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Capacity with a pOsitive enviRonmEntal and societAL footprInt: portS in the future era

COREALIS
THE PORT OF THE FUTURE

D.6.2: Final Impact Assessment and Evaluation Report

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List of Acronyms

Abbreviation / acronym	Description
AIVP	Association Internationale Villes Ports (French for: International Association of Port Cities)
CFO	Cargo Flow Optimiser
CO_2	Carbon Dioxide
CRL	Commercialization Readiness Level
CTE	Critical Technology Elements
D6.2	Deliverable number 2 belonging to WP 6
DtF	Docks the Future
EARTO	The European Association of Research and Technology Organisations
EC	European Commission
ERP	Enterprise Resource Planning
FR	Functional Requirements
HPCS	Hellenic Port Community System
HSLO	High-Level Strategic Objectives (from Port of the Future / Docks the Future)
ICT	Information and Communication Technology
ISO	International Standard Organization
KCT	Kotka Container Terminal
KPI	Key Performance Indicator
LL	Living Lab
MIP	Multimodal Inland Planner
MRL	Manufacturing Readiness Level
NASA	National Aeronautics and Space Administration
NFR	Non-Functional Requirements
PCI	Potential Contribution to Innovation; or Project Common Index
PCS	Port Community System
PCT	Piraeus Container Terminal
PoFSG	Port of the Future Serious Game
PoF-TA	Port of the Future - Transferability Analysis
RIA	Research and Innovation Action
RO/AO	Release/Acceptance Orders
Ro-ro	Roll on roll off
RTM	Requirements Traceability Matrix
STEP	Terminal Operating System in Livorno
TAS	Truck Appointment System
TEU	Transport Equivalent Unit
TOS	Terminal Operating System
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
UN SDGs	United Nations Sustainable Development Goals
WP	Work Package
WPSP	World Ports Sustainability Program

Executive Summary

COREALIS comprises a palette of port-driven technological and societal innovations, implemented and tested in real operating conditions in five Living Lab (LL) environments associated with the five COREALIS ports: Piraeus, Valencia, Antwerp, Livorno and HaminaKotka. This report describes and consolidates outcomes of the evaluations across all Living Labs with defined Key Performance Indicators (KPI) for assessing technical, operational, environmental, economic and societal impacts and transferability potential. It is the result of tasks T6.2-T6.5. After Chapter 1 Introduction, each task's results are presented in its own chapter and includes:

Chapter 2 describes the work carried out in the task T6.2 Integration Framework and Technical Assessment. The objective has been to ensure that technical implementations are properly interworking with the necessary ICT infrastructure during the LL demonstration phase. The second aim was to technically evaluate the deployment of innovations within the third phase of the LLs.

Chapter 3 presents the results from the task T6.3 COREALIS Impact Assessment to future port and supply chain operations and to the environment/climate change. The objective was to quantify the impact of applying the project innovations.

Chapter 4 includes the results from the task T6.4 COREALIS Societal Impact Assessment within a port-city context. The work is complementarily to the technological and operational impacts' assessment of the innovations and evaluate their social impact to the individual, be it a port worker, a port stakeholder or a city resident in the vicinity of a port, and also to the society as a whole.

Chapter 5 describes the work done in the task T6.5 COREALIS Impact and solution transferability to other transport hubs. This chapter starts with a description of the chosen approach, which is based on the DtF PoF-TA methodology. After the explanation of the approach, first the overview of the entire project is presented followed by an analysis per innovation.

COREALIS innovations are tailored to realise the project four main objectives. The test results from each innovation are presented in relation to the project objectives in Chapter 6 Summary of the results, where also the development of the COREALIS innovations is presented with a scale of technology readiness levels (TRL). Finally, Chapter 7 Conclusions draws up the main findings. The Annexes contain 1. Full lists of goals, focus areas, goals, strategical/tactical objectives and measures, 2. Potential Contribution to Innovation score, 3. Full list of KPIs from the PCI-Tool and 4. Proof-of-Transferability score.

The deliverable "D6.1: Impact assessment methodology for technical, operational, environmental and societal impact and list of KPIs" (public) described the impact assessment methodology for all impacts of the COREALIS innovations (technical, operational, environmental/climate change and societal) as well as listed and explained the associated Key Performance Indicators used for the evaluation. To avoid unnecessary repetition, only the essential of the previous work has been presented in this report.

Data from the following COREALIS project reports have also been utilised as background information about the innovations: "D5.6: COREALIS LLs Interim Progress Report"

(confidential), “D4.2: Port energy assessment framework and green cookbook” (public), “D8.3: COREALIS incubator activities” (public).

To avoid unnecessary overlapping, co-operation has also been had with the contributors of the public report “D5.7: COREALIS LLs Final Progress Report” where, for example, test processes have been thoroughly described.

Despite the challenges caused by COVID-19 pandemic that arrived in Europe in February 2020, COREALIS innovations were successfully tested in the Living Labs with minor modifications in the test plans.

The COREALIS innovations matured during the execution of the project from lower Technology Readiness Levels (TRL) to higher TRL in the end of the project, even more than it was anticipated in the Description of Action.

Majority of the COREALIS innovations have proved to be so useful and effective that Living Lab ports have decided or already started the deployment of the innovations after the project-related test period.

The transferability of the COREALIS innovations has been measured using the TA-score. COREALIS’ scores range from 2 to 5 with a consolidated score of 3.4. This shows that the innovations are becoming mature from being implemented in a single environment towards wider deployment.

1. Introduction

This report will describe and consolidate all outcomes of the evaluations across all LLs with defined KPIs for assessing technical, operational, environmental, economic and societal impacts and transferability potential. It is the result of the tasks T6.2-T6.5.

The data required for WP6 evaluation and impact assessment has been produced during the real-life or simulated deployment of the innovations from the LLs in WP5 and presented thoroughly in D5.7 COREALIS LLs Final Progress Report summarising the results of T5.1-T5.6 by the end of the project. It is a report detailing the final outputs of real-life and simulation tests performed in each LL, after the full or test-phase integration of COREALIS innovations in the port-city infrastructure. Figure 1 describes the overall evaluation framework of COREALIS.

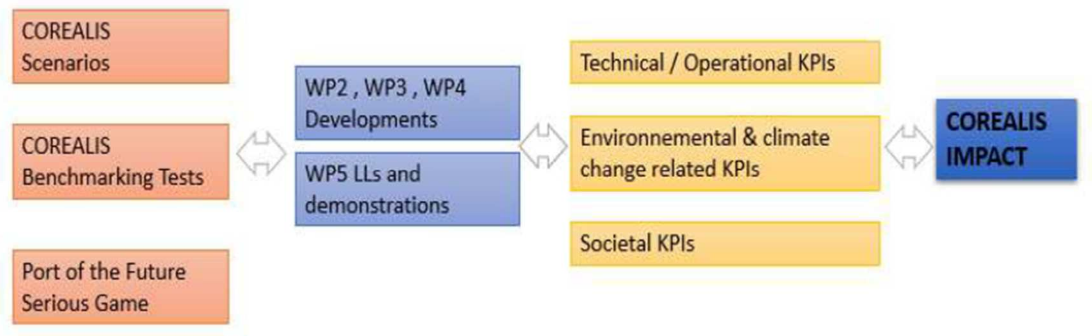

Figure 1: COREALIS Impact Assessment Framework

COREALIS comprises a palette of port-driven technological and societal innovations, visualised in

Figure 2.

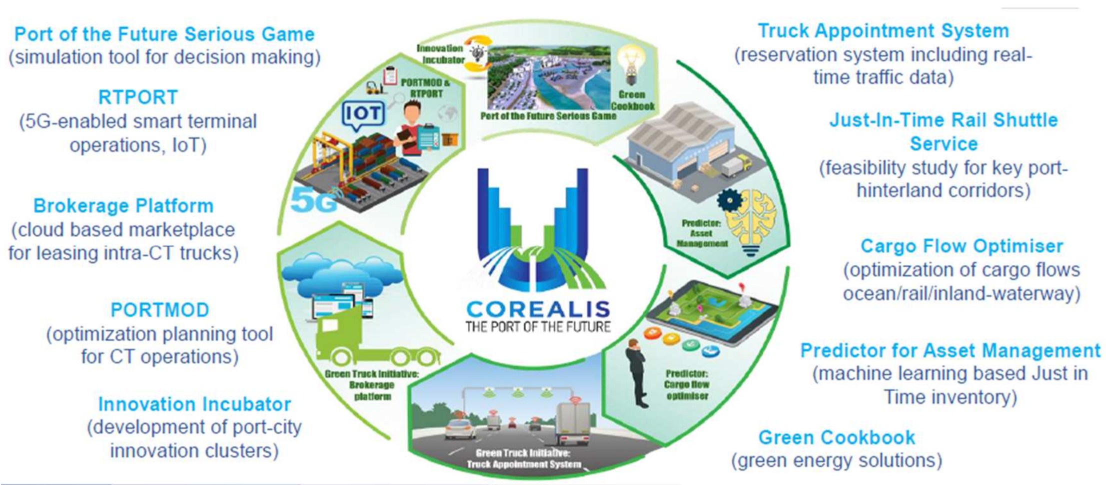

Figure 2: COREALIS innovations

COREALIS innovations are tailored to realise the project objectives presented in Table 1. COREALIS Predictor asset management tool and the chassis brokerage platform of the Green Truck Initiative implement O1; the TAS and Cargo flow optimiser realise O2; PORTMOD and RTPORT modules implement O3, while O4 is realised by the PoFSG and the innovation incubator.

Table 1: Project objectives and their corresponding COREALIS solutions

O1. Embrace circular economy models in its port strategy and operations.
Cloud Brokerage Platform
Predictor Asset Management
Green Cookbook
O2. Reduce the port's total environmental footprint associated with intermodal connections and the surrounding urban environment for three major transport modes, road/truck, rail and inland waterways.
IoT based TAS (Truck Appointment System)
Cargo Flow Optimiser
JIT Rail shuttle service feasibility study
O3. Improve operational efficiency, optimise yard capacity and streamline cargo flows without additional infrastructural investments.
RT PORT
PORTMOD
Predictor
O4. Enable the port to take informed medium term and long term strategic decisions and become an innovation hub of the local urban space.
Port of the Future Serious Game PoFSG
Innovation Incubator

The innovations were implemented and tested in real operating conditions in five Living Lab environments, associated with the five COREALIS ports: Piraeus, Valencia, Antwerp, Livorno and HaminaKotka Living Labs (LLs). Figure 3 presents the COREALIS innovations tested in each living lab.

	Hinterland connectivity			Intra-Terminal operations				Decision making/ Innovation		
	TAS	Brokerage platform	JIT Rail Shuttle Service	Cargo Flow Optimiser	Predictor / Asset Mgmt	PORTMOD	RTPORT	Energy assessment & Green cookbook	PoF Serious Game	Innovation Incubator
Valencia	X		X							X
Piraeus					X			X	X	
Livorno						X	X		X	
Antwerp		X		X						
Haminakotka	X					X			X	

Figure 3: COREALIS innovations tested in each living lab

1.1 Integration Activities and Technical Assessment

Based on the work carried out during the first half of the project, in terms of scenarios, user requirements and system requirements definition, it was possible to define a proper methodology for integration and technical assessment to be used during different phases of the project (First Iteration M4-M16, Second Iteration M17-M24 and Third Iteration M25-M32).

The methodology allowed setting up a time plan for the system requirements validation and verification by means of a concise and defined set of test cases per innovation. A Requirements Traceability Matrix (RTM) was used to keep track of the verification process during different phases of the project. On one hand, test cases definition and execution were done according to the system requirements specifications collected and included within the scoping documents, allowing to check their fulfilment during on-field validation (benchmarking tests).

On the other hand, test cases definition and execution allowed also performing measurements campaigns in different LLs providing a starting point for the technical, operational, environmental and societal KPIs assessment (including either baseline and target values) as well as for the related impacts.

While executing defined tests, integration of the innovations with the existing ICT infrastructure was also performed to make sure the innovations have been properly deployed in each LL and integrated with expected components.

1.2 Impact Assessment to future port and supply chain operations and to the environment/climate

Assessing the impact from the COREALIS innovations to future port and supply chain operations includes quantifying the impact of applying the project innovations to port terminal internal operations, as well as seamless cargo transport from ocean to truck/rail/barge and vice-versa. The evaluation was planned to include datasets from the deployment of components in a period of 7 months in the late 2020, so that the improvement may be profiled and assessed for different periods and cargo volumes. Due to the COVID-19 pandemic, the deployment periods have varied in the Living Labs.

Environmental impact assessment will quantify the impact of applying the project innovations to the environmental footprint gains stemming from applying COREALIS innovations. The main result of environmental impact assessment is the information about the amount of decreased CO_2 emission (in figure and in percentage), where applicable. In order to evaluate the effect on COREALIS innovations to the environment and climate, it is necessary to know the current situation, i.e. information of the current vehicles or equipment in use. In addition, there is a need to know the effect of COREALIS innovations to the port and supply chain operations. The methodology has been described in D6.1 and it has been followed when the input data has been precise enough for emissions calculations. The input data for this deliverable was gathered directly from the LLs.

1.3 Societal Impact Assessment within a port-city context

Apart from the operational and environmental impact assessment of the COREALIS innovations, the analysis of their social impact is considered as quite important, in order to evaluate how the port stakeholders are affected by their implementation and operation. These stakeholders can be either direct, such as port employees and workers, external port associates etc., or indirect, such as city residents in the vicinity of the port, employees in companies located near the port, local communities and the society as a whole. Assessing the societal impact is in general more complex and less tangible than evaluating operational and environmental aspects. For this reason, a combination of methods is used, both participatory and desk-based, that go beyond traditional methods of questionnaire-based evaluations, which are usually rigid, one-directional and sometimes tedious to participants. Among others, the Port of the Future Serious Game (PoFSG) and its gamification strategy supports the evaluation of social impact.

1.4 Impact and solution transferability to other transport hubs

The transferability analysis was executed in Task 6.5. The task initially started in April with workshops organised by DocksTheFuture (DtF) on the Transferability Analysis (TA) methodology realised by DtF for the Port of the Future (PoF) RIA projects. The methodology liaises the innovation objectives with (among others) the UN SDG 17 objectives, allowing public authorities to map which innovation is the most suited to achieve what goal. In an answer to the concerns posed by the projects, additional guidelines have been made available.

In relation to the task, webinars were organised for each Living Lab in which the innovations implemented at the Living Labs were presented. These webinars allowed us to investigate the initial interest from external parties in the COREALIS innovations.

Chapter 5 starts with a description of the chosen approach, which is based on the DtF PoF-TA methodology. After the explanation of the approach, first the overview of the entire project is presented followed by an analysis per innovation.

2. Integration Activities and Technical Assessment

In this chapter, the integration activities and technical assessment are presented. Integration activities did not require a huge amount of effort, since a great part of COREALIS solutions did not need to be integrated with the existing and local ICT infrastructure.

An integration framework should be intended as a set of common tools and or a unique environment for integration activities. Nevertheless, within COREALIS project we did not expect to have a common architecture with different components interacting with each other. COREALIS output instead was a set of innovations that does not require this cross-interoperability. For this reason, no specific Integration Framework was used, but we have considered only integration activities with external systems, where applicable.

Indeed, in some cases these solutions are standalone components and web-based applications performing their functionalities without a direct integration with the external systems, while in other cases a physical and software integration has been done for a proper innovation validation. Nevertheless, in the following section 2.1, integration activities and considerations are provided and described for each LL.

As far as the technical assessment is concerned, it has been performed during the lifetime of the project according to a common methodology that have been adopted by all LLs for the on-field validation of the COREALIS innovations. The technical assessment methodology details are further presented and discussed in the section 2.2.

2.1 Integration Activities

2.1.1 Port of Piraeus LL

From integration point of view, the COREALIS Predictor Asset Management tool was the main innovation considered for this LL. Predictive maintenance utilises condition monitoring, advanced inspections, and data analytics to predict component or equipment failure. It comprises different analytical algorithms in the context of predictive maintenance, providing a data-driven preventive maintenance schedule as well as a data-driven schedule of purchases.

In order to provide this output, the Predictor tool consumes historical maintenance and yard truck telemetry data. The data are updated in real time and the end-user can select the period to be used for the training of the ML algorithm accordingly. This functionality was necessary in order to determine the optimal reference period since the training of the ML algorithm is a time-consuming process that can go on for several hours for a reference period of six months. Several iterations have revealed that the optimal period is 2 to 3 months prior the day of execution of the algorithm.

The Hellenic Port Community System (HPCS) has been designed to allow different ports and terminals to join and use available services. A new functionality of the Hellenic Port Community System (HPCS) has been implemented in 2019 providing hosting capabilities of third-party applications. The Predictor functionality will be offered as a service to terminals joining the HPCS and the current web interface of the application was developed using the templates of the HPCS.

2.1.2 Port of Valencia LL

For this LL, the Truck Appointment System (TAS) is taken into the consideration from integration perspective.

This specific innovation includes several modules with different functionalities aiming at optimising road transport processes and ensuring optimal operations with predefined time slots for container delivery/pick-up operations.

The modules are interconnected with each other, but they are not integrated with the Port Community System (ValenciaportPCS) from the Valencia Port at this stage.

Nevertheless, this possibility is also considered as a future step, since in principle the TAS module can receive information related to the release/acceptance orders (RO/AO) from the ValenciaportPCS limiting time slots booking in case RO/AO has not been received yet.

2.1.3 Port of Antwerp LL

While the Cloud Based Marketplace is a stand-alone solution allowing stakeholders to book equipment for efficient planning and use of assets, the Cargo Flow Optimiser provides the status of all seagoing vessels that are expected or that are currently in the port of Antwerp.

The Cargo Flow Optimiser is able to predict how many containers are going to arrive or leave the port for a certain day/week/month and their arrival/leaving mode of transport. In order to combine data (mostly a dynamic information) into one complete dataset, the tool consumes data from the Port Community System by means of the Nxtport PortCall+ API.

The Cargo Flow Optimiser will allow the integration and seamless work with the Cloud based Marketplace & yard equipment brokerage platform also developed in this project.

It could also be integrated with the Terminal Operating System (TOS), where the port authority and the terminal operators would have a full visibility on the statuses of the shipments mapped, but this possibility should be further investigated in the future.

2.1.4 Port of Livorno LL

Livorno LL was mainly involved into the validation of RTPORT and PORTMOD modules in the Container Terminal context. PORTMOD's container-flow visualisation capability has been tested within the Container Terminal Lorenzini area. Historical container movements have been extracted from the Terminal Operating System (STEP) and provided offline as input to PORTMOD. Due to environmental restrictions of the container terminal area, the flow visualisation allowed to identify potential congestions over the roads as well as to get idea of different road configurations and their impacts in terms of CO_2 emissions and fuel consumptions. In the future, it will be assessed the possibility to retrieve real-time data by means of integration with the Terminal Operating System.

As far as RTPORT is concerned, different integration activities with the existing ICT infrastructure have been performed during the testbed set-up. RTPORT is thought to provide real-time processing capabilities and a staging environment (connected through an o.f based link) has been used as an edge node for a real-time interaction with oneM2M platform and the Port Monitoring System (MonI.C.A).

More in details, the following integration activities have been performed:

- Integration with oneM2M standard platform for forklifts and cargo data collection (the Main Control System can interact with M2M platform through existing o.f backbone);
- Integration with Port Monitoring System from Livorno Port for the forklifts' visualisation by means of REST API (Figure 4);
- Integration between the 5G equipment and the existing o.f backbone of the Livorno Port. A dedicated o.f cable has been laid for this interconnection (Figure 5).

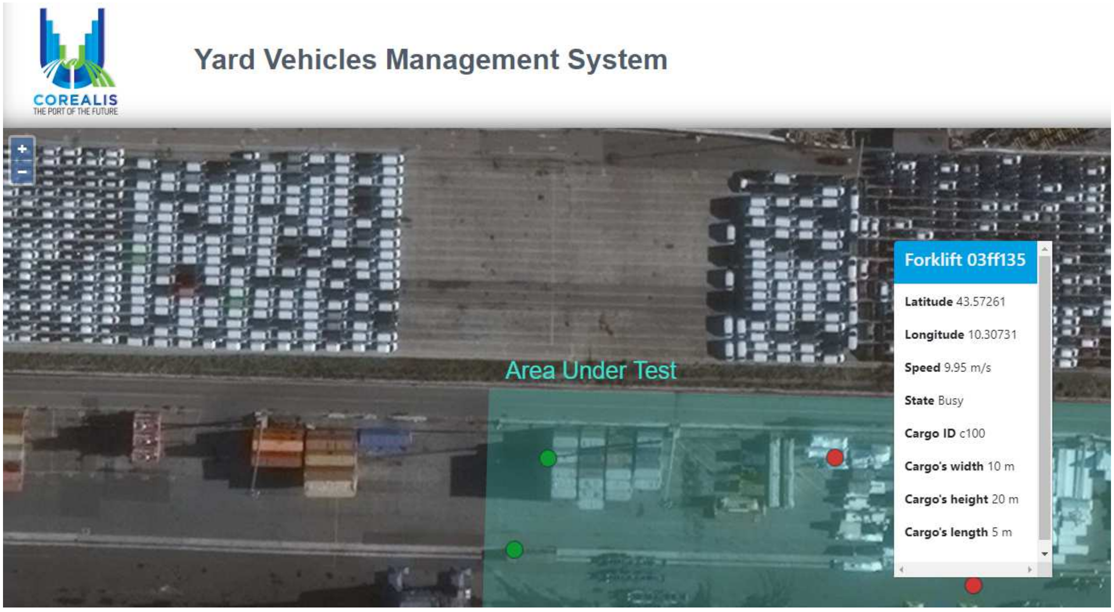

Figure 4: Yard Vehicles Management System - Graphic User Interface

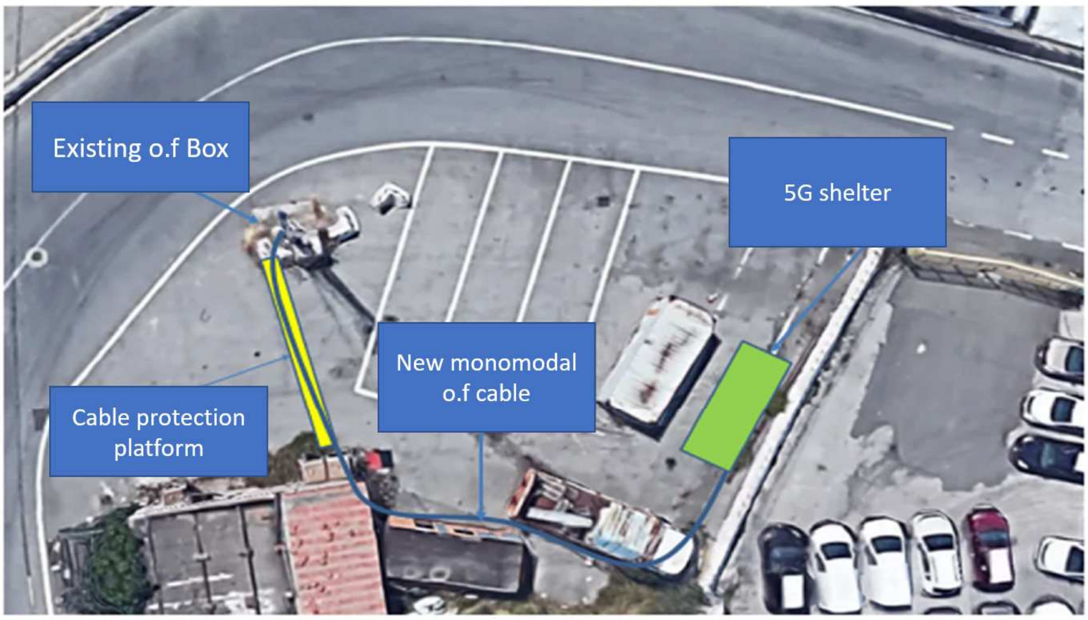

Figure 5: Connection between on-field 5G Equipment and o.f backbone from the Port of Livorno

2.1.5 Port of HaminaKotka LL

In this LL, Light-TAS as well as PORTMOD have been tested. Light-TAS is a simpler version of TAS at Valencia LL with less functionalities: number of available time slots, booking information, bookings confirmation and pre-booking operations. As for the case of Valencia LL, Light-TAS is not integrated with external data sources such as the Port Community System.

