledge and modelling of the supply chain and port activities (machine type, duration of use, position in the port) enable the building of activity scenarios that are used to identify the energy sources and local emissions of pollutants but also to estimate the flow of cargo entering or leaving the port. Using this approach, the resulting modelling scenario might be used by the ports as a support for decision making. PAS and energy models have been used in order to be able to simulate the energy consumption related to the port activities and the related pollutants emissions. Thus the output of the PAS and energy models can be used as an input for the Port Environmental Index in order to calculate air emissions eKPIs.*
Business perspective		 *The Port Activity Scenario (to be used as a model within PIXEL or outside the platform as a standalone tool) can be utilized to i) model and ii) simulate a maritime port terminal. The PAS allows to i) "predict" the behaviour of terminal, ii) forecasting how time it will take to operate each unit, and iii) how much energy will be used to do so and the internal operations required. The previous will allow port operators (and actually upcoming elements in the supply chain) to plan ahead and minimize round-trip-time. Additionally, PAS is providing information that can be distributed in the internet regarding the expected timing of ports operations (such as loading and unloading of vessels) that can impact the logistics chain as well as their surrounding communities, through Port Community Systems. Thus, it can then be used to normalize a logistics chain, minimize storage times, warn about*

		upcoming traffic, etc. The modularity of PIXEL allows PAS to connect and provide data to multiple models (calculation modules).
Involved PIXEL ports		*GPMB, PPA, THPA, APT*
Requirements	Hardware	*PIXEL as a whole (all modules and configurations included) requires the following:* *• 2 virtual machines (VM), CORE and PUBLIC. Each of them must have:* *o 4 cores* *o 16GB RAM* *o HD 300-500 GB* *Depending on the quantity of inputs (number of vessels calls) the PAS model take more time to run (between 1min to 5 min (for a year of data))*
	Software - General	*To run just PAS as a model, Docker (and enough HW resources would be enough). As it has been said, it is considered to be run using PIXEL, therefore the software requirements are:* *• OpenSSH* *• FIWARE ORION (included in DAL)* *• ELK stack (Elasticsearch, Logstash, Kibana), Apache Kafka and Zookeeper (included in Information Hub)* *• FIWARE KeyRock and Wilma (included in the PIXEL Security module)* *• Vue.js, Apache eCharts, FIWARE ElastAlert (included in the Dashboard)* *• Nagios and MySQL* *For running the agents, again Docker + Data Acquisition Layer should be enough. If it is selected to run agents isolatedly, then a compiler/executor of the language used must exist (in general, Python). If the pyngsi library (developed by ORANGE for facilitating the development of NGSI agents) is used, it also must be installed*
	Software - PIXEL dependencies	*Being part of the PIXEL project, the PAS has been developed making use of its basic components, then relying on Data Acquisition Layer, Information Hub, etc. Although the PAS as a model has been conceived to be used standalone (outside of PIXEL), in this table it is assumed that PAS will also be used by a port upon PIXEL basic infrastructure.* *In addition, the PAS use the following PIXEL products (models):* *• PIXEL Dashboard and PAS forms that have been design to have a user-friendly GUI to help ports defining their supply chains, operations, machines, energy used, ...* *• PIXEL Operational Tools that are used to schedule the PAS model execution*

	Data requirements	*To run the PAS model the following prerequisites are necessary:* *• Deploy an NGSI agent for the vessel calls that is compliant with the associated Data Model (https://gitpixel.satrdlab.upv.es/marc.despland/DataModels/src/master/DataModels/VesselCall.md).Once the NGSI agent has been developed, nothing is expected from the end-users. The PAS model will then automatically retrieve the vessel call from the Information Hub for the time period defined by the user.* *• Push the "setting file" in the Information Hub. This setting file is used to define the timestamp format of vessel call, PAS module to activate. For example, it is used to activate or not the delay of operations based on constraints defined by users (number of machines, area occupancy, ...).* *• Fulfill the PAS forms. For doing this each port has modelled their port activities by describing: type of energy used, machine specifications, sequence of operations associated with a type of cargo, areas where the operation happened, ... This description of the port activities takes some time and has to be done by port agents with an expertise on how the port works. However it only has to be done once.*
	Code Adaptation	*List/Explain if the pre-product requires some code adaptation for each port (e.g. traffic PA may require additional regressors)*
	Staff Skills	*The main effort to be done in order to run the PAS model is to be able to model the port activities. Depending on the level of accuracy needed for the PAS output, the accuracy of the port activities description must be adapted. Once the vessel calls agent is running and once the PAS forms have been fulfilled, the PAS model is able to run in an automatic way. However, if the input data are poor in quality the PAS output will just give some order of magnitude. On the contrary if the PAS forms have a fine level of detail, the PAS outputs will be able to give more realistic results.*
	Timing	*Try to provide an estimation of the amount of time needed to:* ** install the pre-product/component* ** install and configure the needed data* ** do a basic test to check the pre-product/component* ** any additional analysis of (historical) data to provide valid input*
Source code		*The Docker instance for the PAS model is available at* https://hub.docker.com/r/erwansimon/pas_model *The source code is available at* https://gitpixel.satrdlab.upv.es/Erwan/pas_modelling
License		*Apache 2.0*
Documentation	Installation Manual	https://pas-model.readthedocs.io/en/latest/
	User manual	https://pas-model.readthedocs.io/en/latest/
	Other manuals & tutorials	Supply Chain Modelling As A Transversal Tool:Port Activity Scenario Model https://www.youtube.com/watch?v=4QNn_xGcnK4 Port Digitalization Through an Activities Scenario Model as a First Step for a Digital Twin of Port https://pixel-ports.eu/wp-content/uploads/2021/06/20210615_IPIC_CATIE.pdf
Support		*Erwan Simon (e.simon@catie.fr), Charles Garnier (c.garnier@catie.fr)*

Appendix 4. PIXEL Maritime Analytics

Item	*Sub-Items (if any)*	*Comments*
General description		*Powerful algorithms feeding on different types of data sources (based on FAL forms) that improve the business intelligence at the port, enhancing ETD and other optimizations of vessel traffic and manoeuvring with machine learning methods towards port digitalisation.*
Business perspective		*(1) improves ETD, helping to plan arrival/departure times to minimize congestion at the port, optimising costs/gains* *(2) improve resources and monitor waiting times for vessel voyage, as well as port operation resources* *(3) improves the business intelligence at the port based on optimized AIS data openly accessible*
Involved PIXEL ports		*ASPM, THPA, PPA, GMPB*
Requirements	Hardware	*Recommended: 4 core server with 8GBb RAM, 20Gb disk space*
	Software - General	*Dockerised (just need docker support)*
	Software - PIXEL dependencies	*Information Hub*
	Data requirements	*Vessel call data (FAL forms)*
	Code Adaptation	*If data is standard there is no need of re-adaptation, only retraining*
	Staff Skills	*Deployed through Operational Tools, just need to use Dashboard*
	Timing	*No particular timing, is part of PIXEL platform*
Source code		
License		*Commercial license*
Documentation	Installation Manual	*https://pixel-ports.readthedocs.io/en/latest/#predictive-algorithms-pas*
	User manual	*https://pixel-ports.readthedocs.io/en/latest/#predictive-algorithms-pas*
	Other manuals & tutorials	*video to be recorded*
Support		*Contact person: Joao Costa (XLAB)* *Email: joao.pitacosta@xlab.si (preferred channel).* *Skype ID: joao.pitacosta@xlab.si* *GitHub profile: joaopitacosta*