PORTMOD is a standalone software (TRL 5) built on open-source components with a graphical user interface. PORTMOD enables the user to visualise container flows and perform container flow analyses. In addition, it offers limited capabilities to simulate container terminal operation. The input data for PORTMOD is a sequence of incoming and outgoing containers retrieved from a TOS. In practice, Steveco's TOS that is NAVIS offers the capability to write a text file of a requested period that is used as input for PORTMOD. The benefit of having the two separate systems without integration is that users can use PORTMOD without access to the TOS. Furthermore, this avoids the unexpected overloading of TOS due to PORTMOD, which is desirable.

2.2 Technical Assessment

The main aim of the Technical Assessment was to define a common methodology to be used by each LL in order to:

- guarantee that each COREALIS innovation has been properly defined in terms of user and system requirements and ensure that all requirements can be tracked during the project lifetime (First Iteration);
- define small-scale test cases for the requirements verification and alpha versions of the innovations' validation (Second Iteration);
- collect experimental results from full-scale test cases and on-field deployments, allowing benchmarking against defined KPIs for the project objectives achievements (Third Iteration).

During the First Iteration of the project, User and System requirements have been collected according to a common structure by means of defined template and included in all LLs Scoping Documents. The above-mentioned template is shown in the Table 2 below:

Table 2: System Requirements template used for their collection within all LLs

Attribute	Description
Unique ID	*A unique identifier of the requirement, following the format:* *System_LL_scenario_xx* *where LL= the Living Lab to which the requirement applies, scenario= the number of the scenario to which the requirement applies , xx= an ascending enumeration.*
Type	*It specifies the type of the requirement. Two types of requirements will be considered* ▪ ***Functional Requirements (FR),*** *They are the fundamental or essential subject matter of the product. They describe what the product has to do or what processing actions it is to take [1].* ▪ ***Non-Functional Requirements (NFR),*** *They are the properties that the functions must have. These requirements are as important as the functional requirements for the product's success [1].*

Priority	*The priority of a requirement is the decision on the importance of the requirement implementation. The priority depends highly on the specific domain of the application Priority is divided by [2]:* ▪ *MUST: It means that the definition is an absolute requirement of the specification.* ▪ *SHOULD: It means that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.* ▪ *MAY: It means that an item is truly optional.*
Category	*The category is used to aggregate the requirements into coherent sets. The following set of categories shall be used:* ▪ Port-hinterland connections, ▪ Intra-terminal operations, ▪ Sustainable Development, ▪ Other.
Description	Describes What, Not How. *There are many characteristics of a good requirement. First and foremost, a good requirement defines* what a system must do, *but does not specify* how to do *it. A statement of a requirement should not be a preconceived or inadvertently implied solution to the problem to be solved. To avoid falling into this trap, ask why the requirement is needed, and then derive the real requirements. For example, it would be a mistake to require a relational database for requirements [3], [4].*
Rationale	*The rationale is the reason behind the requirement existence. It explains why the requirement is important and how it contributes to the system's purpose (provide mapping to the project objectives whenever possible).*
Relevant User Requirement(s)	*As per the user requirement in the section above.*
Dependencies	*Indicate if the requirement depends on another one. Relations between two or more requirements should be traced.*
Conflicts	*Conflicts between requirements imply that there exists contradiction upon system implementation, or one requirement makes the implementation of another requirement less feasible.*
Relevant WP	*The COREALIS work package teams that will address each specific requirement.*
Comments	*Any additional comment or observation regarding the specific requirement. In particular, it should include comments on possible technology limitations or to identify aspects which may be only partially relevant to the scope of the project (or totally out of scope, even).*
COREALIS System	*A mapping towards the system in which the system requirement applies and will be implemented.*
Owner	*The partner that is responsible for the correct implementation of the requirement.*

This was considered as a proper approach for the system requirements collection, since it provides a way to keep track of the system requirements for each innovation in relation to defined set of the user requirements for each LL. Based on its priority, it was also possible to identify mandatory system requirements and find out a minimum and sufficient set of requirements to be validated per COREALIS innovation. Moreover, the cross-dependencies between different system requirements were also tracked by means of this approach.

In order to keep track of the requirements validation by means of test cases, a Requirements Traceability Matrix (RTM) was used.

The RTM is a document that maps and traces user requirements and system requirements with test cases. It captures all requirements proposed by the users and requirement traceability in a single document, delivered at the conclusion of the COREALIS project life cycle. The main purpose of Requirement Traceability Matrix is to validate that all requirements are checked via test cases such that no functionality is unchecked during COREALIS innovations testing.

In this project, we used two different RTMs:

- the first one collects all requirements associated to each COREALIS innovation in order to provide a unified view and it was used during the first phase of the project;
- The second one keeps track of User Requirements, System Requirements and their validation by means of test cases and it was used during testing activities.

The following tables (Table 3 and Table 4) show the main structure used by mentioned RTMs.

Table 3: First Requirements Traceability Matrix (RTM)

Innovation	Requirement ID	Living Lab	Requirement Type	Prioritisation	Versioning
Truck Appointment System	TAS_F_GEN_1	Valencia, HaminaKotka	F	MUST	Alpha Version
Truck Appointment System	TAS_F_GEN_2	Valencia, HaminaKotka	F	MUST	Alpha Version
Truck Appointment System	TAS_F_GEN_3	Valencia, HaminaKotka	F	MUST	Alpha Version
Truck Appointment System	TAS_F_GEN_4	Valencia, HaminaKotka	F	MUST	Alpha Version
Truck Appointment System	TAS_F_GEN_5	Valencia, HaminaKotka	F	MUST	Alpha Version
Truck Appointment System	TAS_F_GEN_6	Valencia, HaminaKotka	F	MUST	Alpha Version
Truck Appointment System	TAS_NF_GEN_1	Valencia, HaminaKotka	NF	MUST	Alpha Version
Truck Appointment System	TAS_NF_GEN_2	Valencia, HaminaKotka	NF	MUST	Alpha Version
Truck Appointment System	TAS_F_Valencia_1	Valencia	F	MUST	Alpha Version
RTPORT	RTPORT_F_GEN_1	Livorno	F	MUST	Alpha Version
RTPORT	RTPORT_F_GEN_2	Livorno	F	MUST	Alpha Version
RTPORT	RTPORT_F_GEN_3	Livorno	F	MUST	Alpha Version
RTPORT	RTPORT_F_GEN_4	Livorno	F	MUST	Alpha Version
RTPORT	RTPORT_F_GEN_5	Livorno	F	MUST	Alpha Version
RTPORT	RTPORT_NF_GEN_1	Livorno	NF	MUST	Alpha Version
RTPORT	RTPORT_NF_GEN_2	Livorno	NF	MUST	Alpha Version
RTPORT	RTPORT_NF_GEN_3	Livorno	NF	MUST	Alpha Version
RTPORT	RTPORT_NF_GEN_4	Livorno	NF	MUST	Alpha Version
RTPORT	RTPORT_F_GEN_6	Livorno	F	MUST	Alpha Version
RTPORT	RTPORT_NF_Livorno_1	Livorno	NF	MUST	Alpha Version
RTPORT	RTPORT_NF_Livorno_2	Livorno	NF	SHOULD	Alpha Version
RTPORT	RTPORT_NF_Livorno_3	Livorno	NF	MUST	Alpha Version
RTPORT	RTPORT_F_Livorno_1	Livorno	F	MUST	Alpha Version
RTPORT	RTPORT_F_Livorno_2	Livorno	F	MUST	Alpha Version

RTPORT	RTPORT_F_Livorno_3	Livorno	F	MUST	Alpha Version
PORTMOD	PORTMOD_F_Livorno_1	Livorno	F	MUST	Alpha Version
PORTMOD	PORTMOD_F_Livorno_2	Livorno	F	MUST	Alpha Version
PORTMOD	PORTMOD_F_HaminaKotka_1	HaminaKotka	F	SHOULD	Alpha Version
PORTMOD	PORTMOD_F_HaminaKotka_2	HaminaKotka	F	MUST	Alpha Version
PORTMOD	PORTMOD_F_HaminaKotka_3	HaminaKotka	F	SHOULD	Alpha Version
PORTMOD	PORTMOD_F_HaminaKotka_4	HaminaKotka	F	COULD	Alpha Version
PoFSG	PoFSG_F_GEN_1	HaminaKotka, Livorno, Piraeus	F	MUST	Alpha Version
PoFSG	PoFSG_F_GEN_2	HaminaKotka, Livorno, Piraeus	F	MUST	Alpha Version
PoFSG	PoFSG_F_Piraeus_1	Piraeus	F	MUST	Alpha Version
PoFSG	PoFSG_F_Livorno_1	Livorno	F	MUST	Alpha Version
PoFSG	PoFSG_F_Livorno_2	Livorno	F	MUST	Alpha Version
PoFSG	PoFSG_F_HaminaKotka_1	HaminaKotka	F	MUST	Alpha Version
Predictor	PREDICTOR_F_GEN_1	Piraeus	F	MUST	Alpha Version
Predictor	PREDICTOR_F_GEN_2	Piraeus	F	MUST	Alpha Version
Predictor	PREDICTOR_F_GEN_3	Piraeus	F	MUST	Alpha Version
Predictor	PREDICTOR_NF_Piraues_1	Piraeus	NF	MUST	Alpha Version
Predictor	PREDICTOR_NF_Piraues_2	Piraeus	NF	MUST	Alpha Version
Energy Assessment Framework	COOKBOOK_F_Piraeus_1	Piraeus	F	MUST	Alpha Version
Energy Assessment Framework	COOKBOOK_F_Piraeus_2	Piraeus	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_1	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_2	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_3	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_4	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_5	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_6	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_7	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_8	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_9	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_10	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_11	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_F_GEN_12	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_NF_GEN_1	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_NF_GEN_2	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_NF_GEN_3	Antwerp	F	MUST	Alpha Version
Cargo Flow Optimiser	CFO_NF_GEN_4	Antwerp	F	MUST	Alpha Version
Marketplace Brokerage Platform	MARKETPLACE_F_GEN_1	Antwerp	F	MUST	Alpha Version
Marketplace Brokerage Platform	MARKETPLACE_F_GEN_2	Antwerp	F	MUST	Alpha Version
Marketplace Brokerage Platform	MARKETPLACE_F_GEN_3	Antwerp	F	MUST	Alpha Version
Innovation Incubator	INCUBATOR_F_GEN_1	Valencia	F	MUST	Alpha Version
Innovation Incubator	INCUBATOR_NF_GEN_1	Valencia	NF	MUST	Alpha Version
JIT Rail Shuttle Service	JIT_F_GEN_1	Valencia	F	MUST	Alpha Version

Table 4: Second Requirements Traceability Matrix (RTM)

Requirements Traceability Matrix
COREALIS Living Lab

User Requirement ID	COREALIS Scenario	System Requirement ID	Requirement Classification	Priority	Test Case ID	Execution Status	Defect
Unique User Requirement identifier.	Linked COREALIS Scenario.	Unique System Requirement identifier.	Type of System Requirement.	System Requirement Priority.	Unique Test Case identifier.	Test Case execution Status.	Any arisen defect.

Both RTMs are stored and shared through a project management web application adopted by the consortium (namely Redmine). This allowed keeping track of testing activities over the time, updating RTM according to performed validation activities expected by the project.

The main output of the First Iteration was a set of benchmarking tests for COREALIS technical components' alpha versions per LL. During benchmarking tests, it was possible to perform a preliminary and partial system requirements coverage per innovation in view of the test cases definition. Benchmarking tests results have been then included in the *First Iteration Reports* and delivered to each LL.

After benchmarking tests performing, detailed test cases were defined for each COREALIS innovation according to the system requirements collected in the LLs Scoping Documents, as well as according to the partial testing results from the mentioned benchmarking tests (Second Iteration).

Test Cases definition and collection was performed according to a common template used by all LLs and it is reported in the Table 5 below:

Table 5: Test Cases definition and collection template

Test case ID	Test Case Description
Test case description	*A short test case description: what is it about?*
Input to the system	*What is used to feed the system under test during testing activities?*
Output of the system	*What is the main output of the system while the test is performed?*
System requirements covered	*What System Requirements are covered by means of considered test case?*
Success Criteria	*What are the success criteria used for the test results assessment?*
KPIs	*What KPIs are linked to the considered test?*
Who will do the test?	*Who is in charge of the considered test execution?*
Feedback for technical partners	*Any feedback for technical partners in order to assess the test results?*

Test cases definition and execution was also complemented by considering the following related aspects:

- date of launching and duration of tests has been defined in order to be sure results are delivered in time for each LL;

- potential issues and risks were also considered and some mitigation actions were provided in order to fulfil the main expectations from tests execution;
- training activities were considered for some COREALIS innovations in order to be sure end users are properly formed for the COREALIS innovations utilisation (e.g. RTPORT, TAS, PORTMOD, etc.).

The main output of the Second Iteration was a set of concise test cases specifications for COREALIS innovations and their validation according to innovations' roadmap. As per benchmarking tests, LLs' technical partners performed test cases and the results have been included and documented in the 2nd *Iteration Reports*, delivered to each LL.

Finally, during the Third Iteration, a full set of solutions has been deployed, allowing complete testing, demonstration and results evaluation in the target port-city environment (real environment) of different COREALIS innovations. The final measurements campaign allowed collecting the main results for the KPIs-based assessment in order to assess whether the innovations properly match the target values defined for their validation. These results are collected and reported in D5.7 COREALIS LLs Final Progress Report, while in this deliverable the KPIs assessment has been provided for technical, operational, environmental and societal impacts quantification across all LLs.

3. COREALIS Impact Assessment to future port and supply chain operations and to the environment/climate change

This chapter presents the results from the task 6.3. The task objectives were to quantify the impact of applying the project innovations to:

- port terminal internal operations;
- seamless cargo transport from ocean to truck/rail/barge and vice-versa;
- the environmental footprint gains stemming from applying COREALIS innovations, namely the Green Truck Initiative (TAS and Marketplace); the cargo flow optimisation component; the energy consumption assessment framework and adoption of the JIT rail shuttle service.

The evaluation was planned to include datasets from the deployment of components in a period of 7 months (in the last part of 2020), so that the improvement may be profiled and assessed for different periods and cargo volumes. Due to the COVID-19 pandemic, the deployment periods have varied in the Living Labs.

3.1 The methodology and KPIs

The impact assessment methodology for technical, operational, environmental and societal impact was described in D6.1 Impact assessment methodology for technical, operational, environmental and societal impact. The list of associated operational/technical Key Performance Indicators (KPIs) used for the evaluation are presented in Table 6 and environmental & climate change related KPIs in Table 7.

Table 6: List of operational/technical KPIs per LL

List of operational/technical KPIs per LL	
Piraeus LL	Yard equipment performance.
	Fuel and spare part consumption.
	Total container moves performed after applying the data-driven preventive maintenance schedule.
	Reduction of false-positives/negatives as regards to replacement / renewal decisions for assets.
	Reduction of operational and maintenance costs of the port spare parts, including tires.
Valencia LL	Truck waiting time inside the terminal.
	Truck waiting time outside the terminal.
	Time for gate-in/out operations (average, max …).
	Number of slots per hour.
	Number of bookings per hour.

	Maximum Live queue.
	% use of the time slots.
	Number of cancellations.
	Number of bookings changed.
	Number of gate incidents.
	Congestion at container terminal gates.
	External systems connected to the TAS.
	Number of daily roundtrips.
	Composition characteristics: a) Composition TEU Capacity; b) Composition UTI Capacity; c) Composition length; d) Composition maximum load.
	Container Cost per Unit transported (€/TEU).
Antwerp LL	Number of terminals that reduced the number of handlings (data to be provided by the terminal operator).
	Average time that the container is in the terminal (pick up time) (data to be provided by the terminal operator).
	Number of active users of the application per month (Active user > 3 logins).
	Number of cargo routes requested per month.
	Number of different locations/destinations chosen per month (locations within 20km distance are considered the same).
	Percentage of locations/destinations chosen that have an available train route.
	Percentage of locations/destinations chosen that have an available barge route.
	Percentage of CO_2 reduction of rail compared to truck on the requests performed with the multimodal inland planner.
	Percentage of CO_2 reduction of barge compared to truck on the requests performed with the multimodal inland planner.
	Number of successful transactions per month.
	Percentage of transport shifted to rail and barge.
	Number of new "shared" on-demand transport services.
	Number of uses/logins of the application per month.
	Number of successful transactions per month.
	Number of offerings by a supplier per month.
	Number of demands per month
	Number of assets added per month

	Saved idle time of assets per month
	Number of asset categories used per month
Livorno LL	Vessel operation completion time.
	Loading (on the ship)/ Unloading (from the truck) operations completion time.
	Time to find a pallet on the yard.
	Occupied space during the cargo storage phase.
	Vessel idle time at berth.
	Amount of data related to the cargo.
	Cargo registration completion time.
	Average operation execution time (by the forklift).
	Total number of movements per cargo unit.
	Driving distance per productive container move inside the CT.
HaminaKotka LL	Productivity: (STS_operating_time - waiting_time) / STS_operating_time.
	Equipment usage time: equipment usage time / possible usage time.
	Lifts/hours per crane.
	Vessel turnaround time: Arrival - Departure time from port.
	Loading & unloading efficiency: number of containers / vessel turnaround time.
	Driving distance per productive container move inside of the terminal.
	Temporal distribution of terminal/port gate operations.
	Time of gate-in/out operations (average, maximum, minimum, etc.).
	Temporal distribution of events related to transport planning (transport order, TA pre-booking, TA confirmation, TA execution).
	Number and classification of gate incidents
	TAS compliance levels (trucks and terminals): a. % of compliance with slots; b. Number and % of delays, cancellations, changes; c. % of slots usage; d. Waiting times.
	Decrease in operation costs by transferring diesel to electricity.

Table 7: List of environmental KPIs per LL

List of environmental KPIs per LL

Piraeus LL	Energy consumption percentage that can be replaced by renewable energy sources.
	Measure overall and per crane power consumption.
Livorno LL	Awareness of measures to adapt to climate change.
	Impact of new infrastructures in the port.
HaminaKotka LL	Reduction of CO_2 emissions
	Improvement of air quality (could be indicated by PM2.5/visibility).

In the following Living Lab -specific chapters (3.2-3.6), the results from each LL are presented. In the first sub-chapter, there is a short introduction about each innovation including a brief description on how the tests were realised and succeeded in the respective Living Lab. KPIs are assessed in a similar way as in D6.1: The tables present the scenarios and their respective operational, technical and environmental KPIs, giving the baseline, and target set for result are copied from D6.1. In addition, there is a new column where the result of the real-life or simulation tests performed in LLs is presented as a KPI.

In the second sub-chapter under each LL, the operational and environmental impacts are assessed. The main result from the operational impact assessment is the information of the impact of applying the project innovations to port terminal internal operations, as well as seamless cargo transport from ocean to truck/rail/barge and vice-versa. The main result of environmental impact assessment is the information about the amount of decreased CO_2 emission (in figure and in percentage). When the fuel consumption and type is known, it is possible to calculate CO_2 emissions. The impacts are then reflected to the research hypotheses given in D6.1 for each innovation. The data received from the LLs was not always detailed enough to perform the impact assessment in the pre-described manner in all the LLs. Nevertheless, all data available has been utilised to perform the impact assessment as accurately as possible.

Despite the challenges caused by COVID-19 pandemic that arrived in Europe in February 2020, COREALIS innovations were successfully tested in the Living Labs with some modifications in the test plans. The traffic situation was not normal in all ports due to the pandemic and this posed challenges in the comparison of KPIs (baseline / result). In some countries, there were so strict lockdown measures in use at times that port personnel could not come to the worksite. This complicated the implementation of innovations and forced to modify the schedule of the tests. The additional four months to the original project schedule as well as the periodic relaxing the pandemic restrictions helped in rescheduling the tests. Several workshops were replaced by webinars, and the KPIs related to the attendance were modified accordingly. In the end, the unexpected obstacles created by the pandemic were overcome and the planned activities completed in due time.

The data for this report was collected directly from the Living Labs. The testing processes for each of the Living Labs are presented in D5.7 COREALIS LLs final progress report along with results and benefits that do not affect the KPI targets.

3.2 Port of Piraeus LL

Greece and Athens suffered from COVID-19 lockdown measures during 2020. The LL was heavily affected that led to a re-planning of activities. At times, only necessary personnel were allowed on site, which forced to deviate from standard maintenance schedule.

3.2.1 Project innovations and KPI results

The innovations tested in Piraeus LL were PREDICTOR and Green Cookbook, as well as Port of the Future Serious Game, which results are reported in Chapter 4.

Scenario 1: PREDICTOR

Based on D3.2 and D5.6, benchmarking tests have been performed successfully. However, due to the COVID-19 situation, the operations were not normal during the final version tests, and the test results did not measure the planned operations. PREDICTOR tests focused on fast moving spare parts instead of the whole spare parts inventory for two main reasons: (a) fast-moving spare parts are the ones that mainly affect the day-to-day operations, (b) for the remaining parts, there were predictions of 0 – 1 occurrence on an annual basis that could not be verified within the project timespan. Tests were carried out on a monthly basis and the algorithm was re-trained every time based on historical data for variable periods ranging from 2 to 12 months prior to the test run. PREDICTOR is consistently producing credible results throughout the tests and is expected to continue doing so once the operational schedule is restored to prior-COVID period.

In order to determine the effects of applying the maintenance schedule suggested by Predictor, 4 yard-trucks were selected randomly. The results from these vehicles were compared with the predicted maintenance schedule for the entire fleet to extract the performance values for the KPIs. This process revealed that it is possible to reach three out of the five KPI targets when the system is in use. For one KPI the performance value was very close to the target value even though spare part and transport prices were increased due to the effects of the pandemic and the limited supply related to reduced spare parts production worldwide. For the fifth KPI, the average results surpass KPI value clearly. See Table 8 for KPI results.

Scenario 2: Energy Assessment (Green Cookbook)

Green Cookbook aims to provide an energy assessment framework for the Piraeus Container Terminal (PCT). Green Cookbook feasibility study has been completed and the most prominent and financially viable cases have been identified. Deliverable D4.2 has been used as the main source to describe the results. The scope of the D4.2 Alpha-version Green Cookbook was to investigate cost-effective solutions for the integration of renewable energy sources, the reduction of the carbon-footprint of the port in particular and the improvement of the air-quality of the port-environment in general.