Appendix 5. PIXEL Traffic Prediction Algorithm asset

Item	*Sub-Items (if any)*	*Comments*
General description		*Predictive algorithms based on traffic volume and average velocity, that allow ports and logistic nodes to better plan road transport and improve the port-city dynamics and environmental performance.*
Business perspective		*(1) allows to compare economic and environmental time impacts of different transport mode* *(2) supports the planning of port transport operations monitoring the environmental impacts* *(3) can support a shared planning of freight transport with business operators in order to reduce the impact on hinterland and environment*
Involved PIXEL ports		*ASPM, THPA, PPA, GMPB*
Requirements	Hardware	*Recommended: 4 core server with 8GBb RAM, 20Gb disk space*
	Software - General	*Dockerised (just need docker support)*
	Software - PIXEL dependencies	*Information Hub*
	Data requirements	*Traffic volume (or average speed)*
	Code Adaptation	*If data is standard there is no need of readaptation, only retraining*
	Staff Skills	*Deployed through Operational Tools, just need to use Dashboard*
	Timing	*No particular timing, is part of PIXEL platform*
Source code		
License		*Open Source Apache 2.0*
Documentation	Installation Manual	*https://pixel-ports.readthedocs.io/en/latest/#predictive-algorithms-pas*
	User manual	*https://pixel-ports.readthedocs.io/en/latest/#predictive-algorithms-pas*
	Other manuals & tutorials	*video to be recorded*
Support		*Contact person: Joao Costa (XLAB)* *Email: joao.pitacosta@xlab.si (preferred channel).* *Skype ID: joao.pitacosta@xlab.si* *GitHub profile: joaopitacosta*

Appendix 6. PEI FAQ (Port of Valencia)

Q1: Which environmental KPIs are being considered in the PEI calculation?

A1: Based on the available scientific and technical literature, a list of all existing eKPIs was compiled and presented in the Deliverable 5.1 (Environmental aspects and mapping to pilots)- Section 9, considering significance, representativeness, measurability and usefulness.

In the Deliverable 5.2 (PEI Definition and Algorithms v1) -Section 4, they were correlated with port activities and categorized according to different environmental aspects: emissions to the atmosphere, wastewater emissions, noise emissions, waste production, odours, and light emissions. The methodology of data acquisition was also pointed out.

- **Emissions to the atmosphere (D5.2 -Table 4.1)**: Carbon dioxide (CO2 emissions), NOx and SOx emissions, Non-Methane volatile organic compounds emissions (NMVOC), Particulate Matter (PM emissions),

- **Wastewater discharges (D5.2 - Table 4.2)**: ballast water recuperation from ships (m3 per unit cargo), grey and black wastewater recuperation (m3 per unit cargo), storm water network (%), sanitary wastewater (m3 per unit cargo), total water consumption (m3 per unit cargo), accidental leakage or spill (m3 per unit cargo)

- **Noise emissions (D5.2 - Table 4.3):** compliance with limits at day, evening and night, Lden (overall day-evening-night noise level), Lnight (23:00-7:00 hrs noise level)

- **Waste (D5.2 -Table 4.4):** amount or total of waste produce, generation of hazardous waste, generation of non-hazardous waste, total garbage from ships, percentage of waste recycled in a port

- **Light emissions**

- **Odour emissions**

- **Energy consumption**: electricity, fuel, ratio of renewable energy/total energy consumed, total energy

Mappings between eKPIs and port data are described in detail in Deliverable D5.2- Section 5 and summarized in Table 5.1 (2-pages table) and Figure 5.1

Additional info: D5.1 -Section 9, D5.2 - Section 4 and 5

Q2: How are the different environmental KPIs (eKPIs) mixed together (missing data, normalization, weighing)?

R2: The PEI is a **composite indicator**. According to the Competence Centre on Composite Indicators and Scoreboards (COIN) (https://ec.europa.eu/jrc/en/coin/10-step-guide/overview) and to the Handbook on Constructing Composite Indicators (Joint Research Centre-European Commission 2008), there are a set of steps to be followed when a composite indicator is built. All these steps are iterative by nature.

PIXEL defines a **full methodology** to follow (Deliverable D5.2 - Table 8.2) in order to build the Port Environmental Index with a clear methodology and mathematical background (mainly based and adapted from Tax Justice Network (2013)).

Knowing the theoretical background of PEI and the difficulty to obtain data with associated uncertainty, we think that the following methods will be suitable (see Deliverable D5.2 -

Section 8.3.4) for **missing data**: Case deletion, Hot deck imputation, Substitution, Cold deck imputation, Unconditional mean/median/mode, Regression.