As described in D4.2, a purpose-built simulation environment is created, which analyses and models the energy consumption of the port, the integration of renewable energy sources, the flexibility offered by battery storage and the interaction with the grid. The simulation environment considers several constraints, such as the power of the grid connection and the energy content of the battery and allows us to draw conclusions regarding the self-sufficiency of the port, the cost of the different solutions and the achievable CO_2 reduction.

Based on the study, the KPIs have been achieved. For the first KPI, the KPI target value has been clearly exceeded. The second KPI target will be achieved, if the measurement system can be implemented. The results are from the simulation conducted by Dynniq, as no real-life tests in the port were performed. See Table 8 for KPI results.

Table 8: Piraeus LL KPI results.

ID	Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)	KPI (Result)
P1.1	#1	Yard equipment performance (moves/week).	450	480	488
P1.2	#1	Monthly average yard equipment breakdown hrs.	0.20	0.15	0.12
P1.3	#1	Monthly average fuel and spare part consumption.	3.150,00€	3.000,00€	3.024,00€
P1.4	#1	Total container moves performed after applying the data-driven preventive maintenance schedule.	2,9M	3,1M	4,9M
P1.5	#1	True-positives/negatives as regards to replacement/renewal decisions for assets.	-	75%	85-89.7%
P2.1	#2	Energy consumption percentage that can be replaced by renewable energy sources.	-	10%	clearly exceeded
P2.2	#2	Measure overall and per crane power consumption	-	100%	100%

Notes:

KPI result means materialised or achieved during the project, from either real-life tests or simulation.

P1.4 Extrapolated from 409.000 monthly average since Nov 2020. It is obvious that there are numerous other factors affecting the performance of the port in terms of container moves and the effects of Predictor cannot be isolated but the 40% reduction of breakdown hours for yard trucks, clearly improves the terminals capacity to exceed the target performance value.

P1.5 Average values presented, actual values depending on spare part.

3.2.2 The impacts to future port and supply chain operations and to the environment

PREDICTOR

In D6.1, the following research hypotheses were given. The use of COREALIS Predictor is expected to:

- Increase yard equipment availability;
- Decrease fuel and spare part consumption;
- Increase total container moves performed after applying the data-driven preventive maintenance schedule;
- Reduce the number false-positives/negatives (Increase the number of true-positives/negatives) as regards to replacement/renewal decisions for assets;
- Reduce operational and maintenance costs of the port spare parts, including tyres.

The KPI results (Table 8) show that the yard equipment performance has increased over the target level and the number of total container moves performed has increased substantially. Fuel consumption cannot be quantified as a result of PREDICTOR, since it is affected by other far more important factors, such as mileage, hours of operation etc. PREDICTOR has a minimal effect due to the "better maintained" engine, but it cannot be quantified. However, the consumption of spare parts can be clearly demonstrated since there were fewer spare parts used and more importantly batteries that have a significant environmental impact. The percentage of true-positives/negatives has reached the target and more.

Energy Assessment (Green Cookbook)

In D6.1, the following research hypotheses were given. The use of COREALIS Energy Assessment is expected to:

- Identify power consumption patterns in the container yard;
- Determine percentage of power consumption that can be replaced by power generated from renewable energy sources.

Both of the expectations have been fulfilled.

Renewable Energy Sources (RES) produce electrical power with a much lower carbon footprint and fewer harmful emissions than fossil fuel-based electricity generation. In the case of PCT, two RES are considered, photo-voltaic (PV) generation and wind-turbines. The CO_2 impact of the renewable generation and battery storage is determined in D4.2, both in absolute value as in CO_2 per kWh of generated electricity.

Calculation of the CO_2-impact of the renewable sources and battery is described in D4.2 and presented here in short:

First, the total CO_2 impact of the installation itself is calculated. This is compared to the electricity generated and stored by the renewable energy sources and battery to determine the CO_2 impact per kWh of electricity. As the CO_2 per kWh is much lower for the renewable energy sources compared to the current fossil fuel-based electricity production in Greece, the CO_2 reduction can also be determined. In a last step, the cost of the renewable sources and battery installation is compared to the CO_2 reduction to determine the cost per ton CO_2 reduction.

CO_2 footprint of the PV-modules, PV-inverters, battery-modules and battery-inverters is taken into account. The inverters have a CO_2 footprint of 124 kg CO_2/kW (nominal power), the batteries have a CO_2 footprint of 123 kg CO_2/kWh (kWh gross energy content as this represents the physical size) and the PV-modules have CO_2 footprint of 824 kg CO_2/kW (module peak power).

By taking the renewable energy sources in use, great emissions savings are possible. With the current consumption in the quay cranes, yard cranes, reefers etc., the annual consumption is around 40 GWh. The percentage possible for renewable electricity production use is estimated to be 89% of the total use. This can be achieved by:

With 2,5 MW of rooftop PV and 7,4 MW in nearby solar fields, some 10 MW of PV is a realistic target for Pireaus. Additionally 7 windturbines of 3 MW can generate 21 MW, so the total RES production becomes 31 MW.

Without batteries, this installation provides 59 GWh of renewable energy, sufficient to achieve 81% self-sufficiency of the load. The self-consumption of the generated renewable electricity is 55%, the remainder is either exported to the high voltage grid (some 15 GWh), but more than 10 GWh is curtailed without the batteries.

With batteries (36 MWh in 5 containers + 2 power conversion containers) the curtailment drops to 7 GWh. The installation obviously still produces 59 GWh of which 52 GWh is effectively used. The self-sufficiency of the port increases to 89%, while the self-consumption of the renewable generation increases to 61%. The battery not only increases the self-sufficiency and self-consumption, but also allows to increase the export to 16 GWh (to avoid curtailment). The port now only needs to import 4,4 GWh of electricity out of a 40 GWh load.

The battery does have an impact on the CO2-emission factor of the renewable power installation, but one should keep in mind that the battery is used for thousands of cycles, hence the impact per kWh is low. For this specific installation (10 MW PV + 21 MW windturbines + 36 MWh batteries, including the converters for all three) the CO2-emission factor is 24 g CO2/kWh.

The current emissions for producing 40 GWh with the emission factor of 1167 g CO_2 / kWh creates 46 680 tons CO_2 emissions per year. In the case where 11% of total consumption is still produced in traditional way, i.e. 4,4 GWh (emission factor 1167 g CO_2 / KWh) and 89% of total consumption produced with RES, i.e. 35,6 GWh (emission factor 24 g CO_2 / kWh) the total CO_2 emissions are 5 989 tons per year.

In addition, there is a possibility to save additional 18 288 tons CO_2 emissions per year when the port is able to export port the produced renewable energy (16 GWh export). This also improves the perception of the port: Instead of a polluter, the port becomes a producer of renewable energy.

Further improvements can be achieved by replacing the diesel yard vehicles, which transport the containers between ship and container yard, with electric drive yard vehicles. 8 000 tons of CO_2 emissions would be saved per year as diesel is replaced with electric drive and the self-consumption increases, resulting in less curtailment of the renewable generation.

3.3 Port of Valencia LL

3.3.1 Project innovations and KPI results

The innovations tested in Valencia LL were TAS and JIT Feasibility study, as well as Hackathon, which results are reported in Chapter 4.

Scenario 1: TAS

The Advanced Truck Appointment System (TAS) tested in the LL of the Port of Valencia, aims at optimising road transport processes and ensure optimal operations. To achieve this objective, the TAS is based in predefined time slots for container delivery/pick-up operations that allow terminal operators to define the capacity for the land operations. With this system, logistics operators, shipping agents and truck companies can plan their operations and select the most suitable time slot to perform them.

Besides the slot-based system, the Advanced TAS of the LL of Valencia also gathers real time truck positioning information thanks to the TAS mobile App, which allows to calculate in real time the ETA (Estimated Time of Arrival) of each operation and show it in the TAS e-platform (driving status on the TAS dashboard).

The slots of the TAS of the Valencia LL were set to 1h and the capacity of them was not limited. This approach is explained because the objective of the pilot is to increase the visibility and information of road transport operations and not to create a restrictive system with limited number of operations allowed per slot.

The testing of the TAS was divided in two testing periods: Tests 1 and Test 2:

The first testing period (Test 1) used the first version of the TAS e-platform and the TAS app with basic functionalities. A transport company using two trucks tested this first version: one truck for local operations (less than 2h of driving time to the port) and another truck for regional operations (more than 2h of driving time to the port).

Key figures of the first testing period:

- Start: March 2020
- End: June 2020
- Terminals = 3
- Transport companies = 1
- Vehicles = 2
- Total Operations = 71
- ETA Use = 18 operations

The second testing period (Test 2) used the improved version of the TAS e-platform that included a new statistics module and an improved dashboard. Besides, the TAS app was upgraded with the start of the trip button and the possibility to reschedule the preselected time slot. This second version was tested by a different transport company that in Test 1, and they also used two trucks.

Key figures of the second testing period:

- Start: June 2020
- End: November 2020
- Terminals = 3
- Transport companies = 1
- Vehicles = 2
- Total Operations = 28
- ETA Use = 19 operations

See Table 9 for KPI results calculated after the testing periods (Test 1 and Test 2).

Scenario 2: JIT feasibility study

COREALIS project only covers the feasibility assessment of the Just-In-Time Rail Shuttle Service and the service has been assessed through the study carried out in WP2.

JIT Rail Shuttle service is not going to be implemented in the Port of Valencia in the short term. As this scenario was made theoretically only, the obtained KPI-values are only estimations. Therefore, there is also need for estimate the preconditions, which are needed to achieve these KPIs. So, when this scenario is theoretical exercise, maximising the values of those KPIs is one result, another result is to evaluate which KPI level is possible to achieve with reasonable efforts.

See Table 9 for KPIs. The KPIs set were not possible to be calculated in the study as these KPIs were proposed to be assessed once the JIT service will start real operations, which was never foreseen in the framework of the project. The target column presents the numbers that could be achieved according to the feasibility study.

Table 9: Valencia LL KPI results.

ID	Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)	KPI (Result)
V1.1	#1	Average Estimated Time of Arrival (ETA).	-	2h	3h 3min (Test 2)
V1.2	#1	Number of slots per hour.	N/A	1000	Unlimited
V1.3	#1	Maximum number of bookings per hour.	Maximum of 500 trucks per hour in an average day.	-	Unlimited
V1.4	#1	% use of the time slots preselected.	N/A	95%	18% (Test 1) 37% (Test 2)
V1.5	#1	Number of cancellations.	N/A	1%	Less than 1%
V1.6	#1	Number of bookings changed.	N/A	4%	No results available
V1.7	#1	External systems connected to the TAS.	N/A	1	0
V1.8	#1	Waiting time in terminals	25:23 min	-	14:47 (Test1) 17:07 (Test2)
V2.1	#2	Number of daily roundtrips.	-	2 (5 days a week)	
V2.2	#2	Composition characteristics: Composition TEU Capacity.	-	72 TEU	
V2.3	#2	Composition characteristics: Composition ITU Capacity.	-	43 ITU	
V2.4	#2	Composition characteristics: Composition length.	-	475m	
V2.5	#2	Composition characteristics: Composition maximum load.	-	1.935 tons	

V2.6	#2	Cost per Unit transported (€/TEU).	-	93.29-95.37€/TEU	
V2.7	#2	% of containers delivered on time.	-	-	-
V2.8	#2	Turnaround time.	-	-	-
V2.9	#2	Average number of handling movements per container.	-	-	-
V2.10	#2	Minimum time required for booking.	-	-	-

Notes:

KPI result means materialised or achieved during the project, from either real-life tests or simulation.

1.6 This KPI has not been reported. Even though the bookings can be changed, the system does not record these changes. If necessary, this functionality can be added in future versions of the TAS.

1.7 This KPI has not been reported. Initially it was foreseen the possibility of integrating the TAS with the Port Community System of the Port of Valencia, but this possibility was finally rejected because of the high requirements needed to integrate them just for a pilot test.

1.8 Additional KPI was calculated in order to compare the benefits of implementing a TAS in port environments to optimise road transport flows.

2.1-2.6 The feasibility study was performed with the data in the target column.

2.7-2.10 These KPIs were proposed to be assessed once the JIT service will start real operations. They cannot be calculated in the study phase.

3.3.2 The impacts to future port and supply chain operations and to the environment

TAS

Research hypotheses given in D6.1 stated that the use of COREALIS advanced TAS will:

- Increase information available of container delivery and pickup operations;
- Facilitate better planning for terminals, transport companies and logistics operators;
- Increase collaboration between the actors of the container supply chain;
- Improve quality service of delivery and pick-up operations;
- Reduce congestion inside and outside the port.

Considering the Total Driving Time, it results that the average ETA of the delivery operations in the Test 2 is 3 hours and 3 minutes. Differentiating the average time by long-distance movements (over 2 h) and for short-distance (less than 2 h drive to the port) we find following driving times:

- Long-distance (over 2 h): 4h and 28 minutes' drive
- Short-distance (less than 2 h): 1h and 14 minutes' drive

The slots of the TAS were set to 1h and the capacity of them was not limited because the objective of the pilot was to increase the visibility and information of road transport operations and not to create a restrictive system with limited number of operations allowed per slot. Therefore, there was no limit in the number of operations that were allowed per day and slot.

The total bookings done with the TAS in the LL of Valencia considering Test 1 and Test 2 is 108. Only one of them was cancelled in the Test 1 period.

As can be seen from the KPI results, only 18% of the operations in the Test 1 and 37% of them in the Test 2 were finally carried out in the preselected slots, which are far below the target value of 95%. These low values of predictability can be explained due to the difficulty of transport operators accurately determine the arrival times one or two days in advance. The improvement in the results of Test 2 compared to Test 1 can be explained due to the upgrade of the TAS App that includes the functionality of rescheduling by the truck drivers. Drivers have increased accuracy on the arrival times because they know when they finally start the trip to the port compared to transport planners that predict this arrival time few days before. As a result, it can be said that this functionality is very useful for the system because it has clearly improved the accuracy of the predictability compared to Test 1.

The KPI results show that the use of the TAS has reduced the waiting time inside the terminal in almost 10 minutes in average compared to the results of 2019. This has a huge impact considering the volume of trucks that call at the port gates in daily basis in the Port of Valencia, which has an average number of 5000 trucks movements per day. The trucks' engines are not running all the time during waiting times at ports, but assuming the engine is on 50% of the waiting time with a fuel consumption of 2 l/h (on average), it can be estimated that 833 litres of diesel is saved daily. Considering both the fuel production and consumption, the maximum possible emission savings due to TAS reducing trucks' waiting time in Valencia can be estimated to be 862 tons of CO_2 per year.

However, it must be remarked that the variability of the maximum and minimum values of the waiting times in Test 1 and Test 2 is very high. Besides, the sample of both tests is much smaller than the sample of benchmarking, which would require more testing and a deeper analysis on the root causes. Overall, reduction of waiting times optimises the efficiency of the operations.

JIT feasibility study

Research hypotheses for the use of COREALIS Just-In-Time Rail Shuttle service were:

- Increase collaboration and information exchange between the actors of the container supply chain;
- Optimise rail composition;
- Increase rail modal share for container cargo;
- Decrease the cost per unit transported by rail (€/TEU);
- Reduce waiting time of the cargo in port container terminals;
- Reduce container-handling movements inside container terminals.

The hypotheses were not all possible to assess in the study phase, but the results show that it is possible to increase rail modal share for container cargo. With the optimised rail composition, the fuel consumption and related costs and emissions would decrease significantly.

This section estimates the savings in energy terms (reduction in fuel consumption) that would be achieved thanks to the implementation of the JIT Rail Shuttle service. Firstly, it is assessed the traffic in the area: Zaragoza and its surroundings. Currently, the goods traffic in the area of Zaragoza, both imports and exports, enter/leave mainly through the ports of Barcelona, Bilbao and Valencia. The three ports are located at very similar distances from Zaragoza and all three have both road and rail connections. The following table (Table 10) shows the distances between Zaragoza and the nearby ports by road and rail:

Table 10: Distances between Zaragoza and nearby ports

	Bilbao	Barcelona	Valencia
Total Distance by Rail (km)	301	316	355
Total Distance by Road (km)	301	316	315

It is taken as a starting hypothesis that all the traffic captured by the JIT Rail Shuttle has as origin/destination one of these three ports: Barcelona, Bilbao or Valencia. Furthermore, it is considered that the traffic is uniformly distributed in each of the three ports, that is, 33,3 % of the total goods transported enter/exit from each of them.

The modal distribution of the three ports has also been analysed. The following table (Table 11) shows the modal distributions by road and rail of each of the ports:

Table 11: Modal distributions by road and rail of the three ports

	Bilbao	Barcelona	Valencia
Rail Modal Share (%)	23 %	13 %	8,39 %
Road Modal Share (%)	77 %	87 %	91,61 %

As it has been taken as a starting hypothesis that traffic is uniformly distributed between the three ports (33,3 % each), this result is an average modal distribution of traffic entering and leaving the Zaragoza area as follows:

- 14,8 % by rail
- 85,2 % by road

In the JIT Rail Shuttle Service feasibility study, the most optimal and plausible scenario is the scenario 6, with a total of 2 daily runs for 5 days a week and 475m long trains with a capacity of 72 TEUs. The following table (Table 12) summarises the main results of this scenario:

Table 12: Main results of the scenario

Train Capacity	72	TEU/Train
Weekly trips	10	Trips/week
Weeks per Year	52	Weeks/year
Annual Kilometres travelled	184.600	Km/year
Total TEU transported	37.440	TEU/Year

Considering that the cargo to be transported by the JIT Rail Shuttle is distributed between road and rail with the average modal split mentioned above, the JIT Rail Shuttle would have to capture a traffic of 37.440 TEUs that are currently distributed in the following way:

- Road 31.900 TEU captured from road.
- Rail 5.540 TEU already travelling by rail.

Then it is calculated the energy consumption of the captured traffic from the road transport mode per unit of transport. It is calculated in litres of diesel per TEU (Table 13).

Table 13: Fuel consumption per unit for the TEUs shifted from road to rail

Modal Sift (Road → Rail)	31.900	TEU/Year
Locomotive fuel consumption	5,4	L/km
Total Fuel consumption	996.840	L/year
Total Fuel consumption per TEU	31,25	L/TEU

The traffic captured from road would be 31.900 TEU and the comparison of fuel consumption and emissions from road transport versus rail allows identifying the energy savings due to the modal shift. Therefore, to make this comparison it is needed to calculate the fuel consumption of these 31.900 TEUs transported by truck.

Firstly, it is assessed the distribution of 20' and 40' container types to calculate the number of trucks needed. Considering only the volume, a truck can transport two 20' containers. However, when the containers are full, only one 20' container is transported per truck. The 40' containers are transported full or empty on a single truck.

The traffic between Zaragoza and Valencia was analysed and the following table (Table 14) summarises the distribution of TEUs, types of containers and trucks according to the type of cargo:

Table 14: The trucks used to transport 31 900 TEU per year

Total TEU transported	31.900	TEU/Year
20' Containers	20%	1 TEU
40' Containers	80%	2 TEU
20´ Trucks	6.524	Trucks
40' Trucks	12.688	Trucks
Total Trucks	19.212	Trucks

From the previous table, a total of 19 212 trucks would travel between Zaragoza and Valencia transporting cargo. Moreover, between both cities, there is a distance of 315 km by road and the average consumption of a diesel truck is 35L/100km (0.35l/km). Thus, following table (Table 15) shows fuel consumption calculations by road transport:

Table 15: Fuel consumption per unit for road transport

Annual Kilometres travelled	6.051.744	km/Year
Truck Fuel Consumption	0,35	L/km
Total Fuel consumption	2.118.110	L/year
Total Fuel consumption per TEU	66,39	L/TEU

Comparing the fuel consumption per TEU transported between the JIT Rail Shuttle Service and the road transport by truck, road transport has a consumption of 66.39L/TEU while in the case of rail transport it reduces to 31.25L/TEU. This represents a reduction of more than 35.14L/TEU, which is almost 53% in fuel savings and its associated GHG emissions. Annual savings would be 1 121 270 litres diesel and 2 623 tons of CO_2 emissions respectively, using emission factor 2.339 kg CO_2 per one litre of diesel.

It shall be noted that this analysis is an estimation of the energy savings comparing only the main transport segment between Zaragoza and Valencia. The required transport between factories and rail terminals by road as well as energy consumptions at rail terminals were not considered.

3.4 Port of Antwerp LL

3.4.1 Project innovations and KPI results

The Antwerp Living Lab was strongly influenced by the COVID-19 pandemic and the lockdown that went into effect on 16 March in Belgium. Nevertheless, the partners involved in the LL identified alternatives in order to cope with these issues and challenges and meet the objectives set at the beginning of the project. The innovations tested in Antwerp LL were Cargo Flow Optimiser and Market and Chassis Brokerage Platform, of which the latter is reported in Chapter 4.

Scenario 1-3. Cargo Flow Optimiser

The Cargo Flow Optimiser (CFO) helps to reduce the storage time at ports and increases the share of more sustainable transport modes, by using real time vessel data sharing and rail/barge data for cargo bundling and consolidation. In a broader sense, the Cargo Flow Optimiser aims at improving the modal split from truck towards rail and barge.

The Cargo Flow Optimiser consists of two complementary modules, based on the three scenarios describing the implementation of the innovation and previously defined in Task 1.3. The first module is the Multimodal Inland Planner (MIP). Its main aim is to give a complete overview of the most efficient connections from Port of Antwerp to its hinterland by rail, barge or truck. It calculates the optimal door-to-door container routes between two points in terms of estimated duration, price and CO_2 emissions.

The second module is the Cargo Flow Prediction. It predicts the traffic of containers going from Port of Antwerp to different European destinations. The developed forecasting algorithm can predict the flow of containers, the destination and the mode of transport by means of historical and real-time data.

Scenario 1 - CFO: Optimising port's terminal logistic ops

The goal of this scenario is to achieve a smart organisation of containers placed on a port’s terminal with different destinations and modes of transport. To achieve it, the CFO should be able to predict how many containers are going to arrive or leave the port for a certain day/week/month and their arrival/leaving mode of transport. To achieve it, both real time information and historical data will be connected and integrated in order to create a unique data model. This data model will be provided with information related to container, terminal main characteristics as well as main inland transportation parameters related to the arrival to the terminal.

This scenario was not realised after all as the scope of the Antwerp LL changed during the testing period and it was decided to put more effort in the development of the MIP rather than on the optimisation of containers placed on a port terminal.

Scenario 2 - CFO: Enhanced route planner with price information and flow prediction

This scenario will produce a list of routes that show transport time and a prediction of availability and economical cost based on:

- Routes information from transport operators, including price and transport time.
- Flow prediction inferred from transport offer and containers historical movements (destination and transport mode).

The optimiser in this scenario outputs the recommendation of the best transport option.

Scenario 3 - CFO: Propose "shared" on-demand transport services

This scenario will propose a new shared transport services based on historical demand and current offer in order to promote multimodal sustainable modes of transportation, and in order to benefit the different stakeholders in and around the Port of Antwerp.

The technical tests that were performed for the Multimodal Inland Planner (MIP) are summarised in Table 16. Key users have gathered information on actual transports from the operational departments. Actual pick-up/delivery address of recent transports were used to test the MIP. The results were compared with the operational route and mode of transport. For most of these destinations, truck was primary choice in both MIP as operational situation but for some destinations, multimodal options were shown in MIP that were not known by the test companies.