There are different mathematical methods for data normalization (see Deliverable D5.2 - Section 8.4), data weighting (see Deliverable D5.2 -Section 8.6) and data aggregation (see Deliverables D5.2 - Section 8.7). PIXEL has pre-selected some for each type, but the team will study and compare most of them during its pilots in order to recommend one or another method.

Additional info: D5-2 - Table 5.2, D5.2 - Section 8.3.4, D5.2 - Section 8.4, D5.2 - Section 8.6, D5.2 - Section 8.7

Q3: What do I need to provide if I want to test the PEI in my port?

R3: In order to calculate the PEI, you should provide **as many data as possible** related to the defined environmental KPI (eKPIs). Check FAQ1 if you want to have a brief overview.

Note that the PEI is a composite index that differentiates between ships, terminals and port authority. A detailed description of the needed eKPIs and how the data can be obtained or estimated is provided in **Deliverable D5.3 -Section 2 and 3**, including summary tables. It also includes more information related to odour and light pollution that were not included in previous deliverables (D5.1, D5.2)

From an ICT dimension, the PIXEL core platform is expected to work on an infrastructure with the following (preliminary) hardware requirements: 2 servers, each of them with 4 cores (i7), 16 GB RAM, 1 TB HD. Linux environment mandatory (Ubuntu 18.04 recommended).

The software is mainly installed (deployed) as Docker containers.

Additional info: D5.3 - Section 2 and 3

Q4: What are the core parts of the PEI implementation?

R4: The computation of the PEI is split in two clearly differentiated parts (see Deliverable D5.3 -Section 5.1.1):

1) **Agents block:** NGSI agents converting data to eKPIs. It is worth to mention that the NGSI agents' development is an action that will deviate from one port to another. As data will be different, the treatment at this level will vary and it is responsibility of each port aiming at deploying PEI to handle the development of the agents (with the support of the PIXEL Consortium)
2) **Composite index block:** Calculating PEI. This is the part that constitutes the "PEI as a model" component. This block consists of a series of calculations that will be invariant, following a clear algorithm

Note that depending on the availability of data and the required intermediate interpretations, other PIXEL models (e.g. PAS model) will be required.

Additional info: D5.3 - Section 5.1.1

Annex 1. Letter of intent (PIXEL)

Dear Sir or Madam,

We are contacting you on behalf of the **PIXEL** project (https://pixel-ports.eu), a Research and Innovation Action under the framework of H2020. **PIXEL (Port IoT for Environmental Leverage)** is the first smart, flexible and scalable solution for reducing environmental impacts while enabling the optimization of operations in port ecosystems through IoT. In the last stage of the project we are releasing new approaches and technologies ready to be implemented in ports of all sizes to fit you to the challenges ahead. They will seamlessly integrate your infrastructure and provide you with a dynamic quantitative measure of your environmental performance, leveraging the data sources and sensors you already have at the port.

In the framework of analysing the **transferability** of the PIXEL outcomes, we are launching a series of **Proof-of-Concepts** that will allow external ports to test our **PIXEL assets**, being the most relevant ones:

- **IoT platform**: core infrastructure to attach sensors and develop applications on top.
- **PEI (Port Environmental Index)**: innovative model able to quantify as a composite index the environmental impact of a port considering multiple Key Performance Indicators.
- **PAS (Port Activity Scenario)**: a meta-model simulating the supply-chains of a port and able to predict estimations about energy, pollutants, etc.

The PIXEL project also released **other models and predictive algorithms**, such as **ETD** (Expected Time of Departure) prediction, Hinterland multimodal transportation models, etc. We are also launching in parallel a series of webinars available in our YouTube channel (https://www.youtube.com/channel/UCuV-XLjawh3CfsP3BYfITyg) to provide plenty of information about the PIXEL assets.

To facilitate and simplify your decision, we have elaborated a set of **summary sheets** describing those PIXEL assets, so that you can evaluate in short potential impacts and needed requirements in terms of infrastructure, data and development.

If you are interested in evaluating any of our PIXEL assets, please **contact us**. We will be glad to further help you and make a Proof-of-Concept in your port based on **agreed terms, scope and limitations**.