Table 16: Summary of the technical tests that we performed for the MIP

Test Scenario ID	Test case description	Test result
Geocoding operations	Geocoding and reverse geocoding. Translate lat, long geo-coordinates to an address and an address to its geo-coordinates.	Successful API and FE app. The user obtains a geo-coordinate from an address and an address from a geo-coordinate.
Truck router	Get a road route by truck between two addresses or geo-coordinates in Europe.	Successful API and FE app. The user receives the information of the proposed road routes between two predefined places.

Train router	Get a rail route between two addresses or geo-coordinates in Europe.	Successful API and FE app. The user receives the information of the proposed rail routes between two predefined places. If there is not a rail connection available between the two points, the system informs about that and no route is returned.
Barge router	Get an inland waterways route by barge between two addresses or geo-coordinates in Europe.	Successful API and FE app. The user receives the information of the proposed river routes between two locations. If there is no river connection available between the two points, the system informs about that and no route is returned.
Antwerp inland connections finder	Provides different multimodal transport connections (road, rail, river) from PoA to any destination (address or coordinate) inside PoA's hinterland. It includes last-mile connection by truck for rail and river routes.	Successful API and FE app. The user receives all the available connections specifying transport mode, inland terminal, connection id reference, and route information (shape, distance, etc…)
Antwerp inland connections optimiser	Provides the optimal multimodal transport connections (road, rail, river) from PoA to any destination (address or coordinate) inside PoA's hinterland. The result will provide the most convenient available connections considering price, time and CO_2 emissions.	Successful API and FE app. The user receives the optimised connections list specifying transport mode, inland terminal, connection id reference, and route information (shape, distance, etc…)
Inland connection details	Provides detailed information (operator, terminals, schedules, etc.) of a specific inland connection.	Successful API and FE app. The user receives detailed information for a specific connection.
Inland terminals	The system returns the inland terminals according to specific parameters.	Successful API. The user receives the list and details of all the terminals available by the search criteria parameters.

In the case of the Cargo Flow Prediction, the testing consisted in rerunning the model with the new data from containers and compare the results with the results that were received from the initial prediction model.

See Table 17 for KPI results.

Table 17: Antwerp LL KPI results.

ID	Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)	KPI (Result)
A1.1	#1	Number of terminals that reduced the number of handlings (data to be provided by the terminal operator).	0	2	-
A1.2	#1	Average time that the container is in the terminal (pick up time) (data to be provided by the terminal operator).	3 days	2 days	-
A2.1	#2/3	Number of active uses of the application per month (Active user > 3 logins).	0	10	3
A2.2	#2/3	Number of cargo routes requested per month.	0	150	90
A2.3	#2/3	Number of different locations/destinations chosen per month (locations within 20km distance are considered the same)	0	20	30
A2.4	#2/3	Percentage of locations/destination chosen that have an available train route.	0%	70%	86%
A2.5	#2/3	Percentage of locations/destination chosen that have an available barge route.	0%	30%	56%
A2.6	#2	Percentage of CO_2 reduction of rail compared to truck on the requests performed with the multimodal inland planner.	0%	85%	-1.1% (weighted by container volume) -61.4% (not weighted by container volume)
A2.7	#2	Percentage of CO_2 reduction of barge compared to truck on the requests performed with the multimodal inland planner	0	70%	-0.3% (weighted by container volume) -19.3% (not weighted by container volume)
A2.8	#2/3	Number of successful transactions per month.	0	2	-
A2.9	#2/3	Percentage of transport shifted to rail and barge.	0%	50%	-
A2.10	#2/3	Number of new "shared" on-demand transport services that could be created.	0	2	

Notes:

KPI result means materialised or achieved during the project, from either real-life tests or simulation.

A1.1-1.2 Change of scope of the tool, thus no results.

A2.8-2.9 As most participants in the Antwerp LL. did not use the MIP in a production environment, but used the MIP as a basis for comparison, these KPIs will not be taken in account.

3.4.2 The impacts to future port and supply chain operations and to the environment

Cargo Flow Optimiser

The first priority was to get users and data, and then try to find first places where the benefits of CFO can be easily obtained. Conclusion was that MIP has added value already in this development stage. Current parameters as duration, distance, price indication and emissions are a first indicator. In order to make real decisions on the operational route also live data on closing and delivery time and actual cost is necessary.

Research hypotheses given in D6.1 stated that the use of COREALIS Cargo Flow Optimiser will:

Scenario 1: CFO - Optimising port's terminal logistic operations.

- Result in a number of terminals that reduced the number of handlings;
- Reduce the average time that the container is in the terminal (pick up time).

Scenario 1 was not assessed after all, as there was change of scope of the tool.

Scenario 2: CFO - Enhanced route planner with price information and flow prediction.

- Result in a number of companies that will use the application per month;
- Result in a number of successful transactions per month;
- Reduce the CO_2 consumption per connection;
- Increase the percentage of transport shifted to rail and barges;

Since the baseline was zero, all the activities done with the help of COREALIS innovations had a positive effect on the KPIs. Implementation of the innovations require adequate number of user companies and big amount of data. This was a challenge, the target KPIs related to user companies, and transactions were not reached. Anyhow, the KPIs achieved related to number of locations and rail and/or barge routes available exceeded the targets. Decrease in CO_2 emissions was anyhow lower than expected, and almost negligible when weighted by the container volume. Data about actual shift to rail and barges was not available in production environment.

Scenario 3: CFO - Enhanced route planner with price information and flow prediction.

- Increase the number of new "shared" on-demand transport services.

As most participants in the Antwerp LL did not use the MIP in a production environment, but used the MIP as a basis for comparison, this could not be assessed.

3.5 Port of Livorno LL

Northern Italy has been one of the most heavily COVID-19 affected areas in 2020 with lockdown measures never experienced in the past. The LL was heavily affected that led to a re-planning of activities. The innovations tested in Livorno LL were RTPORT and PORTMOD, as well as Port of the Future Serious Game, which results are reported in Chapter 4.

3.5.1 Project innovations and KPI results

The Livorno Living Lab is involved into the implementation of RTPORT module for the management of the general cargo at the CT Lorenzini, through the instantiation of a 5G network. Livorno Living Lab is also one of the participants developing scenarios in the Port of the Future Serious Game in order to be able to assess the impacts of the 5G technology. The third innovation, PORTMOD, will be tested in the Livorno Living Lab in order to analyse the current container flows at CT Lorenzini, identifying operational inefficiencies.

Scenarios 1 and 2: RTPORT

RTPORT module has two strictly interlinked scenarios, namely General Cargo Management System and Yard Vehicles Management System.

Due to pandemic restrictions, the original tests plan at the seaport has been revised to minimise contacts between people. Therefore, testing activities for the seaport logistics application were proceeding using VR environments and only a limited number of tests have been performed in field.

The VR environment is able to reproduce with high fidelity the seaport yard and all the testing conditions. Forklifts and freights are simulated and detected through virtual cameras that reproduce the optics of the real ones. The correspondence between the real and virtual cameras was verified with dedicated experiments in the Ericsson lab.

The VR environment allow us verification of all applications, their working and their interactions, generating physical data streams as in the real context.

The exchange of data through the 5G network, instead, has been experimented in the real context to check requirements on bandwidth, latency and stability.

A test of the applications and cameras with 5G was done before the lockdown using the alpha version with positive results. Therefore, communications are reliable and fulfil the requirements.

The KPIs, described in D6.1, were refined based on further measurements taken at the seaport. Exploiting VR, all the KPIs were verified.

Benchmarking data

The KPIs verification was done using, as benchmarking, data provided by the Lorenzini's terminal and collected on field. The Lorenzini's terminal performed an agreed set of measurements with their forklifts to acquire typical timings when a freight is moved between places and when a box must be searched in the yard.

The terminal, for the general cargo part, is operational 12h a day and the activities are organised in 6-hour work shifts during which 1-2 forklifts operates (alternatively).

Typically, tower cranes operate for 12 hours a day, loading cargo onto the ships, while supporting vehicles, such as forklifts, operates for 14 hours a day.

Supposing to handle one general cargo ship at a time using one crane, the terminal is able to process 90 freights in a shift with an average of 15 freights per hours.

Thus, considering that typically the terminal handles general cargos ships with an average cargo load of 270 freights corresponding to an average of 2400 m^3 of general cargo, we can estimate a *vessel operation completion time* of about 18h.

The *Vessel idle time at berth* on average is estimated to be 36 hours, given by the sum of the 3 shifts needed to load 270 freights (90 objects per a 6 hours shift), the crane idle time of 12h a day, and the time needed by the ship to prepare for loading operations, other activities to secure the load and departure procedures.

To allow the ship to be loaded with the aforementioned rate of 15 freights per hour, the forklift works 2 hours more than the 12-hours working time of the crane, that, distributed over the single work shift, correspond to 1 extra hour per shift. Considering this, the *average operation execution time (by forklift)* is about 5 minute per object.

The *average time of activity/inactivity of the forklift* is linked to the fact that the cranes do not operate during the night (crane activity/inactivity time is 50%/50%). Thus, considering that forklifts work 2 hours longer than cranes, the activity time for a forklift is 60% and consequently the inactivity time is 40%. In this case, an improvement of the situation means that the forklift activity time for a specific ship should decrease, leaving it available for other tasks.

During the goods acceptance phase the terminal can handle up to 500 m^3 of general cargo in a work shift. Thus, the *unloading operations completion time* is estimated in about 36min for a single truck.

As far as the registration phase is concerned, in the current procedures, it is completed off-line, at the end of the work shift, when the forklift driver delivers the waybills to the terminal offices and it takes about 3min per object.

The available data related to each object are not always complete; in 1% of cases, the information of the size of the object is not reported on the waybill.

One of the issues related to the management of the general cargo is linked to the fact that today there is no knowledge on where the specific freights are positioned so the *time to find a pallet on the yard* (a specific freight) is quite high, on average 8 minutes are needed.

The *occupied space during the storage phase*, instead, for a medium size load, likes the one we are considering, is about 5000 m^2 (three times the space occupied by the freights, to allows forklift operations) and on this area the freights are stored in a random order. For this reason, up to 4 movements are required per cargo unit: unloading from truck and transfer to the storage area, transfer to the crane, and an average of 2 more movements to get the right object in the storage area.

A summary of the benchmarking values (KPI baseline), used for the KPIs verification, is reported in Table 18. They strongly depend on the load for each ship, thus the reported values are related to a medium size load (270 freights).

For the environmental benefit analysis, the "Carbon footprint technical report" produced by the Port of Livorno in 2019, has been used as reference. The source data refers to observation during 2017.

KPI verification

From tests at the seaport and the VR simulations carried out, we measured the KPIs reported in Table 18 (KPI measured). The results reported are average values related to a medium-size general cargos load of 270 freights. The target KPIs were fulfilled.

The instantiation of a pervasive 5G network at the Port of Livorno, as well as the use of advanced AR/VR-based services, provide optimisation of the intra-terminal operations.

In particular, the forklift operations can be optimised reducing the operation execution time from 5 min to 3.4 min.

This means a reduction of the vessel operation completion time from 18h to 15.7h, thus allowing a reduction of the vessel idle time at berth of about 6%, from 36 to 33.7 hours.

As far as the occupied space in the storage area is concerned, in fact, it remained unchanged. This is because we decided to sacrifice the reduction of the occupied space to the advantage of a better distribution of the freights. Indeed, the proposed solution provides an optimal distribution of the cargo that always allow all the freights to be reachable.

This made forklift extra-activities, to organise the freights and prepare them for loading, no longer necessary, bringing the working hours of the forklifts to match with those of the tower crane. Consequently, the percentage time of activity/inactivity of the forklift became equivalent to that of the crane (50%/50%).

Moreover, since all the objects are always reachable and having digitised the registration and localisation operations with the aid of AR/VR, the time to find a pallet on the yard is drastically reduced from 8 min to 1 min.

In addition, the total number of movements per cargo unit is reduced to 3 because no further movements are necessary to reach a specific object, at most, it could be necessary to unstack some freights, but as happens today, objects stacked over the target freight can be moved altogether to the crane. A small freights buffer area in front of the crane is typically used.

Thanks to 5G and enhanced digital applications, the proposed solution, compared with the current acceptance goods procedures, provides an improvement of the registration phase allowing the collection of all the goods information (100%) with a decrease of the cargo registration completion time (per general cargo unit) from 3 min to 1 min. Note that, the registration phase in the current procedures is completed off-line. It occurs at the end of the shift when the forklift driver delivers the waybills to the terminal offices. With the proposed solution goods information are registered in the relational DB in real time making the information available for the optimisation of the following operations.

The advantages of the solution are also evident on the time to complete the unloading operation (from a single truck) which decreases from 36 to 26 minutes.

Table 18: KPI verification

Operation	KPI (average value)	KPI baseline	KPI measured	What improved	Benefited Stakeholder	Environmental analysis	
						CO_2 saving per container operation	What improved
Vessels' berthing time	Vessel operation completion time	18h	15.7h	Increased operational speed	Shipping Company and Terminal operator	-	
	Vessel idle time at berth	36h	33.7h			-	
Cargo release	Cargo registration completion time	3 min	1 min	Increased operational speed	Haulers and Terminal operator	-	
	Amount of data related to the cargoes	90%	100%			-	
	Loading (on ship) /unloading (from a single truck) operations completion time	18h/36 min	15.7h/26 min			8.2% CO_2 saving	Fuel reduction
	Time to find a pallet on the yard	8 min	1 min				Fuel reduction
Quays and yards operations	Forklift operation execution time	5 min	3.4 min	Increased operational speed and reduced operational costs	Terminal operator		Fuel reduction
	Occupied space during the storage phase	5000 m^2	5000 m^2			-	
	Percentage time of activity/ inactivity of the forklift	60%/40%	50%/50%			-	
	Total number of movements per cargo unit	4	3			-	

KPIs are presented in the original KPI format in Table 19.

Scenario 3: PORTMOD

This scenario focuses on the efficient management of containers at the CT Lorenzini. One of the main problems that is currently affecting the CT Lorenzini, concerns the availability of physical space for containers storage. PORTMOD will permit to visualise container movements and, therefore, assist in identifying environmental improvements in container movements. The results of the analysis will be used at the CT Lorenzini for the following purposes:

- To allow CT Lorenzini operators to identify possible bottlenecks in the container flows;
- To enable to identify efficiency improvements.

Benchmarking tests have been performed by using an initial containers movements data set, extracted from the Terminal Operating System used by the Container Terminal Operator

Lorenzini. The tests have been successfully performed by visualising the historical data through the user interface, setting up the considered containers storage area layout. 1 000 container historical movements manually extracted from the TOS have been considered and these movements have been performed by CT Lorenzini in three operative days during the period from 11/06/2019 (08:09 am) to 14/06/2019 (11:28 am).

Based on this initial result, three different simulations have been performed by considering three different layouts for the Container Terminal Lorenzini as far as containerised cargo movements is concerned. Different CT layouts have been considered taken into account environmental restrictions from the CT Lorenzini (e.g. available roots for containers). The layouts and simulation results are presented in more detail in D5.7.

In order to visualise containers flows within different CT layouts, environmental changes have been applied to the available roots so that it has been also possible to assess potential improvements to be done in terms of available roots and the driving distance per container.

Based on this layout, historical data visualisation has shown that the current driving distance per container move was 593 m. Three different layouts were simulated giving the following driving distance per container move: 493 m, 395 m and 378 m.

See Table 19 for KPI results.

Table 19: Livorno LL KPI results.

ID	Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)	KPI (Result)
L1.1	#1	Vessel operation completion time.	18 h	16 h	15.7 h
L1.2	#1	Loading (on the ship)/Unloading (from a single truck) operations completion time.	18 h / 36 min	16 h / 30 min	15.7 h / 26 min
L1.3	#1	Time to find a pallet on the yard.	8 min	7 min	1 min
L1.4	#1	Occupied space during the storage phase.	5000 m^2	4500 m^2	5000 m^2
L1.5	#1	Vessel idle time at berth.	36 h	34 h	33.7 h
L1.6	#1	Amount of data related to the cargoes.	90%	95%	100%
L1.7	#1	Cargoes registration completion time.	3 min	2 min	1 min
L1.8	#1	Average operation execution time (by forklift).	5 min	4 min	3.4 min
L2.1	#2	Average time of activity/inactivity of the forklift.	60%/40%	55%/45%	50%/50%
L2.2	#2	Total number of movements per cargo unit.	4	3	3
L3.1	#3	Driving distance per productive container move inside of the container terminal.	593 m	N/A	422 m

Notes:

KPI result means materialised or achieved during the project, from either real-life tests or simulation.

L1.6 and L1.7 were verified physically, all other tests related to Scenarios 1 and 2 were verified in simulations.

L3.1 Baseline is from the historical data. There was no set target. The result is an average from three simulations (493 m - 395 m - 378 m).

3.5.2 The impacts to future port and supply chain operations and to the environment

The main aim of the development activities at the Port of Livorno is to increase the operational efficiency of the intra-terminal operations. The environmental KPIs studied include awareness of measures to adapt to climate change and impact of new infrastructures in the port.

RTPORT

In D6.1, research hypotheses for Scenario #1 – General Cargo Management System stated that the use of this COREALIS RTPORT module is expected to:

- Reduce the vessel operation competition time;
- Reduce the loading/unloading operations time;
- Reduce the time to find a specific pallet on the yard;
- Reduce the occupied space through an optimal distribution of the cargo;
- Reduce the ship idle time at berth;
- Better management of the cargo data = Improve the amount of data stored in the cargoes database for each freight

Research hypotheses for Scenario #2 – Yard Vehicles Management System stated that the use of this COREALIS RTPORT module is expected to:

- Reduce the total number of movements per general cargo unit;
- Reduce the time to find a proper forklift on the yard to carry out the required operation. = Improve the usage of forklifts
- Reduce the amount of time required for the registration of freights

These hypotheses were all fulfilled and the expectations either reached or exceeded, except for the occupied space, which remained unchanged.

Economic benefit analysis

To assess the wider economic benefits of 5G deployment for port terminals/land operations, the Port of Livorno focused on the two main operational areas:

1. Faster ship turnaround at the quay, leading to lower costs for shipping companies and terminal operators.
2. Faster freight release through port gates, implying lower costs for haulers serving the terminal and terminal operators.

The following development patterns were identified:

- Reduction of operational costs, fuel consumption and machine working hours.
- Increase of speed rate of operations, thanks to improved processes.

It should be noted that investment costs are not included in this analysis, only operational savings are considered. Table 20 reports the results of the economic benefit analysis for the analysed scenarios.

Table 20: Economic impact of 5G and digital technologies

Operation	What improved	Benefited stakeholder	Savings per cargo terminal (EUR)
Vessels' berthing time	Increased operational speed	Shipping companies	126.5k
Cargo release	Increased operational speed	Haulers	164k
Quays and yards operations	Quays and yards operations	Terminal operators	20k
			70k

Environmental benefit analysis

The reduction in CO_2 emissions (Table 21) is estimated by considering the time needed to accomplish each terminal operation and the average fuel consumption of machines/vehicles.

5G technologies, facilitating the exchange of real-time information among actors in the terminal process, lead to a reduction in movements in cargo handling. This optimises the process and lowers fuel consumption as well as associated CO_2 emissions.

Typically, tower cranes operate for 12 hours a day loading and unloading cargo from ships, while supporting vehicles such as forklifts operate for 14 hours a day. These forklift actions can be optimised with 5G, reducing working time from 14 to 12 hours for the same amount of cargo, and matching that of tower cranes.

The reduction of CO_2 emissions in this scenario is calculated by taking the average amount of fuel consumed by forklifts per hour, and then multiplying that by the CO_2 emission coefficients supplied by ISPRA (about 2.6 t/m^3). The conversion factor from m^3 to kg used is 1m^3=845 kg. Under the assumption that forklift operating hours are reduced from 14 to 12 per day, the annual fuel consumption saving is estimated to be 56 m^3 (47 320 kg). This means that CO_2 emissions associated with the yard movements are reduced by 23.8% (148 tons per year).

Based on this, it is estimated that due to the 5G technologies introduced in the Port of Livorno, CO_2 emissions decreases by 8.2% overall as a result of the improved yard movements. This figure demonstrates an improvement in the environmental sustainability of the port and more specifically how it is contributing to a reduction in greenhouse gas emissions, saving cost, and meeting targets set out in SDG 13 (Climate Action).

Table 21: Environmental impact of 5G and digital technologies

Activity	Machines	Measurement in 2017 (before 5G)			COREALIS project (with 5G)		
		Hours activity/ years	Diesel/ Years (m^3)	CO_2/ Years (ton)	Hours activity/ years	Diesel/ Years (m^3)	CO_2/ Years (ton)
Vessel loading/unloading	Tower crane	4380	399	1055	4380	399	1055
Truck loading/unloading	Forklift	1575	43	114	1575	43	114

Yard movements	Forklift	3681	235	622	2805	179	474
Total		-	677	1791	-	621	1643 (-8.2%)

PORTMOD

The research hypotheses given in D6.1 stated that the use of COREALIS PORTMOD is expected to:

- Enable the allocation of work effort and costs to each stage of the process;
- Allow CT Lorenzini operators to identify possible improvements within the container management processes.

As far as the hypotheses are concerned, they have been achieved since PORTMOD enables efficient management of the container flows in the terminal and the savings in driving distance and fuel consumption can be estimated from different layout configurations. Layout changes also allowed CT Lorenzini to visualise possible environmental improvements (in terms of new roads/paths to be developed) to be done for a better container handling within the terminal.

Based on data collected from CT Lorenzini, the following fuel data was available for impact calculations:

- Fuel Cost in Port of Livorno: 1.12 Euro/Litre
- Average Fuel consumption (reach stackers) in CT Lorenzini: 13 Litres/hour (diesel)

Based on this, it was possible to estimate savings is fuel consumption and fuel costs, as well as CO_2 emissions reduction for different CT layouts configuration (Table 22). The best scenario (Layout 3) would decrease the fuel consumption by 37.6 kg/year and CO_2 emissions by 116.8 kg/year, assuming vehicles consume 13 l/h, which produces 34.3 kg CO_2 /h. Density used for diesel here is 835 kg/m^3.

Table 22: Fuel and CO_2 estimation for different CT Lorenzini layout configurations

CT Layout	Driving distance per container (meters)	Fuel consumption (litres)	Fuel costs (Euro)	CO_2 emissions (kg) in 3 days	Reduction in %
Original	**593**	**1.01**	**1.13**	**2.66**	
Layout #1	493	0.84	0.94	2.22	- 17%
Layout #2	395	0.67	0.75	1.77	- 33%
Layout #3	378	0.64	0.72	1.69	- 36%

3.6 Port of HaminaKotka LL

3.6.1 Project innovations and KPI results

HaminaKotka LL is based on the needs of the Kotka Container Terminal (KCT) operated by Steveco Oy and it participates in three main scenarios: PORTMOD visualisation and simulation tool, Truck appointment System (TAS) and the Port of the Future Serious Game (PoFSG). PoFSG results are reported in Chapter 4.

Scenario 1: PORTMOD visualisation and simulation tool

PORTMOD is a visualisation and simulation tool developed by VTT and Steveco that aims to find improvements to the Container Terminal operations. The PORTMOD tool can help in identifying bottlenecks and find answers to questions related to the most efficient way to use the straddle carrier fleet, with the help of data analysis and simulation. Technically, PORTMOD consists of two main modules: PORTMOD FlowAnalyzer and PORTMOD Simulator, presented below.

PORTMOD FlowAnalyzer visualises container flows by using the data provided by the Terminal Operating System (TOS) system. Furthermore, it offers a graphical user interface where the user can interactively request different ways of data filtering. In addition, summaries of the filtered data are given with the visualisations. This gives the user the possibility to search and quantify bottlenecks, as well as quantify how some operational changes would affect the operational efficiency, e.g. equipment and infrastructure investments. The final version is in test use and the application can be used for historical container flow analysis to get relevant KPIs, e.g. volumes per crane and transport distances inside the terminal. The potential savings can be achieved when inefficiencies are identified and solutions that are more efficient are found.

PORTMOD Simulator has been used to analyse the efficiency of ship loading and unloading operations, hence, the result is a set of simulation results. However, no operational tests have been made. The analysed scope considers the operation of a number of cranes (Ship-To-Shore Gantry Cranes) and a number of machines (Straddle Carriers). The currently used job dispatching strategy is compared against a machine pooling strategy by using data retrieved from the Terminal Operating System (TOS). It should be noted that operational tests could not be performed in practice yet, because the TOS feature of machine pooling has been disabled. However, in the beginning of year 2021, Steveco is gradually taking in use the TOS feature that enables machine pooling.

The investigated loading and unloading periods were chosen in such a way that several STS are in use and that similar periods reoccur. The pilot period consists of 6 shifts with a duration of around 8 hours each during October 2020. The baseline denotes the port performance, estimated by the simulator, using the current strategy. The pilot resulted in a simulation result and there was no impact on the actual terminal operation.

The simulator is used to estimate the benefit of pooling and if less straddle carrier could be used in the selected periods. The summarised results (Table 23) show the comparison between baseline and machine pooling with 10 machines. The performed simulation tests are described in detail in the deliverable D5.7.

Table 23: Summarised comparison of all tests: baseline vs. machine pooling with 10 machines that minimises driving distance.

	Baseline	Pooling with 10 machines	Improvement	Improvement (%)
Statistics				

Number of containers	4645	4645		
Share of containers loaded to ship (%)	55%	55%		
Crane KPI:s				
Crane operating time (min)	11282	11024	258	2%
Lifts/hours/crane (value)	24.7	25.3	0.6	2%
Productivity: productive time / operation time (%)	89%	91%		2%
Machine KPI:s				
Machine operating time (min)	32264	27952	4312	13%
Machine travelling distance (km)	4784	4468	316	7%
Productivity: productive time / operation time (%)	57%	62%		6%
Driving distance per container move (km)	1.030	0.962	0.068	7%

These KPI improvements are limited to the test setup; hence, no yearly improvements can directly be extrapolated. The test setup does not consider jobs beyond ship loading or unloading because this was not in focus and, additionally, PORTMOD Simulator is currently not capable of simulating such a scenario. However, a rough and modest expert opinion is given by Steveco and it is based on the observed simulation results and operational expertise that considers situations for which less STS cranes are in use and were benefits of machine pooling during other operations like truck loading and unloading can be obtained. The result can be seen in Table 24.

Table 24: A rough expert opinion by Steveco of potential yearly savings.

	Value	Improvement	Improvement (%)
Statistics			
Number of containers	318000		
Share of containers loaded to ship (%)	161226		
Crane KPI:s			
Crane operating time (h)	13879	13720	1.1%
Lifts/hours/crane (value)	22.9	23.2	1.2%
Productivity: productive time / operation time (%)	NA		
Machine KPI:s			
Machine operating time (h)	43714	41171	5.8%
Machine travelling distance (km)	796318	756797	5.0%
Productivity: productive time / operation time (%)	NA		
Driving distance per container move (km)	1.29	1.23	5.0%

Final performance reports and KPIs are presented in the original KPI format in Table 25. The KPIs were calculated in the following way:

Original KPI *Equipment usage time / possible usage time* was changed to *Handled container pcs / Equipment usage time hours*. The new way to measure is similar to the old one, but it is unambiguous and easier to measure. The estimation shows that the machines would be more productive. The baseline is calculated from Table 25 by dividing 318,000 containers with 43,714 machine hours. The result is calculated from Table 25 by dividing 318,000 containers with 41,171 machine hours. In D5.6 the productivity improvement target was set to 5% ((3.407-3.237)/ 3.407) and here we report an improvement opportunity of ca. 6% ((7.724-7.275)/7.275).

The estimation shows that the cranes would be more productive. The baseline is calculated from Table 25 by dividing 318,000 containers with 13,879 crane hours. The result is calculated from Table 25 by dividing 318,000 containers with 13,720 crane hours. In D5.6, we reported a baseline of 20 lifts/h, which is based on the observed result in 2018. Here we report a baseline of 22.9 (estimated), which is very close to the observed result 22.8 in 2020. In D5.6, we had set the improvement target to 5% ((21-20)/20) and here we report an improvement opportunity of ca. 1% ((23.2-22.9)/22.9).

Scenario 2: Truck Appointment System (TAS)

The objective of the TAS in HaminaKotka is that terminals know in advance the quantity of trucks that will be heading the port and when, thus, optimising workload and terminal operations whilst avoiding bottlenecks at the port-gates. Likewise, transport companies also know beforehand which warehouse each driver is to address, thus, shortening transit times and speeding up operations.

The final performance reports and KPI analyses are presented in Table 25. The baseline is based on pilot period test in November 2019, with a duration of 2 weeks. The result is based on test period December 2020. The baseline period for TAS was 22.11.-9.12.2019 (15 trucks during the period). The TAS pilot period was 22.11.2019-9.2.2021, during which 260 trucks participated in the trial (7% of trucks to Pilot Warehouse).

Table 25: HaminaKotka LL KPI results.

ID	Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)	KPI (Result)
H1.1	#1	Handled container pcs / Equipment usage time h (estimated)	7.275		7.724
H1.2	#1	Lifts/hours per crane.	22.9		23.2
H1.3	#1	Vessel turnaround time: Arrival - Departure time from port.	29 h 25 min	27 h 57 min	-
H1.4	#1	Loading & unloading efficiency: number of containers / vessel turnaround time.	2.36	2.24	-
H2.1	#2	Temporal distribution of gate operations.	56%/38%/6 %	56%/38%/6 %	57%/35%/9 %
H2.2	#2	Average time of gate-in/out operations (all)	32 min	30 min	28 min
H2.3	#2	Average time of gate-in/out operations (Stuffing warehouse Pilot 1)	74 min	70 min	65 min

Notes:

KPI result means materialised or achieved during the project, from either real-life tests or simulation.

H1.1 In D5.6 the productivity improvement target was set to 5% ((3.407-3.237)/ 3.407) and here we report an improvement opportunity of ca. 6% ((7.724-7.275)/7.275).

H1.2 In D5.6 we have set the improvement target to 5% ((21-20)/20) and here we report an improvement opportunity of ca. 1% ((23.2-22.9)/22.9).

H1.3: Vessel turnaround time is not relevant KPI after all, as it is not dependent on the port operator alone (vessel size, weather, ship owner's decisions, pilotage, etc.).

H1.4: Based on vessel turnaround time, thus not relevant KPI.

H2.1: Shifts morning/evening/night; in the testing phase the TAS pilot trucks did not have an impact on this but in real production use TAS is expected to have greater impact. Less night-time work can be allocated.

H2.2: Includes all trucks in Kotka Container Terminal in Mussalo. In the testing phase the TAS pilot trucks did not have an impact on this but in real production use TAS is expected to have greater impact.

H2.3: TAS pilot project real impact can be seen in this pilot warehouse results.

3.6.2 Impacts to future port and supply chain operations and to the environment

PORTMOD

According to the research hypotheses presented in D6.1, the use of PORTMOD is expected to:

- Increase productivity of container operations in container yard;
- Increase equipment (productive) usage time;
- Increase lifts/hours per crane;
- Decrease vessel turnaround time;
- Increase loading & unloading efficiency of vessel;
- Decrease driving distance per productive container move inside of the terminal.

Machine pooling has been estimated to improve terminal operation at HaminaKotka terminal during loading and unloading by using PORTMOD Simulator. Furthermore, initial tests have been done on quantifying the potential amount on the reduction of needed work effort. The simulation results show that the productivity of the operations can be increased, as well as the lifts/hours per crane when machine pooling is used. The use of PORTMOD enables calculation of certain figures of container terminal operations based on TOS data. However, operational tests cannot be performed because the TOS feature of machine pooling was disabled.

The two environmental KPIs mentioned for HaminaKotka were reduction of CO_2 emissions and improvement of air quality. Table 24 indicates that the total driving distance of straddle carriers may decrease up to 5% and the machine operating time by 5.8%. This would also mean 5.8% less CO_2 emissions from straddle carriers, which yearly diesel fuel use is 57,720 litres (baseline). This is average consumption per carrier and there are 31 carriers so the total annual fuel consumption is 1,789,320 litres. The decrease in total annual fuel use is 103,781 litres and 242,744 kg in CO_2 emissions, using the emission factor 2,339 kg CO_2 per one litre of diesel (vtt.lipasto.fi).

At the same time, air quality would also slightly improve due to emission decrease. With the cranes, the impact is smaller, as their operating time is calculated to decrease only 1.1%. Crane's yearly electricity consumption is 350,000 kwh (baseline). This is average consumption per crane and there are 5 cranes so the total annual electricity consumption is 1,750,000 kWh. The average CO_2 emission factor for electricity production in Finland is 141 gCO_2/kWh [5] and this leads to saving 2,714 kg CO_2 per year.

The KPIs for "Vessel turnaround times" and "Loading & unloading efficiency" can be calculated from the terminal operating system (TOS). Shorter vessel turnaround time would mean less CO_2 emissions and improved air quality in the port area. Even though the vessel turnaround time was chosen as a KPI in the beginning of the project, it became clear that it is not a suitable KPI to represent the impact from PORTMOD. It would require longer period to show its impact and it is not dependent on the port operator alone (but on vessel size, weather, ship owner's decisions, pilotage, etc.). Although the vessel turnaround time decreased during the pilot period compared to the baseline, it cannot be shown this was due to COREALIS innovations.

It is worth noting that in beginning of year 2021, Steveco has gradually started to implement machine pooling in production use at HaminaKotka.

TAS

According to the research hypotheses, the use of Light-TAS is expected to:

- Decrease visiting time of trucks in terminal area;
- Help CT operator to plan the work of warehouse workers;
- Improve the service level for trucks.

Based on the results, TAS has positive effects on warehouse operations due to the more punctuality of trucks. Trucks will be spending less time in the area: before the average time was 74 minutes and now 65 minutes. The time saving is 12% of a truck's port visit. As TAS does not have any effect on driving time between gate and warehouse or actual unloading time, the saved 9 minutes per visit is almost maximum average time saving that TAS can bring. In Mussalo Container Terminal, the yearly number of truck visits are 37,000, and in Hietanen Ro-Ro terminal 12,000. The decrease of 9 minutes does not have any environmental impact though, since the trucks' engines are not running during loading and unloading. Using Webasto for cabin heating at winter has only a minor impact on fuel use.

TAS will clearly help having resources (people and equipment) in correct place in correct times and waiting times will decrease. Significant impacts on operational efficiency and emissions can be expected, but they are difficult to measure. Based on group discussions between VTT researchers and Steveco representatives, the following operation phases, which will have positive environmental impacts, were found out. However, to get actual figures from e.g. CO_2 savings would need more research:

- There is less need for removal of workforce and warehouse equipment between warehouses. When Steveco knows where the workforce is needed, it has possibilities to rationalise the arrival of incoming trucks based on their destination warehouse. As the distances in terminal area are long, decreased need for movements surely has some impact.

- When trucks can better plan their journey to terminal, they are expected to drive better according to regulations when e.g. there is no need for trucks to be earlier in terminal. Driving according to regulation is safer and friendlier for environment.

- The utilisation rate of trucks can be improved. Even if saving of 9 minutes itself has limited impact on utilisation rate, certainty of accomplishment of terminal visit in certain fixed time will help trucking company to schedule following fare without considering possible delay in port. This improvement will certainty decrease significantly idle time of trucks. When big fleet of trucks have better utilisation rate, a smaller number of trucks are needed and new more developed (and more environmentally friendly) trucks are bought more frequently.

In real production use, TAS is also expected to have greater impact on shift distribution so that, for example, night-time and weekend workload can be allocated as needed. TAS is planned to be taken in use in all terminals in HaminaKotka, due to the good results achieved in the COREALIS innovation pilot. Before the end of COREALIS project, TAS will be implemented at least in Kotka Container Terminal in Mussalo (Pilot location) and in Hietanen Ro-Ro terminal.

3.7 Summary of the CO_2 emission saving potential with COREALIS innovations

Several COREALIS innovations offer great potential in decreasing CO_2 and other GHG emissions. In Table 26, the emissions saving potential is presented for each Living Lab and innovation tested, where CO_2 emissions reduction was demonstrated either during the real-life tests, or in simulations or feasibility studies. Calculation for CO_2 reduction in the operation has been presented in previous LL and innovation-specific chapters.

There are small differences in the CO_2 emission factors depending on e.g. bio-component of the fuel, but where the LL has not performed the emission calculations, the following emission factor from Lipasto database from VTT (lipasto.vtt.fi) has been used: 2.339 kg/CO_2 per 1 litre of fuel (2.80 kg/CO_2 per 1 kg fuel when 1 l = 0.835 kg).

In addition to the CO_2 reduction due to the fuel saving in the port operations, the CO_2 emission reduction from fuel production has been considered in the summary table using an emission factor of 0.5942 kg CO_2/ kg fuel. This emission factor for diesel fuel is from the fuel table developed in the project JOULES – Joint Operation for Ultra Low Emission Shipping (FP7, grant agreement 605190), where VTT was involved [6]. It is well in line with other references where the emission factor is given for all GHG emissions, for example in (JRC, 2014) the factor is 0.693 kg CO_2 eq. / kg diesel.

Table 26: CO_2 emission saving potential of COREALIS innovations

Living Lab	Innovation	CO_2 reduction in tons per year (fuel use + fuel production)	Notes
PIRAEUS	GREEN COOKBOOK	40 691	89% of the total electricity use of the port is possible to produce with

			renewable energy sources. See below the table for additional information.
VALENCIA	TAS	862	5000 trucks save 10 min/day. Assuming trucks consume 2 l/h when running idle (about 50% of the saved queueing time).
	JIT	2623 +556.3	53% reduction
ANTWERP	CFO	-	see below the table
LIVORNO	RTPORT	148 +28	8.2% reduction
	PORTMOD	0.117 +0.022	36% reduction in the best layout
HAMINAKOTKA	TAS	-	negligible, although 134 trucks save 9 min time daily but the engines are not running when waiting.
	PORTMOD	242.7 +51.5	Straddle carriers: 5,8% reduction
		2.714	Cranes electricity: 1,1% reduction
In total		**45 205 tons CO_2**	**annual reduction**

In addition to the absolute numbers presented in the **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** above, some of the innovations have indirect impacts to the CO_2 emissions, for example:

- Green Cookbook demonstrates that great CO_2 emission savings are possible by introducing renewable energy sources. In addition to the number shown in the table, there is a possibility to save an additional 18 288 tons of CO_2 emissions per year when the port is able to export the produced renewable energy (16 GWh export). Further improvements can be achieved by replacing the diesel yard vehicles with electric drive yard vehicles. 8 000 tons of CO_2 emissions per year would be saved as diesel is omitted and the self-consumption increases, resulting in less curtailment of the renewable generation.
- TAS improves the utilisation rates of trucks. In long term, this leads to truck fleets with smaller number of vehicles and the average age of vehicles is lower. Newer vehicles are more environmentally friendly than older.

- Cargo Flow Optimiser calculates the optimal door-to-door container routes between two points in terms of estimated duration, price and CO_2 emissions. When choosing the option with the lowest CO_2 emissions, the emission savings are possible. Nevertheless, the saving potential when weighted by container volume seem to be very small (~1%).

4. COREALIS Societal Impact Assessment within a port-city context

Social impact assessment is a process for the identification, analysis, assessment, management and monitoring of the potential social impacts of a project, both positive and negative. The social impacts of a project are the direct and indirect impacts that affect people and their communities during all stages of the project lifecycle. In a port-related environment, the main barriers that is possible to arise from the social perspective may concern unfamiliarity of port authorities and stakeholders with "green" practices, lack of awareness from market players, lack of community engagement, conflicting interests among stakeholders, negative visual effect of new equipment and machinery on the landscape etc. On the other side, the development of a port and the adoption of innovative solutions may lead to benefits for the local communities, including increase of employment, safety etc.

As it was mentioned in the introduction, the societal impact assessment is in general more complex and less tangible than evaluating operational and environmental aspects, as it requires collecting valuable feedback regarding the interaction of a port and its surrounding area and local communities. Moreover, even if this feedback is collected through active involvement of communities and stakeholders in the assessment process, the quantification of this feedback is even more difficult. In order to overcome this barrier, the methodology that was followed for the societal impact assessment of COREALIS innovations in the established Living Labs included among other practices the active utilisation of the PoFSG tool in the assessment process. In parallel, the organisation of a Hackathon event that was conducted in the port of Valencia LL supported the increase of awareness of the local communities regarding the developed innovations and led to the creation of synergies between start-ups, IT companies and entrepreneurs with the port community.

The methodology that was followed for the societal impact assessment of COREALIS innovations was analysed in deliverable D6.1, where the "Sustainable Development Goals and Smart Port" (SDG-SP) model was presented. A summary of the societal KPIs that were defined for each one of the COREALIS Living Labs is presented in the following table (Table 27):

Table 27: Societal KPIs per LL

List of societal KPIs per LL	
Livorno LL	Increase the engagement and satisfaction of residents and/or employees.
	Increase the awareness of the port-city context.
Valencia LL	Number of Hackers (Participants)
	Number of Sponsors
	Number of Stakeholders involved.
	Number of challenges
	Number of proposals
	Number of publications in social media.
	Number of projects with scalability.

HaminaKotka LL	Increase the satisfaction of resident nearby or employee (e.g. can be measured by surveys, health data, employment, etc.).
Piraeus LL	Monitor socio-economic adoption of the port in the surrounding urban environment.

4.1 PoFSG validation

As the Port of the Future Serious Game (PoFSG) is primarily intended to raise awareness and stimulate debate, it primarily relates to the environmental and societal KPIs. The PoFSG can help to look at (technical) innovations from a societal (people), environmental (planet) and economic (prosperity) perspective. Moreover, it stimulates to think about the Port of the Future from different stakeholder perspectives. The PoFSG is a means to engage stakeholders, stimulate discussion on their different viewpoints, and create awareness of the multidisciplinary aspects of port developments and how they may affect People, Planet and Profit. As such, the PoFSG can be used as part of a stakeholder engagement process, (pre-) feasibility studies, and Socio-Economic and Environmental Impact Assessments (SEIAs). Therefore, the game could be useful for port authorities and governments who often are the initiator of a port (-city) development and, hence, responsible for stakeholder inclusion. They could benefit from stakeholder involvement by identifying, mitigating and reducing the risks arising from stakeholder opposition, such as protests, lawsuits and delays in permitting procedures. Furthermore, connecting to the needs of the different stakeholders will help to ensure a better and more inclusive port development plan, which will help to grant/maintain the port's license to operate.

As the PoFSG is a "game" and not a calculation tool, it is difficult to quantify its impact and translate it into KPI measurements. In order to overcome this, the initial plan was to conduct and play the PoFSG in live game sessions with stakeholders from the associated LLs. In these sessions, a relevant scenario would be played with the actual stakeholders for each of the associated LL's and the gameplay could be monitored by means of the qualitative People Planet Profit KPI's in the game. After the game sessions, the stakeholders could participate in a questionnaire-format survey, where the user satisfaction on the implemented features and gameplay could be assessed and the impact of the innovation could be verified, as it was performed in the benchmarking tests. However, due to the COVID-19 outbreak, these live sessions and the user satisfaction surveys were not feasible to be conducted and the actual stakeholder engagement was not possible. Instead, it was decided to replace these workshops by webinars, where the stakeholders participated virtually, got aware about the PoFSG capabilities and were able to discuss about the benefits that could get through its use. In addition, these webinars took places for all LLs and thus, the PoFSG was assessed in all LLs and not only in the ones that was initially planned to be tested.

In parallel, the PoFSG was assessed through a game session that was conducted during the Consortium (plenary) meeting held in Valencia by means of a survey regarding the user satisfaction and awareness perception. The results of this survey have been included in D.5.6: COREALIS LLs Interim Progress Report, as part of the second iteration benchmarking tests. Moreover, as the webinar alternative was selected, the initial KPI targets that has been set should be modified, as the actual participants' number (with physical presence) was not possible to be measured. Thus, it was decided to extract the number of external webinar attendees (excluding the consortium members) and report these measurements.

4.2 Scenarios and societal KPI results

4.2.1 Port of Livorno LL

In the port of Livorno LL, the societal KPIs that were defined were associated with the Port of the Future Serious Game scenario (Scenario #3). This scenario split into two sub-scenarios, namely Innovation and Digitalisation scenario (Scenario #3.1) and Environment and climate proof port development and infrastructure (Scenario #3.2).

Scenario #3.1: Innovation and Digitalisation

In this scenario, players are subdivided into different stakeholder groups. Each group needs to define a strategy from their stakeholder perspective to design their port of the future in several game rounds. Each round represents 10 years. After the teams are formed, the facilitator applies the innovation scenario, which affects People (society), Planet (Environment) and Prosperity (Economy) scores and budget. The scenario describes a world in which the emphasis is innovation and technological solutions, such as 5G. This scenario is suitable for addressing the challenge of technological innovation in the Livorno Living Lab. In each round, each stakeholder group can select two measures to implement its strategy. These measures cost money but can also gain money in time (i.e., through rounds). Furthermore, each measure affects PPP scores. After each stakeholder group has selected two measures, the different stakeholder groups must debate and convince each other to select the final two measures to be implemented in that round. By the end of each round, the selected measures and their associated effects on the PPP scores and budget will be visualised in the digital simulation environment. At the beginning of the following round, the facilitator can run an (unexpected) event that also affects PPP scores. Events are associated with scenarios and can be used to trigger additional conflict, debate and/or a different way of thinking. In the innovation scenario, the associated events can be an IT infrastructure related event (Chaos due to IT network breakdown), which reflects the possibility that the port is not ready for the innovation. Another event can be unemployment in traditional job, reminding the players of the potential impacts of innovations on society or environment. Then the procedure of the first-round repeats. After the completion of the three rounds, a review of the three rounds is presented on the screen. The facilitator gives players the opportunity to discuss with each other the selection of measures, the solutions to the unexpected event and their strategic decisions. The focus lies on the lessons learned regarding the real-world challenges and on the future opportunities for the Livorno Living Lab.

The research hypotheses for this scenario included the investigation of the transferability of new technological solutions to other ports and the assessment of the investments in 5G technology with an associated cost, payback period and impact on port operational and environmental parameters.