Yours faithfully,

The PIXEL team

Annex 2. Letter of intent (Port of Valencia)

FUNDACIÓN VALENCIAPORT

Valencia, miércoles, 22 de septiembre de 2021

Subject: Letter of interest for PIXEL testing at Valenciaport

Información de contacto:

+34 96 393 94 00
info@fundacion.valenciaport.com

Av. Muelle del Turia s/n
Edificio APV, Fase 3
46024 Valencia · España

Dear Mr Molina,

The Fundación Valenciaport has been following the work developed in the context of the PIXEL project and confirms the interest in the Port Environmental Index (PEI) proposed and designed during the project.

In the last period, the Fundación Valenciaport met several times with the Universidad Politécnica de Valencia (UPV), as PIXEL partner, to understand in detail the PEI and plan a possible test in the Port of Valencia. Unfortunately, and due to different reasons, we could not organise and develop the test with the Port of Valencia's data before the end of the PIXEL project in September.

Therefore, we want to express our interest to maintain this contact with the UPV and test the PEI at the Port of Valencia in the following months, even after the end of the PIXEL project.

Best regards,

Salvador Furió

Director de Innovación y Desarrollo del Clúster
Innovation & Port Cluster Development Director

FUNDACIÓN VALENCIAPORT

Annex 3. Letter of intent (Port of Quebec)

September 17, 2021

Mr. Fabrice Klein
Chef des projets d'innovation transversale
F-klein@bordeaux-port.fr

Subject: Letter of interest for PIXEL testing at the Port of Québec

Dear Mr. Klein:

The Port of Québec analyzed the activities of the Port of Bordeaux to evaluate its environmental performance in the context of the PIXEL WP5 project and underline that PIXEL could be of interest as a beneficial addition to the Green Marine program. This improvement needs to be further discussed with Green Marine directly.

In any case, PIXEL shows great potential to give quantitative indicators to complete a qualitative program and the Port of Québec is interested in knowing more about its operation.

Meetings with the PIXEL team were held last June and July, in which demonstration was made of PIXEL's use at the Port of Bordeaux allowing us to understand and highlight its main advantages. Notably, a comprehensive dashboard with a user-friendly interface and a Port Environmental Index that allows tracking of the port's improvement and comparison with others.

Unfortunately, the PIXEL program ends in September, making it too late to organize tests with the Port of Québec's data.

We therefore want to express our interest in being able to maintain these tests at the Port of Québec, even after the end of the PIXEL program.

Best regards,

Marie-Ève Lemieux, M.Sc., VEA®
Director, Environment

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Annex 4. Letter of intent (Port of La Rochelle)

Port Atlantique La Rochelle

September 22nd, 2021

Object: Letter of interest to test PIXEL in Port of La Rochelle
Our reference: 20200922 DST BP

To whom it may concern,

Port Atlantic La Rochelle has participated to the PIXEL presentation to GIE VIGIE in May 2021 and has participated to survey about PIXEL interest.

Effectively, PIXEL seems to show great potential giving environmental indicators but it was not possible in May to have a demonstration of the use case of Bordeaux.

Unfortunately, PIXEL program ends in September, and it's unfortunately too late to organize tests with data of port of La Rochelle.

We therefore wish to express our real interest in being able to maintain these tests at Port Atlantic La Rochelle, even after the end of the PIXEL program.

Bernard PLISSON
Head of Strategy and Ecological Transition

www.larochelle.port.fr

La porte de l'Atlantique en eau profonde - The Atlantic deep sea gateway

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Annex 5. Letter of intent (Port of Bayonne)

Le 24/09/2021

Subject: Letter of interest to test PIXEL in Port of Bayonne

To whom it may concern,

Port of Bayonne is interesting with PIXEL program that seems show great potential to gives environmental indicators.

Unfortunately, PIXEL program ends in September, and it's too late to organize tests with data of port of Bayonne.

We therefore wish to express our real interest in being able to maintain these tests at the port of Bayonne, even after the end of the PIXEL program.

Pascal MARTY

General Manager – Port of Bayonne