Scenario #3.2: Environment and climate proof port development and infrastructure

In terms of climate adaptation and resilience of infrastructure, the PoFSG runs a "climate change adaptation" scenario that simulates the possible effects of climate change over the game period. The scenario describes a future world of increasing impacts of climate change threatening the safety of people and the infrastructure and operations of the port. The players discuss how the port can deal with these changes. The "climate change adaptation" scenario can contain one or more events. For example, an economic event, in which companies may not be satisfied by the port policy on tackling climate change only and ignoring the economic benefits of the business partners, or a big strike from workers that are afraid to lose their jobs. The game also supports climate-related events, such as extreme weather or sea-level rise, triggering players to discuss balance social, environmental and economic benefits. Such a scenario would facilitate a dialogue between stakeholders on the development of climate-related master plans. For instance, how can the port improve climate robustness, in which way the port can resist extreme weather condition, if maintenance cost can be saved, etc. The PoFSG simulates some effects of climate change only and not the full range of possible consequences (as these will be site-specific and require a local assessment).

The research hypotheses for this scenario included the investigation of the effects of climate change over a certain period and the facilitation of dialogue between stakeholders on development of climate-related master plans.

As it was reported in the PoFSG section, the initial KPIs were modified, as the workshops did not take place, in order to report the external stakeholders/attendees of the associated LL webinar. In the case of Livorno LL webinar, the number of external stakeholders/attendees was 61.

4.2.2 Port of Valencia LL

In the port of Valencia LL, the societal KPIs that were defined were associated with the Innovation Incubator scenario (Scenario #3) and the organisation and celebration of a Hackathon that helped to create synergies between start-ups, IT companies and entrepreneurs with the port community of the Port of Valencia. The objective of this hackathon was to present the main concerns and challenges of the port community and see if new ideas and technologies can be useful to overcome them. The most relevant ideas presented in a competition organised in a collaborative environment, would be awarded in the hackathon to be further developed in an incubator scheme.

<u>Scenario 3: Innovation Incubator</u>

In this scenario, a hackathon event is organised, where students, professionals, start-ups and scale-ups tackled challenges within the maritime and logistics sector. During these days, the participants go from idea to a working concept, together with coaching of experts within the industry. In the hackathon event, everybody is welcome to co-create the concept of port of the future, facing the main challenges of the port community of the port of Valencia. Especially, the hackathon involves:

- Hackers: students, start-ups, professionals, researchers, national, international, etc.
- Port Cluster: stakeholders and actors of the port community;
- Technology Corporations;
- Entrepreneur Ecosystem;
- Coaches to help hackers in the preparation of the challenges;
- Experts that will assist hackers in the technical details;
- Jury that will select the winners of each of the challenges proposed.

For the development of the hackathon, the topics to be approached shall be significant for the port community in order to make a real profit of the outputs of the event. In the aim of building such topics, the cluster is requested to show needs and priorities when facing innovation to tackle with their daily and strategic challenges. Some areas that the challenges could cover are the following:

- Circular/Collaborative economy establishment;
- Climate Change overcoming;
- Digitisation for increased efficiency;
- Training technologies adapted to the new profiles.
- Mobility in port-city areas
- Business models

An iterative process is then put in place, in order to define the particular lines of work that the participants have to resolve by innovative solutions, including technologies to be used and/or business models to be applied.

Based on the research hypotheses from D6.1, the Hackathon would increase collaboration between the port industry and the entrepreneur community, facilitate digitalisation of port processes and promote innovation among the port community. The initial plan for the Valenciaport Hackathon of the COREALIS Incubator Scheme was to organise a face-to-face event where local stakeholders, Small and Medium Enterprises (SMEs) and entrepreneurs could come together to face the challenges and develop innovative ideas in a short event (2-3 full days). The Valenciaport Hackathon event was planned to be held within the Webit Conference between 17th to 20th of June 2020 in Valencia, which was a great opportunity for engagement and communication purposes, but also for attracting participants. In the Webit Conference, the Valenciaport Hackathon was going to be one of the activities of the Maritime Summit, but in the end, due to the COVID-19 outbreak, both the Webit conference and the Valenciaport Hackathon were cancelled. Instead, an online version of such an event was decided to take place.

The Valenciaport Online Hackathon was a one-week event where the innovation and entrepreneur ecosystem faced the challenges proposed by the stakeholders of the port community of the Port of Valencia, having stakeholders' support to solve the challenges through mentoring sessions with port-logistics experts. The event was held between the 20th and the 27th of November 2020 through an online platform, where 245 participants grouped in teams had the chance to develop their solutions during one week and exchange ideas with stakeholders, mentors and organisers. During the event, the challenge owners of the port community, proposed four challenges, completely aligned with the strategic plan of the Port of Valencia and covering the following areas:

- Optimisation of hinterland connections
- Digitalisation of port processes
- International trade facilitation
- Circular Economy

Besides the challenge proposal, challenge owners were also responsible of carrying out the mentoring sessions with the participants in order to adapt their proposed solutions to the specific requirements of each challenge and get the opportunity to be on the final demo day. After the Online Hackathon Event, the key stakeholders of the hackathon assessed the event and the lessons learned. Some of them also started discussions with the innovators (not only the winners) to continue the developments proposed in the COREALIS innovation incubator scheme and explore the possibility to do some pilots with them in the near future. In general, the organisers, main stakeholders and sponsors were very satisfied with the hackathon results and they are starting to plan the next edition, as well as exploring possibilities to support participants with upcoming funding opportunities. The KPI results of the Hackathon event are presented in Table 28. It shall be noted that for the hackathon organisation, no baseline values had been set for the KPI measurements, as the COREALIS Hackathon was the first one relevant event that was organised in Valencia.

Table 28: Valencia LL societal KPIs

ID	Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)	KPI (Result)
V3.1	#3	Number of Hackers (Participants).	-	100	245
V3.2	#3	Number of Sponsors.	-	4	4 Challenge owners
V3.3	#3	Number of Stakeholders involved.	-	10	13 Stakeholders in total: – 4 Challenge owners – 2 Organisers – 2 IT Partners – 3 Sponsors – 2 Others
V3.4	#3	Number of challenges.	-	5	4
V3.5	#3	Number of solutions.	-	10	25
V3.6	#3	Number of publications in social media.	-	500	– 18,291 Web Visits – 438 YouTube views (all keynotes) – 27 posts on Twitter (VPF) – 13 posts on Facebook (VPF) – 10 posts in LinkedIn (VPF) – 40 mentions on Twitter
V3.7	#3	Number of projects with scalability.	-	3	4 (2 for COSCO challenge and 2 ROMEU Challenge)

The organisers affirmed that the online hackathon was a success and reached all the above listed objectives. The stakeholders proposed the challenges and involved their personnel to support participants through mentoring sessions with port-logistics experts. The hackathon participants were aware about the main concerns of the port-logistics industry and were able to propose innovative solutions to overcome them. The involvement of a broad range of partners and stakeholders in the first edition of the Valenciaport Hackathon was a clear example of the commitment of the port community of the Port of Valencia with open innovation and the entrepreneur ecosystem. Their support has been key for the successful development of the first edition and they showed their interest to repeat the experience next year. Additionally, challenge owners were interested in continuing the development and testing of some of the solutions that were proposed in the hackathon.

As it was reported in the PoFSG section, a specific LL webinar was conducted for all LLs, in order to replace the initially planned workshops. Through these webinars, the PoFSG was presented in all LLs, even in the ones that was not planned to be tested initially, such as the Valencia LL. This led to the assessment of the tool by the stakeholders and the number of participants was used as metric for its performance. In the case of Valencia LL webinar, the number of external stakeholders/attendees was 22.

4.2.3 Port of HaminaKotka LL

In the port of HaminaKotka LL, the societal KPIs that were defined were associated with the Port of the Future Serious Game and specifically with the analysis of the energy transition scenario (Scenario #3). This scenario was to merge it into two sub-scenarios, regarding energy transition.

Scenario 3: Energy Transition

In this scenario, renewable energy and its coupled infrastructure are expected to develop and make positive effect on climate mitigation. Investment/measures in electrification (to reduce local air pollution) are assessed whether renewable energy sources could be integrated into port facilities and analysed for contribution to reduce CO_2 emission in the port. The game is set up to have an option to include usage of renewable energy at HaminaKotka LL. The transition is tested against strict climate mitigation scenario, and loose/relaxed CO_2 mitigation scenario. With this optional methodology, it gives the players opportunities to focus on port development, while bearing in mind responsibility of climate mitigation. The scenario sparks the discussion among stakeholders of HaminaKotka LL on the energy transition issue, e.g. if it is a good investment on this environment-friendly transition, what will be needed to change in the coming future, etc.

As it is stated in the Research hypotheses from D6.1, the use of the Port of the Future Serious Game could contribute to the following social targets:

- Assessing the future needs, as well as advantages, drawbacks and impact of electrification of machinery and automation in container operations;
- Using renewable energy as a source of electricity for the first measure from local partners or by purchase. HaminaKotka could, for example, provide a master plan, including a layout, for renewable energy investments in windmills, solar panels, etc.;
- Plan energy efficiency measures for ports that can also be used at HaminaKotka, e.g. port layout changes.

As it was reported in the PoFSG section, the initial KPIs were modified, as the workshops did not take place, in order to report the external stakeholders/attendees of the associated LL webinar. In the case of HaminaKotka LL webinar, the number of external stakeholders/attendees was 13.

4.2.4 Port of Piraeus LL

In the port of Piraeus LL, the societal KPIs that were defined were associated with the Port of the Future Serious Game and specifically with the analysis of a scenario related to green port-city connectivity development (Scenario #3). This scenario is based on a game, which reflects the stakeholder-driven essence of the game, i.e. to understand the interlinkages between city and port, and how climate change, extensions to port, increasing (cargo) traffic, and sustainability come together and affect both local authority and local population.

Scenario 3: Port of the Future Serious Game

In this scenario, it is assumed that only automation and environmental monitoring system work sufficiently within the sustainable urban mobility plan at the port of Piraeus. The positive effects reflect on increasing operational efficiency, environmental management, and saving maintenance costs. If rail connection and logistic park-traffic management also work well, truck runs are projected to be minimised at the port and in the city. Vehicle noise is projected to reduce subsequently. The scenario contains two major uncertainties: 1) rail connection that improves hinterland connection and 2) logistic park-traffic management that is implemented to measure and control traffic flow in the port-city area. In addition, whether fuel consumption and air pollution can be decreased highly relies on the usage of renewable energy. Thus, this scenario coordinates with the first energy assessment. Two scenarios can be either played together or in order. The scenario brings discussion of designing port-city traffic master plan. Also, as it is stated in the Research hypotheses from D6.1, the use of the Port of the Future Serious Game could contribute to the following social targets:

- Engage port stakeholders in growth scenarios of the Port of Piraeus;
- Identify sustainable growth scenarios accepted by the majority of port stakeholders;

As it was reported in the PoFSG section, the initial KPIs were modified, as the workshops did not take place, in order to report the external stakeholders/attendees of the associated LL webinar. In the case of Piraeus LL webinar, the number of external stakeholders/attendees was 35.

4.2.5 Port of Antwerp LL

In the port of Antwerp LL, the societal KPIs that were defined were associated with the Cloud Based Marketplace and Yard Equipment Brokerage Platform innovation and specifically with the Market and chassis brokerage platform scenario (Scenario #4).

Scenario 4: Marketplace and chassis brokerage platform

This scenario aims at information sharing on available equipment that can be shared between stakeholders. Many stakeholders of the port own equipment and to increase its utilisation it is necessary to set conditions to share it between terminals. A booking function is made available so that users (terminal operators, ports and transport operators) can make an offer, making it available for other terminals to book the equipment and services. Platform enables management of assets in terms of bookings and tracing. Owner of an asset is able to confirm booking of their equipment and tracing its location. Stakeholders interested in booking equipment are able to search and list offers of different categories. The sub-scenarios that were tested under the Marketplace scenario include the following:

1) Setting-up accounts for customers/stakeholders
2) Asset management
3) Locations management
4) Create and manage asset bookings
5) Localising assets
6) Booking automation on external files

All the sub-scenarios that were tested in the Antwerp LL were successful and the platform achieved to implement and provide the required functionalities. The KPIs that were set for the

Brokerage Platform scenario were related to the societal impact of this innovation and referred to the asset management performance through the platform (Table 29).

Table 29: Antwerp LL societal KPIs

ID	Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)	KPI (Result)
A4.1	#4	Number of uses/logins of the application per month.	0	5	2
A4.2	#4	Number of successful transactions per month.	0	2	0
A4.3	#4	Number of offerings by a supplier per month	0	5	0
A4.4	#4	Number of demands per month	0	5	0
A4.5	#4	Number of assets added per month	0	5	0
A4.6	#4	Saved idle time of assets per month	0	24 hours	n/a
A4.7	#4	Number of asset categories used per month	0	3	n/a

The full list of performance KPIs could not be tested in the Port of Antwerp. Incentives given by the Port Authority have been interesting enough so that stakeholders like Evonik or BASF came into the project expressing their interest and giving specific requirements towards the use of the port's brokerage platform. The first version of the platform has been launched only few months after the first requirements have been stated and from then on, it could be tested and as iterative system has been adopted following requirements were introduced non-in subsequent versions. Despite all the efforts stakeholders did not take up cooperation within the project thus, results on the port level cannot be shown.

The PoA Authority from the very start of the project proposal claimed they saw opportunity to provide the Port Community with a new service with which stakeholders could exchange equipment and other utilities on a common platform. This platform would strengthen the collaboration between the different Community players and confirm their common goal of providing the customers of the Port of Antwerp with the best possible service. The assumption that a far-reaching cooperation and exchange of tools, equipment and people was possible turned out to be wrong. The reasons for specific areas are the following:

- Rail: the rail community is a small community and Belgian legislation prevents the simple exchange of material and people. Most rail operators are connected to (a) specific international platform(s) for rail equipment
- Warehousing: warehousing community uses a specific platform
- Equipment: a single player dominates the port equipment market in the Port of Antwerp: Cuypers Vorkliften that uses its own platform. Moreover, stevedoring companies use their own equipment or rent material from Cuypers Vorkliften.
- Containers: two terminals (PSA and DP World) dominate container handling in the Port of Antwerp. Both companies have their own equipment and tools. They are 'competitors' in the narrow meaning of the word that means no exchange of equipment is possible or can be considered.

- Labour: Belgium has specific legislation that regulates the Port labour (De wet Major). Cepa (de Centrale der Werkgevers aan de Haven van Antwerpen) provides the complete framework for Port Labour in Antwerp. That means no exchange of labour or workers is possible without the explicit approval of Cepa or the different Workers Unions
- Breakbulk: The Breakbulk market is a Niche market with fierce competition. Both Zuidnatie and Roll-it use specialised heavy equipment to handle breakbulk and project cargo. Breakbulk companies see their specialisation as an asset and are not inclined to share their equipment with the competition

Lessons learned

Experience gained from the project implementation brings lessons learned that is a valid point of the project's outcomes. Innovations by its definition bring changes to business models that often modify its core and therefore changes on a higher level are needed. PoA case shows that even though the equipment in terminals has a considerable idle time it is a part of a business model not to exchange it to prevent competition to save on investments. It is however in the Port's community hands to discuss internally on what can be done in order to keep the business running and at the same time to make it cleaner and cheaper. After research on potential savings on trips, emissions or capital, incentives should be offered to the partners who participate in such initiatives that fulfil port's social, ecological and economical objectives. They should be declared upfront. Engaging end-users from the very scratch of a project is also crucial to prevent from further misconceptions and to create necessary involvement.

Innovation's fulfilment to the circular economy

Platforms for sharing resources like the COREALIS Brokerage Platform are promising in achieving objectives of circular economy by reducing demand for resources, thus raw materials and semi products down the supply and production chain. Consistent and trusted information being exchanged within community makes it possible to create value for local society, economy of the businesses as well as footprint of the whole community. The marketplace is a customisable and scalable solution and a port authority can be a great example of maintaining it reaching its goals of its sustainability.

Implementations in other sectors

During the course of the project, the marketplace has been tested in parallel with other sectors of economy. It was possible without actually implementing the port-specific functions such as localising assets or measuring CO_2 required transporting them from one place to another. This became a useful tool for exchanging appliances for co-working areas and in a printing company with a few departments within an industrial zone. From what the owners say, it is easy to use and book facilities, rooms, equipment in a user-friendly manner.

This sector seems natural for business development of the platform. Industrial zones, offices, shared spaces are being in the scope of the marketing forces. Ports however are in a special focus as the custom features are adapted especially for them and integration with operation systems of terminals makes the booking processes automated.

PoFSG

As it was reported in the PoFSG section, a specific LL webinar was conducted for all LLs, in order to replace the initially planned workshops. Through these webinars, the PoFSG was presented in all LLs, even in the ones that was not planned to be tested initially, such as the Antwerp LL. This led to the assessment of the tool by the stakeholders and the number of participants was used as metric for its performance. In the case of Antwerp LL webinar, the number of external stakeholders/attendees was 15.

5. COREALIS Impact and solution transferability to other transport hubs

This chapter records the results and learnings obtained when executing the transferability analysis in T6.5. First, the eventual approach is presented followed by the results of the project, followed by the results per innovation.

The task initially started in April with workshops organised by DocksTheFuture (DtF) on the Transferability Analysis (TA) methodology realised by DtF for the Port of the Future (PoF) RIA projects. The methodology liaises the innovation objectives with (among others) the UN SDG 17 objectives, allowing public authorities to map which innovation is the most suited to achieve what goal. In an answer to the concerns posed by the projects, additional guidelines have been made available.

In relation to the task, webinars have been organised for each Living Lab in which the innovations at the Living Labs were presented. These webinars allow us to investigate the initial interest from external parties in the COREALIS innovations.

The task finalises with delivery of D6.2 at the project.

This chapter starts with a description of the chosen approach, which is based on the DtF PoF-TA methodology. After the explanation of the approach, first the overview of the entire project is presented followed by an analysis per innovation.

5.1 Approach

Numerous methods for assessing transferability exist. All have a different approach. During the project, a method created by the project Docks the Future (DtF) was presented. DtF project created a methodology called the Port of the Future Transferability Analysis (PoF-TA). This methodology was chosen as a basis and is extended with other topics relevant for COREALIS.

In other transferability analyses per innovation, the business case and the barriers and enablers are listed. For COREALIS, these investigations have been performed as part of the deliverables D8.4 IPR Management and Business models and D1.1 Port of the Future Challenges, Enablers and Barriers and will not be repeated here.

The PoF-TA methodology presents a structured approach from the UN Sustainable Development Goals (UNSDG), through the focus areas of the World Ports Sustainability Program (WPSP) and the agenda 2030 goals of the Association Internationale Villes Ports (AIVP), towards 17 DtF High-level Strategic Objectives (HLSO). The PoF-TA methodology identifies for each innovation their relevance for these agendas/goals linking the innovation to higher goals of these programs and with that raising the probability and ease of transferring the innovations through ease of explanation the benefits of these innovations.

In Annex 1, a full list of goals, focus areas, topics and objectives per program is presented. As programs are aimed at realising a strategic objective for the remainder of the analysis, we will refer to external program and (related) strategic objective.

Several tools have been provided by DtF to do the assessment. However, performing a full analysis using the methodology has proven to be impossible given the state of the methodology and available time. Therefore, only the *quick evaluation towards potential transferability of projects* has been performed using the tools; this is further extended in this report using the principles of the methodology have been followed using what is relevant and achievable for COREALIS.

The following items are assessed in the *quick evaluation towards potential transferability of projects*. These items have been incorporated in the COREALIS TA as well and extended to fit the need of COREALIS:

- Links to relevant external programs' strategic objectives giving a view on how well an innovation is tied to what strategic objective what bodies. Unfortunately, the PoF TA methodology only allows limited identification of these items as they are all strictly tied to one-another.
- Identification of applied DtF measures and PoF tactical objectives give a view on the objectives served by COREALIS and with what measures these objectives are served. This gives a more fine-grained view on what COREALIS actually is doing next to the links with higher-level programs.
- The innovativeness measured determining the Potential Contribution to Innovation (PCI). The number ranges from 1 to 5 with 5 being the highest innovativeness.
- The acronym PCI is also used for another result: The Project Common Index. This is a probability the result will be relevant for other organisations and is represented by a score, the TA-score. Re-using acronyms adds unnecessary confusion and makes the PoF-TA methodology difficult to apply. The number ranges from 1 to 5 with 5 being highest probability the projects innovations will be relevant for others respectively. This score is per project.
- Proof of transferability indicating that innovations have actually been (or have not been) transferred to other ports. This is registered in the TA-index, which also runs from 1 to 5, with 1 being no transferability at all. This index is per innovation.

On top of the PoF-TA results, an additional investigation into the fit with strategic agendas has been performed as well as an assessment of (amount of) potential target ports/organisations.

In short, the assessment goes from identification of demand (external programs), to targeting (tactical objectives), to implementations (measures), to innovativeness and to proof of transfer. Giving a full view from demand towards (transferability of) supply.

The data for the assessment has been collected using templates based on the DtF. These templates offer reduced complexity for filling in, and a wider range available for analysis. The templates have been circulated to a core group consisting of T6.5 members. These members are involved in the evaluation as well. The completed template with targeting has been verified/validated by the innovation leaders to ensure correctness. The templates for TA score and PCI score have not been validated, as this validation would require the leaders to obtain in-depth knowledge on the PoF TA methodology, which was too much to ask given the short timelines available. The risk of incorrect data is limited as the T6.5 members were well informed on the relevant information. In the below sections, the validity of the results, given the chosen approach, has been checked as well.

5.2 Project transferability

5.2.1 Fit with external programs

The fit with the external programs has assessed by prioritising the goals per innovation and living lab. The outcome described how much COREALIS intends to contribute to what strategic objective and what strategic objectives are of main interest of the living labs. This information is useful to help identify and target external ports and to help build the commercial message for exploitation. Unfortunately, only data from the COREALIS ports is available to check the fit. Ideally, the priorities of other ports would be available as well.

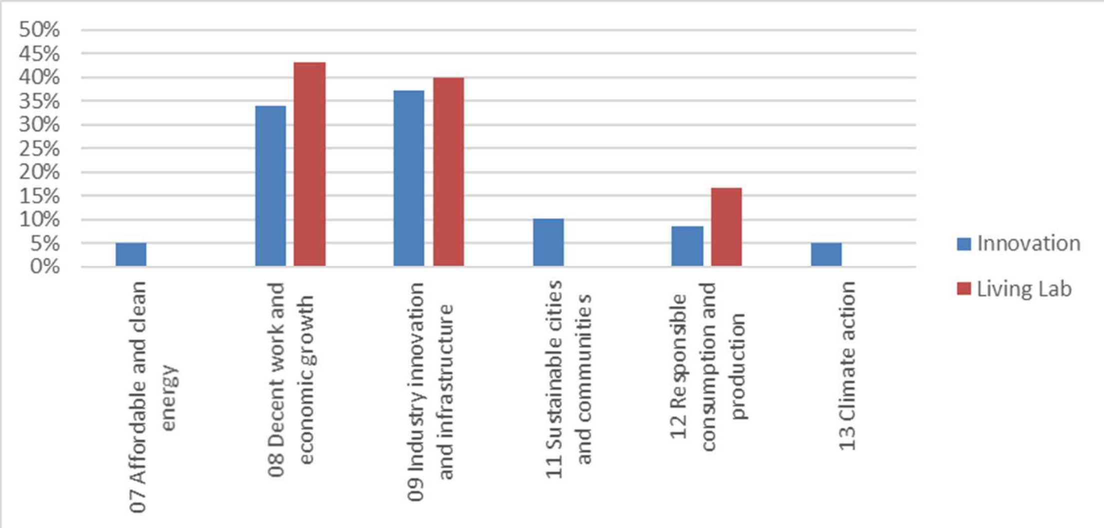

Figure 6: Fit with UNSDG

COREALIS mainly focusses on the following UNSDGs (Figure 6):

- UNSDG-8 Decent work and economic growth
- UNSDG-09 Industry innovation and infrastructure
- UNSDG-11 Sustainable cities and communities
- UNSDG-12 Responsible consumption and production

As expected, the priorities of the Living Labs overlap largely with the main priorities of the innovations. Innovations tend to focus on sustainability more than it is focused on by the Living Labs.

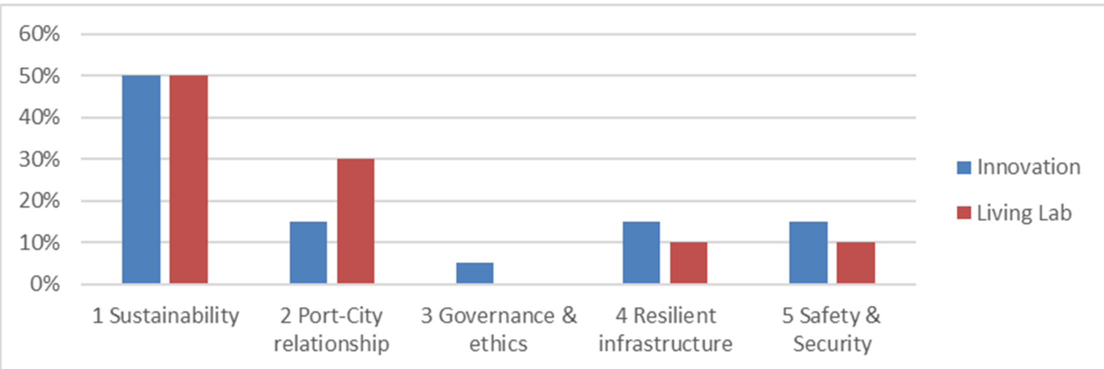

Figure 7: Fit with WPSP focus areas

COREALIS mainly focusses on the following WPSP focus areas (Figure 7):

- 1 Sustainability
- 2 Port-City relationships
- 4 Resilient infrastructure
- 5 Safety & security

With the WPSP focus areas, we can see there is a slight difference in the priorities of the innovations and the living labs. One could argue that '2 Port-City relationship', '3 governance and ethics' and '5 Safety & Security' might be interchangeable on some topics. With respect to the UNSDGs, it is typical to see that the living labs focus more on sustainability in relation to the other topics than was the case with the UNSDGs.

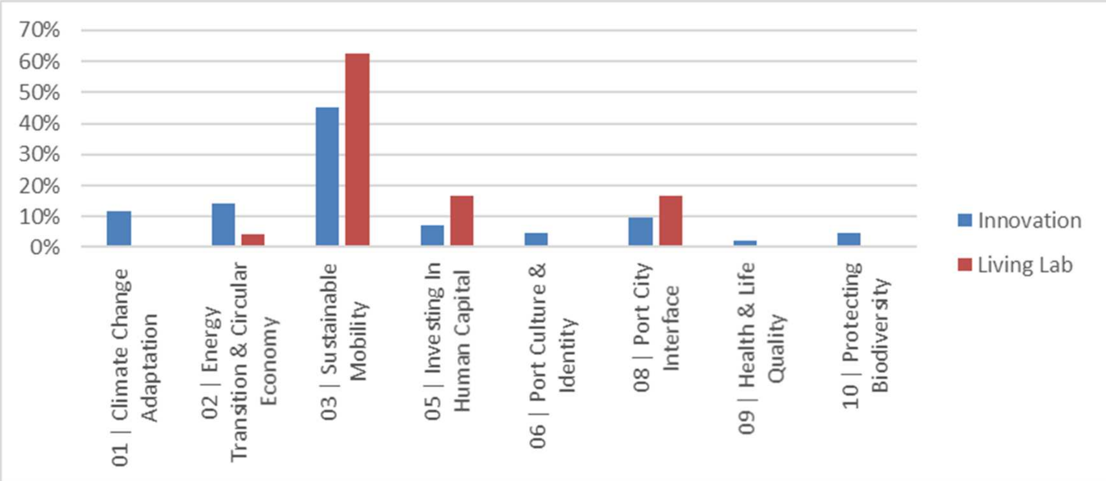

Figure 8: Fit with AIVP agenda 2030 goals

In the fit with the AIVP agenda 2030 goals (Figure 8), one specific goal stands out very clearly for both innovations and Living Labs: 03 | Sustainable Mobility. The priorities of the Living Labs differ slightly from those of the Innovation. It can be observed that the interface with the cities is perceived as more important by the Living Labs than by the Innovations. This is relevant to know when reassessing the business development positioning of the innovations.

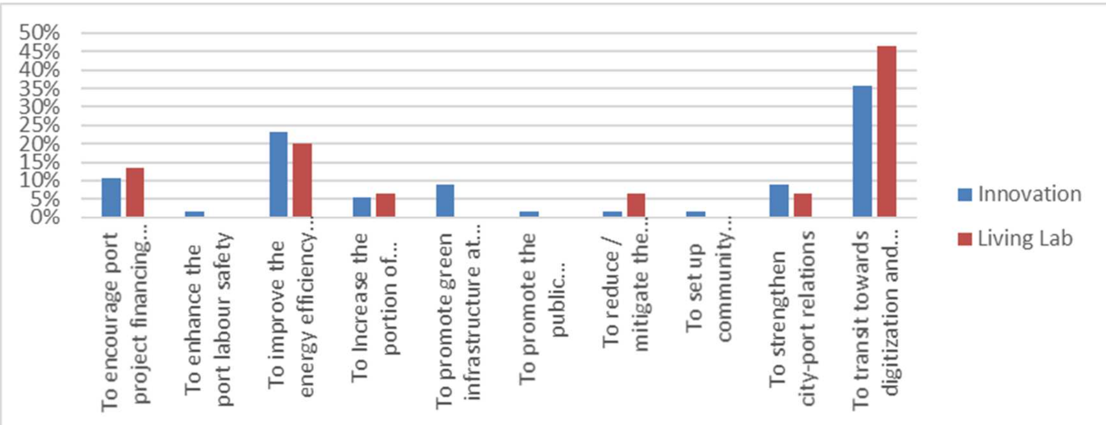

Figure 9: Fit with PoF Topics

Of the 35 PoF topics, there was a clear convergence to the following three topics (Figure 9):

- To transit towards digitisation and automation in port activities;
- To improve energy efficiency of ports;
- To encourage port project financing and investments.

Also, the topic 'to strengthen city-port relations' was a good runner up. Here, a very good overlap of the Living Lab priorities with the innovations' focus is seen. The interesting thing here is that in relation to the previous priorities, the sustainable/circular topics are less visible. This however is slightly misleading, as in the previous programs there where typically 1 or 2 items, whereas in the Port of the Future these have been extended.

From this figure, it becomes very clear that COREALIS aims to improve sustainability not by realising new 'green' technologies, like alternative fuels or the circular economy, but by improving the current, already established processes. A benefit of this is that the process itself is known alongside the points of loss and therefore, implementation or application is easier with respect to totally new concepts.

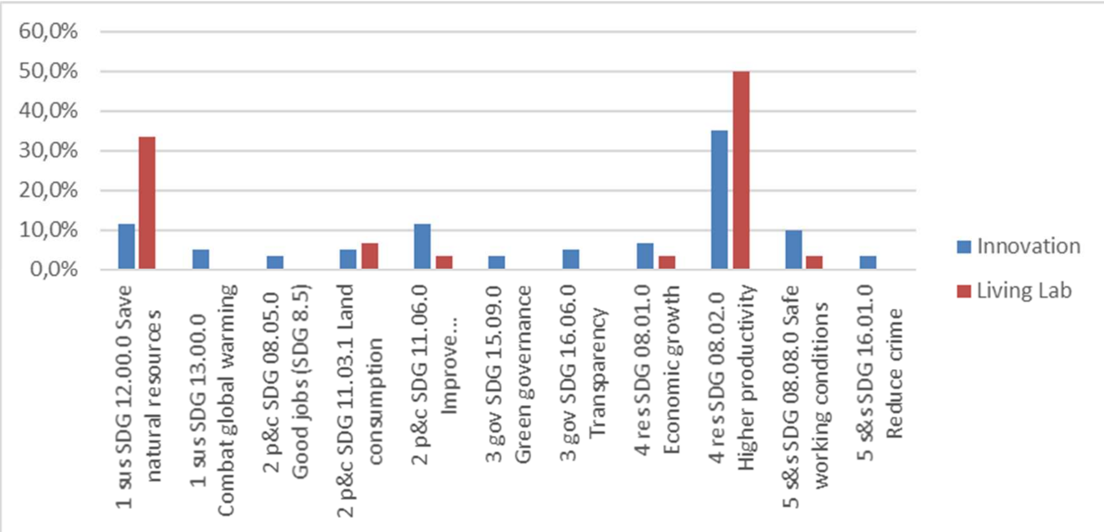

Figure 10: Fit with PoF High-level Strategic Objectives

The fit with the PoF High-level Strategic Objectives (HLSO) (Figure 10) shows an interesting divergence between the priorities of the Living Labs and those of the Innovations. For the Living Labs, 2 HLSOs stand out:

- 1 sus SDG 12.00.0 Save natural resources
- 4 res SDG 08.02.0 Higher productivity

The innovations primarily focus on the last one and have a wider spread with several other topics. One of the reasons that this may happen is that the HLSO's are indeed high-level. An example is "1 sus SDG 13.00.0 Combat global warming." This HLSO can be interchanged with "1 sus SDG 12.00.0 Save natural resources" on COREALIS' aspects. It may be valuable to investigate the priorities of future targeted ports to ensure a fitting commercial message is presented.

5.2.2 Targeted PoF tactical objectives and DtF measures

From PoF and DtF, a set of tactical objectives and measures are available. These sets give a much more concrete view on what is actually being done in relation to the higher-level strategic programs described in the previous section. From the tools of DtF, we can deduct what measures are targeted by other projects to identify the uniqueness of COREALIS on the one hand and to assess the market availability on the other side (more projects on a measure can be regarded as an indication that there is a need).

For below assessment, it is relevant to know that COREALIS contains 10 innovations, and the rest of the database contains 135 projects. Of course, there are more than 135 projects throughout the ports in the world. What is interesting in the comparison is to see what and how often COREALIS targets Tactical Objectives and Measures in relation to the total PoF program (recorded by DtF).

Figure 11 shows a comparison between the addressed tactical objectives by COREALIS and by other projects. In this figure, it is clearly visible that COREALIS has some unique selling points on Tactical Objectives. These are discussed behind the figure.

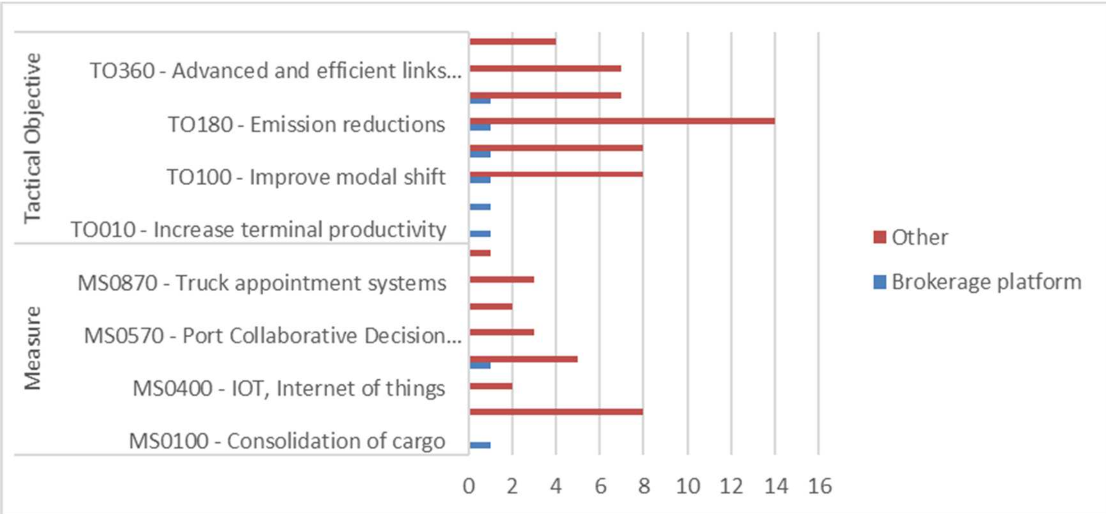

Figure 11: Comparison of amount of addressed Tactical Objectives by COREALIS and other projects

The items in figure 11 can roughly be divided in two groups:

1. COREALIS is the only project in the database that addresses a Tactical Objective. These are the unique selling points of COREALIS that are not addressed by others. Ideally, the targeted ports for exploitation have a need for solutions on these objectives.

2. Tactical Objectives are targeted more by other projects than by COREALIS. This can be an indication that there is more awareness of and knowledge available for these Tactical Objectives. One could argue that when there are more projects targeting certain Tactical Objectives, the need for solutions on these objectives is higher (or at least better identified).

Figure 12 shows a comparison between the measures targeted by COREALIS and by other projects. In this figure, it is clearly visible that COREALIS has some unique selling points on measures as well. These are discussed behind the figure.

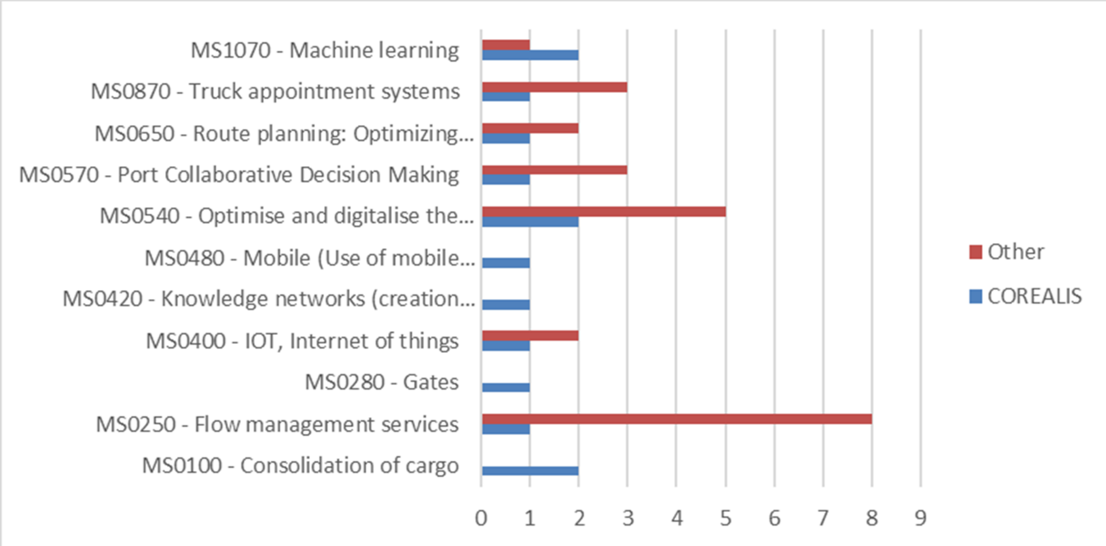

Figure 12: Comparison of amount of implemented measures by COREALIS and other projects

Figure 12 shows COREALIS' uniqueness or overlap on the following measures:

1. USP's:
   - MS0480 - Mobile (Use of mobile technologies).
   - MS0280 - Gates.
   - MS0100 - Consolidation of cargo.
2. More innovation in COREALIS than other projects combined:
   - MS1070 - Machine learning.
3. More innovations in other projects combined than in COREALIS:
   - MS0870 - Truck appointment systems.
   - MS0650 - Route planning: Optimising routing with the support of digital systems, standards for route exchange, Application services such as route optimisation services.
   - MS0570 - Port collaborative decision-making.
   - MS0540 - Optimise and digitalise the logistic chain
   - MS0400 - IOT, Internet of things
   - MS0250 - Flow management services

Group 1 contains the measures for which only COREALIS has innovations, assuming the database is complete. These USPs mean either a competitive advantage or a lack of interest from the market.

Group 2 contains the measures for which COREALIS has more innovations on this measure than all other projects combined. This could indicate a competitive advantage because there is an indication of interest and COREALIS has proven experience on these topics.

Group 3 contains the measures for which more projects innovate than COREALIS. This could indicate both an established and an emerging market.

Above groups closely relate to the technology adoption lifecycle. Where projects in group 1 are most likely executed with innovators and/or early adopters. The projects in group 2 are most likely executed with early adopters. The projects in group 3 are most likely executed with early adopters and/or the early majority. In 'Crossing the Chasm' from Geoffrey Moore, next likely steps to progress the market for an innovation are well explained.

5.2.3 Innovativeness

The innovativeness is measured using the Potential Contribution to Innovation. The name states it quite well: being innovative alone is not a reason on its own for transferability. However, innovation does result in the potential to transfer something.

To establish the innovativeness, instead of scoring the innovations itself, we chose to score the implemented measures. This means that we have a more detailed view on innovation per measure instead of a consolidated view per COREALIS innovation. The reason to do this is that improvements are made by applying measures. When we identify the innovation on measures, it is easier for target ports to assess what COREALIS actually brings.

COREALIS assesses the innovativeness using the PCI-score, based on targeted Strategic Objectives and Measures. To perform this assessment an Excel sheet has been circulated in the TA-team to score the innovativeness of the innovations using the targeted measures and strategic objectives. The PCI-score including description per score is available in Annex 2.

The innovation from COREALIS on PoF tactical objectives and DtF measures result in below spread of PCI-scores.

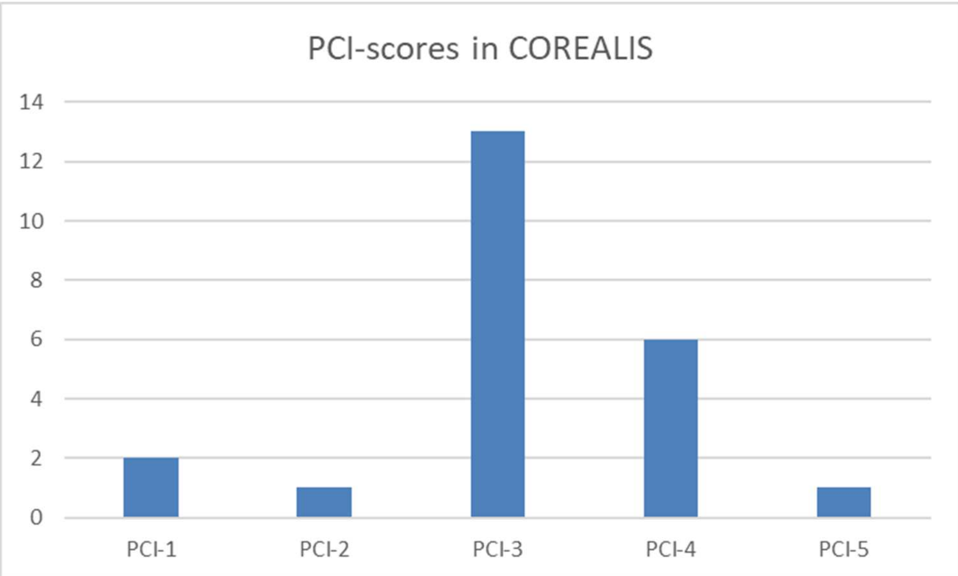

Figure 13: Spread in PCI-scores in COREALIS

Figure 13 clearly shows that the innovations in COREALIS are mostly improvements of existing technologies and adaptations to technology for transferability. This means that processes are identified and known and that technologies should be able to be applied in other ports. The consolidated score for the COREALIS innovations is 3.1.

The way of requesting the input makes it difficult to discriminate between contributions by multiple innovations on a single SO/Measure. This potentially causes a mix of contributions between the innovations in the sections per innovation. This is logical given all innovations are part of the same project.

The way of requesting the PCI-score makes it difficult to discriminate between the innovativeness of the innovations when multiple innovations target an SO/Measure. This potentially causes a mix of innovativeness between the innovations, in the sections per innovation. This actually is logical given all innovations are part of the same project. The innovativeness of one innovation within the project may influence the others, even only if it is in combining discussions.

Innovativeness on its own does not give a good view on the transferability. The results obtained by these innovations should be taken into account. This is investigated in the next section.

5.2.4 Probability of transferability (relevancy)

The probability of transferability is measured using the PoF PCI-tool. This tool collects estimated contributions to KPIs and calculates a score indicating how well the COREALIS results fit with the PoF weighing (or any weighing for that matter). In the tool, this score is called the Consolidated Objectives Index, in the transferability analysis sheet this score is referred to as the Project Common Index.

The KPI's in the PCI-Tool are linked to the WPSP focus areas. In figure 7, we have seen that COREALIS mainly focuses on four of the focus areas. The PCI-Tool states KPIs relevant for these focus areas, these KPIs are scored in the tool. In below table, the WPSP focus area and KPIs relevant for COREALIS are presented. A full list of the KPIs from the PCI-Tool is available in Annex 3.

Note that for COREALIS no formal evaluation on these KPIs has been performed. Instead, an assessment on the potential has been performed. For each focus area, an aggregated score is created using the PCI-Tool and the scores of the individual KPIs.

Table 30: COREALIS contribution to PoF KPIs for WPSP focus areas

	KPI	COREALIS estimate	Score
1 Sustainability (Climate and Energy)			**4**
	Reduction or compensation of port-related CO_2 equivalents emissions/year	45.000 tons	5
2 Port-City relationships			**4.8**
	To which extent does this action foster the port acceptance in terms of the port-city dialogue?	**Medium:** good information policy; account for the population's point of view onto topics in the decision making process; provide possibilities for exchange of views.	3
	To which extent does this action promote the income development in port-related jobs?	**Medium:** efforts in the individual education and the skill improvement of a specific port-related professional group	3
4 Resilient infrastructure			**4.5**
	Growth in port's throughput capacities due to new constructions or constructional or organisational optimisations	100.000 TEU	4

	KPI	COREALIS estimate	Score
	Savings of optimisations due to digitisation and automation in port activities	€ 1.000.000,- per year	5
	To which extent does this action improve the infrastructure's resilience regarding the threats of climate change?	**Low:** The question of climate resilient has been addressed in the constructional planning process	1
5 Safety and Security			**0**
	None to which COREALIS adds		

When observing table 30, immediately one WPSP focus area stands out. From figure 7 we know that COREALIS has a focus on "5 Safety & security", but does not contribute to any of the KPIs on Safety and Security provided by PoF.

The aggregated scores can be best viewed in a radar plot (figure 14), as this shows the total coverage of COREALIS of the WPSP focus areas.

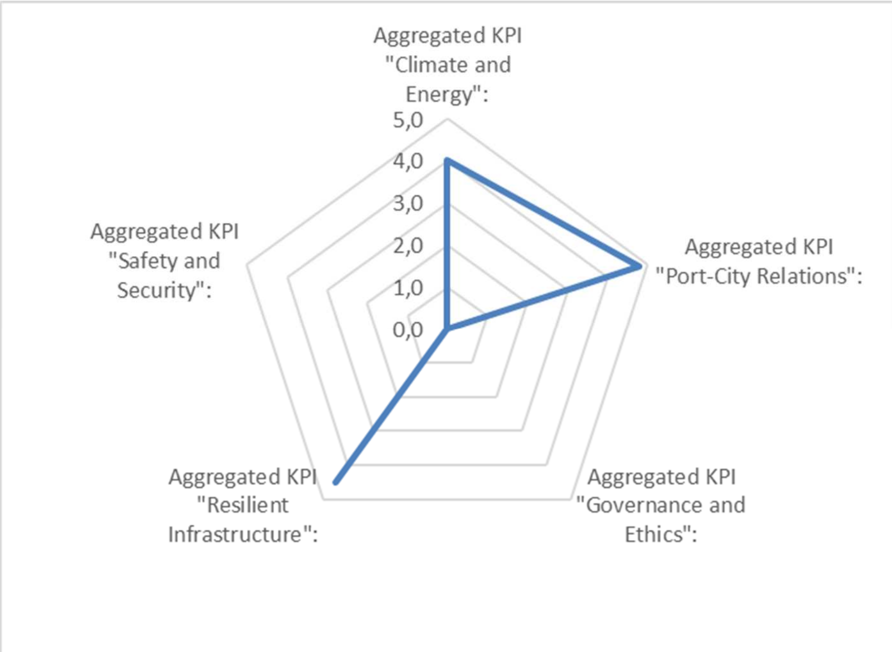

Figure 14: Radar plot to show the coverage of PoF WPSP KPI's by COREALIS potential results

From figure 14, we can indeed conclude that according to PoF COREALIS only contributes to three of the five WPSP focus areas and that, if COREALIS wants to contribute to Safety and Security in line with PoF, additional work needs to be performed.

From figure 14 we can also conclude that COREALIS is well focused with the intended contributions. When all areas would be touched, effort would be diluted.

Using the PCI-Tool, these aggregated KPI's are combined into the Consolidated Objectives Index that is equal to the PCI-score referred to in the PoF TA-Excel sheet. COREALIS obtains a Consolidated Objectives Index of 4.26 on a scale with a maximum of 5. No documentation on how to interpret this index has been identified, but assuming a maximum score of 5, we can conclude COREALIS is performing excellent.

Having this weighed score of KPIs is interesting, however adding the COREALIS cost, innovativeness and ease of transferability to the equation gives a view on the effectiveness of the investments made when using COREALIS innovations.

The allocable costs for COREALIS are estimated to be € 5.000.000,-.

The innovation score is: *High (score: 3): adaptation of existing technology from other sectors or uses to the port sector (e.g. electric AGVs).*

The last item is a transferability score. This will be further explained in the next section (section 5.2.5). The consolidated score is: *Medium (score 2): Modest support for transferability: project supports an innovative aspect, is applicable to targeted ports, has identified constraints/barriers and suggested resolutions, but NO peered resources to implement the solution in other ports*

Combining above values gets COREALIS a Project Common Index of 11.37. DtF indicated this to be a high value without further clarification on how to interpret it. We may assume that this indicates that the (potential) impact of COREALIS is expected to be high and that therefore the relevancy of COREALIS is high as well. Assuming indeed the high relevancy, the probability that the COREALIS results will be used is high.

5.2.5 Proof of Transferability

Proof of Transferability is determined in the TA-score. DtF refers to this score as the Potential Contribution to Transferability; this is slightly misleading as what is measured is the actual transferability. Relevant is to what extent, and in what manner, innovations are 'replicated' within the project. DtF provides an excellent overview on how to score the different innovations. The scores and explanations can be found in Annex 4.

To establish the TA-score, instead of scoring the innovations itself, we chose to score the implemented measures. This means that we have a more detailed view on transferability per measure instead of a consolidated view per COREALIS innovation. The reason to do this is that improvements are made by applying measures. When we identify the transferability of measures, it is easier for target ports to assess how easy it is to implement what COREALIS has available.

Scoring is performed by assessing checking availability of barriers and constraints (discerns between 1 and higher) and counting the number of ports an innovation is deployed (discerns between the 2 and 3). No score of 4 can be given to COREALIS, as this would require 5 or more implementations of the innovations.

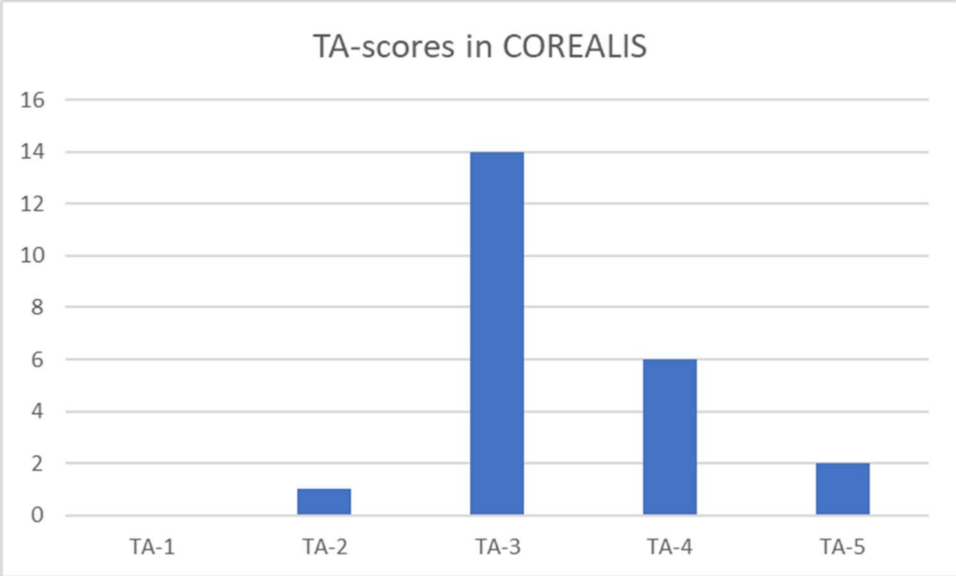

Figure 15: Spread in TA-scores in COREALIS

Figure 15 shows that most innovations have a TA-score of 3. This means that most innovations are single port innovations of which the barriers to transfer are known. Some measures are applied in 3 or more ports and there are even 2 innovations that have already found their way into the broader market. The consolidated score of COREALIS is 3.4.

For the TA-5 scores, it must be noted that when scoring, not only transferability within COREALIS but to external ports as well has been assessed (of course).

The way of requesting the TA-score makes it difficult to discriminate between contributions of innovations when multiple innovations contribute to an SO/Measure. This potentially causes a mix of transferability between the innovations, in the sections per innovation. This actually is logical given all innovations are part of the same project. The transferability of one innovation within the project influences the others.

Combining the PCI-score (3.1 - improving and adapting for transferability) and the TA-score (3.4 - Transferring has started to other ports) gives a view of the innovations within COREALIS being ready for large-scale deployment.

5.3 Truck Appointment System

5.3.1 Link with external programs

The links of TAS with external programs and the fit with the COREALIS Living Labs is indicated in the figure below. Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

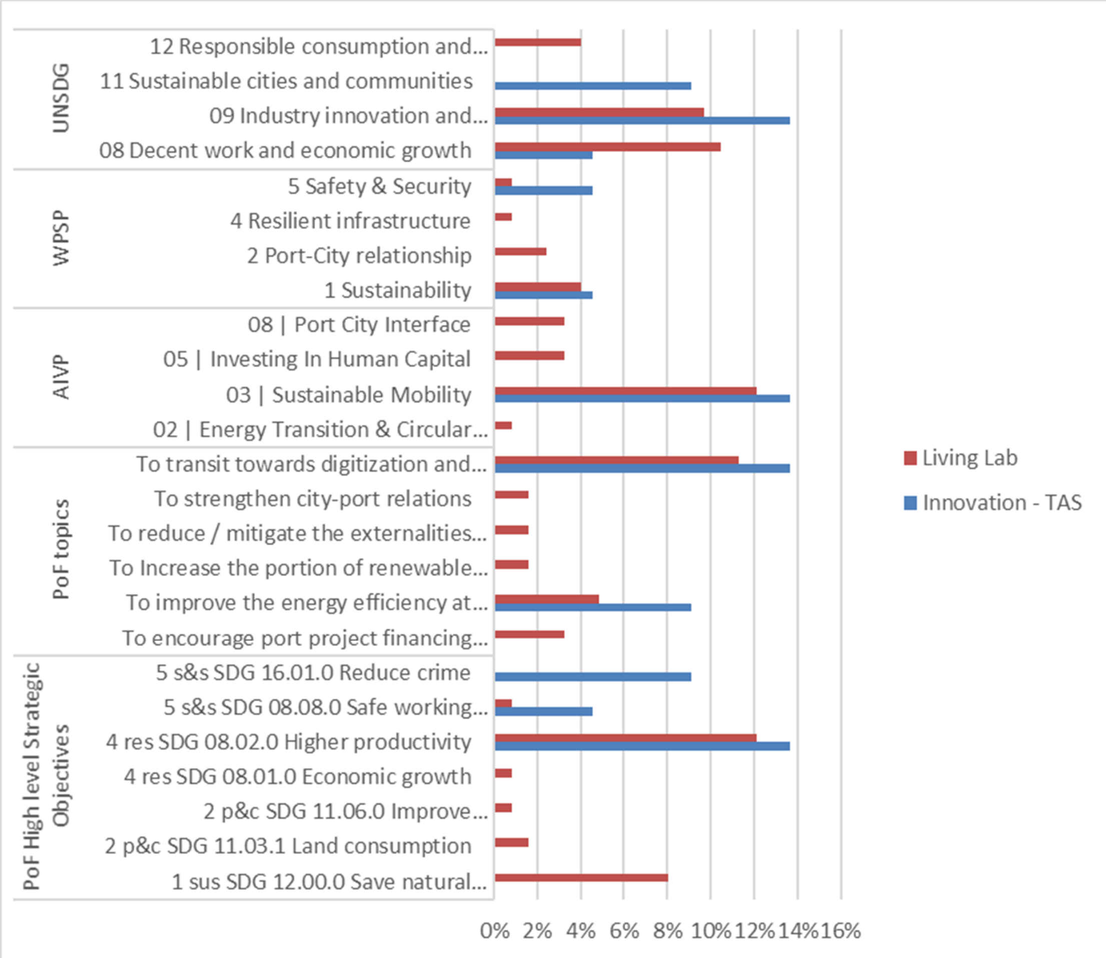

Figure 16: TAS and Living Labs relative importance of the strategic objectives from external programs

Figure 16 shows that the TAS priorities are in line with the Living Lab priorities for AIVP and the PoF topics. From the UNSDSs, responsible consumption is seen as more important than sustainability although there is a link between the two. For WPSP, more focus could be given to port-city relations and for the PoF HLSOs the reduction of crime is not seen as important by the Living Lab ports in COREALIS.

5.3.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of TAS in relation to competing projects are presented in below figure. It shall be noted that the number of projects and targeted PoF TOs and DtF Measures far exceeds the amount targeted by a single innovation. Also, all COREALIS' innovations can only target a measure once (hence the 1).

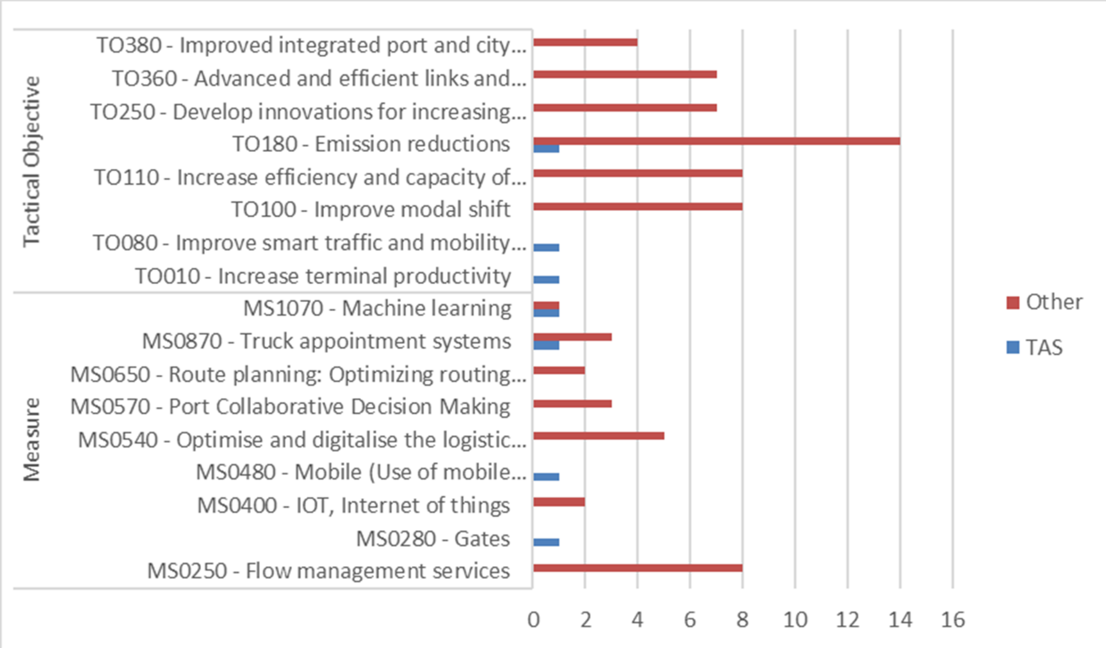

Figure 17: TAS targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects

From figure 17 we can see that TAS uniquely targets some Tactical Objectives and Measures that have not been targeted by other projects within PoF. The USPs of TAS are usage of mobile technologies and controlling the gates. When transferring TAS, it is of relatively limited use to highlight the reductions in emissions, as apparently there are quite a lot of projects targeting that. It is more relevant to describe the effects of the improvements of Smart traffic and mobility management together with the increase in terminal productivity.

5.3.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 7 targeted Strategic Objectives and Measures, TAS has a consolidated PCI-score of 3.2 built up of:

- 5 measures with PCI-3;
- 2 measures with PCI-4.

This score means a focus on moving towards full-scale deployment while at the same time using proven technology. The benefit of this lies in being able to both show proof of ability while at the same time showing innovation.

5.3.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 7 targeted Strategic Objectives and Measures, TAS has a consolidated TA-score of 3.6 built up of:

- 5 measures with TA-3;
- 2 measures with TA-5.

This score means that the limitations of transferring TAS are known and are being handled. This score underlines the PCI-score: the ability is proven; work has been performed to transfer the innovation.

5.4 Brokerage platform

5.4.1 Link with external programs

The links of the Brokerage platform with external programs and the fit with the COREALIS Living Labs is indicated in the figure below. Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

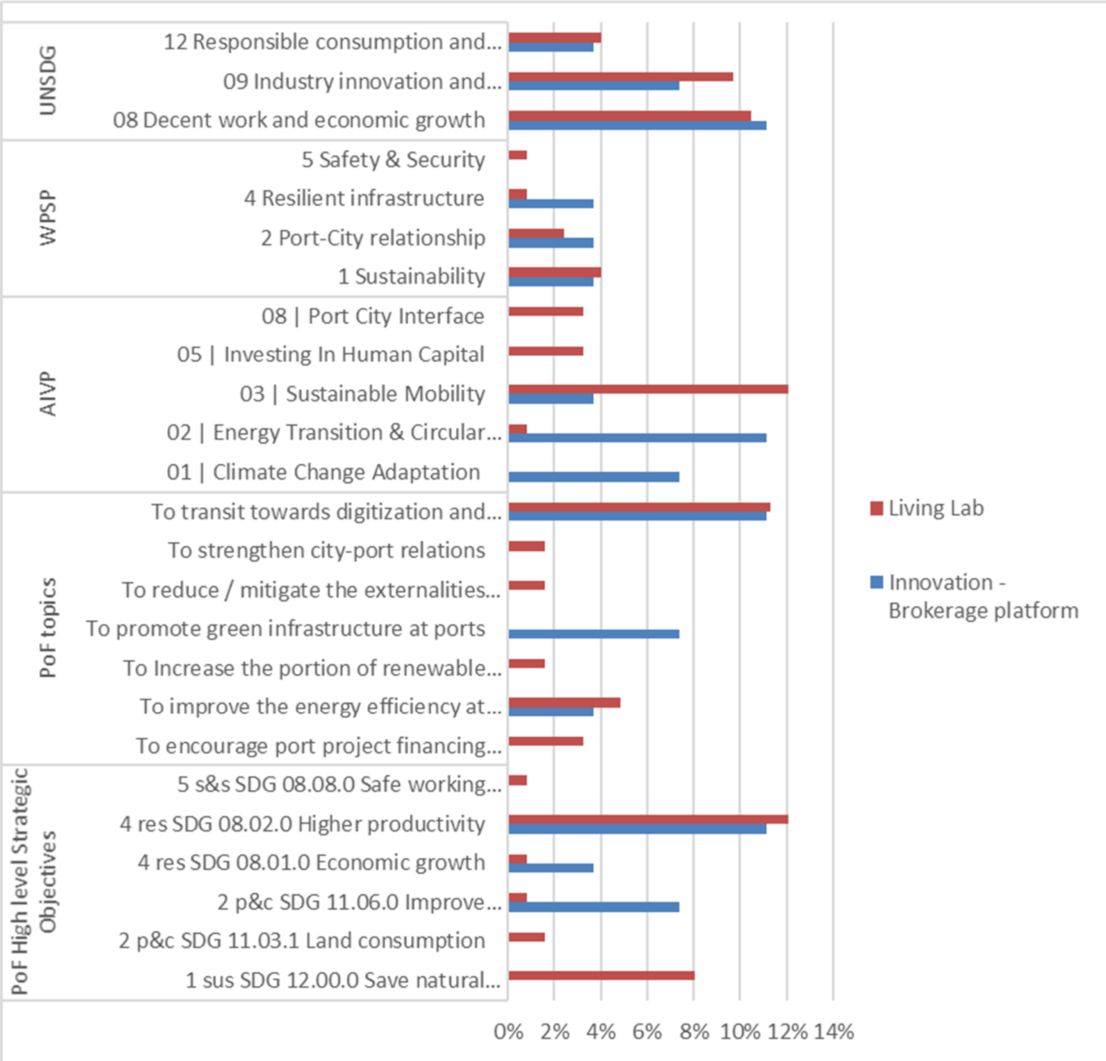

Figure 18: Brokerage platform and Living Labs relative importance of the strategic objectives from external programs

Figure 18 shows a perfect alignment of the priorities of the Brokerage platform and the Living Labs on the programs UNSDG and WPSP. For AIVP, there is a clear mismatch, apparently the Living Labs do not see energy transition and climate change adaptation as a strategic objective necessary to follow up on. If this holds for other ports as well, changing the message may be useful. This is visible in the PoF topics as well where promoting green infrastructure is seen as less important. With the PoF HLSOs something similar is happening, saving natural resources is seen as more relevant than improving environmental quality. When targeting other ports, it may be good to broaden the set of ports and/or customers and look at ports with different characteristics than the Living Lab ports as well, or to change the message a bit.

5.4.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of the Brokerage platform in relation to competing projects are presented in below figure. Please note that the number of projects and targeted PoF TO's and DtF Measures far exceeds the amount targeted by a single innovation. Also note that all COREALIS' innovations can only target a measure once (hence the 1).

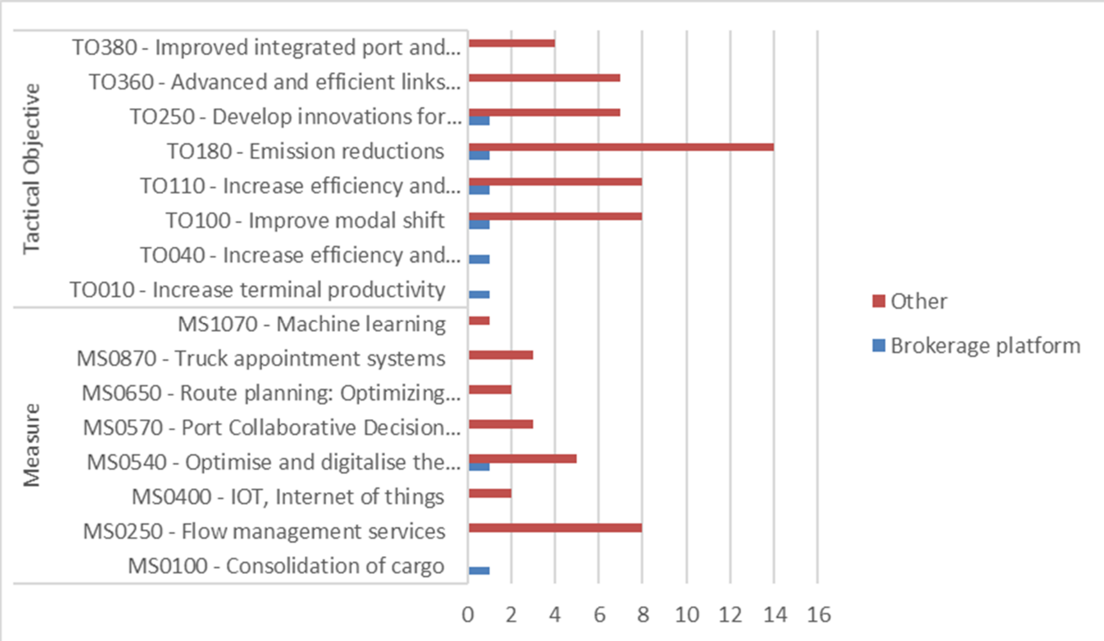

Figure 19: Brokerage platform targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects.

From figure 19 we can see the Brokerage platform uniquely targets some Tactical Objectives and Measures. The main USP of the Brokerage platform in relation to the other PoF projects is the implementation of consolidation of cargo. When targeting other ports, the aim should be at showing the benefits of increased efficiency and capacity of hinterland connections and on increased terminal productivity.

Another thing that stands out is the total targeting of 8 TOs and Measures. Of the 135 projects there are only 4 with 8 or higher targeted TOs and Measures. The average is 3.9. Either this could mean an innovation with many benefits or that the message may be focused more.

5.4.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 8 targeted Strategic Objectives and Measures, the Brokerage platform has a consolidated PCI-score of 3.4 built up of:

- 5 measures with PCI-3;
- 3 measures with PCI-4.

This score means a focus on moving towards full-scale deployment while at the same time using proven technology. The benefit of this lies in being able to both show proof of ability while at the same time showing innovation.

5.4.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 8 targeted Strategic Objectives and Measures, the Brokerage platform has a consolidated TA-score of 3.9 built up of:

- 3 measures with TA-3;
- 3 measures with TA-4;
- 2 measures with TA-5.

This score and the composition is an interesting one. On the one hand, there is a part that is being implemented only in single ports where on the other hand there are parts that have been deployed widely. This could be proof of a product (development cycle) that is (becoming) mature: where on the one hand there are new, local innovations, that are on the other hand transferred as part of business as usual to other ports.

Assuming this maturity an explanation for the mismatch with external programs may be found in that the product (marketing) is serving a broader purpose than only that of the deployments and innovations in COREALIS. Potentially this broader purpose also involves other actors than are available within the COREALIS ports. As a result, the Brokerage platform brings in other priorities.

5.5 JIT Rail Shuttle Service

5.5.1 Link with external programs

The links of the JIT Rail Shuttle Service with external programs and the fit with the COREALIS Living Labs is indicated in the figure below. Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

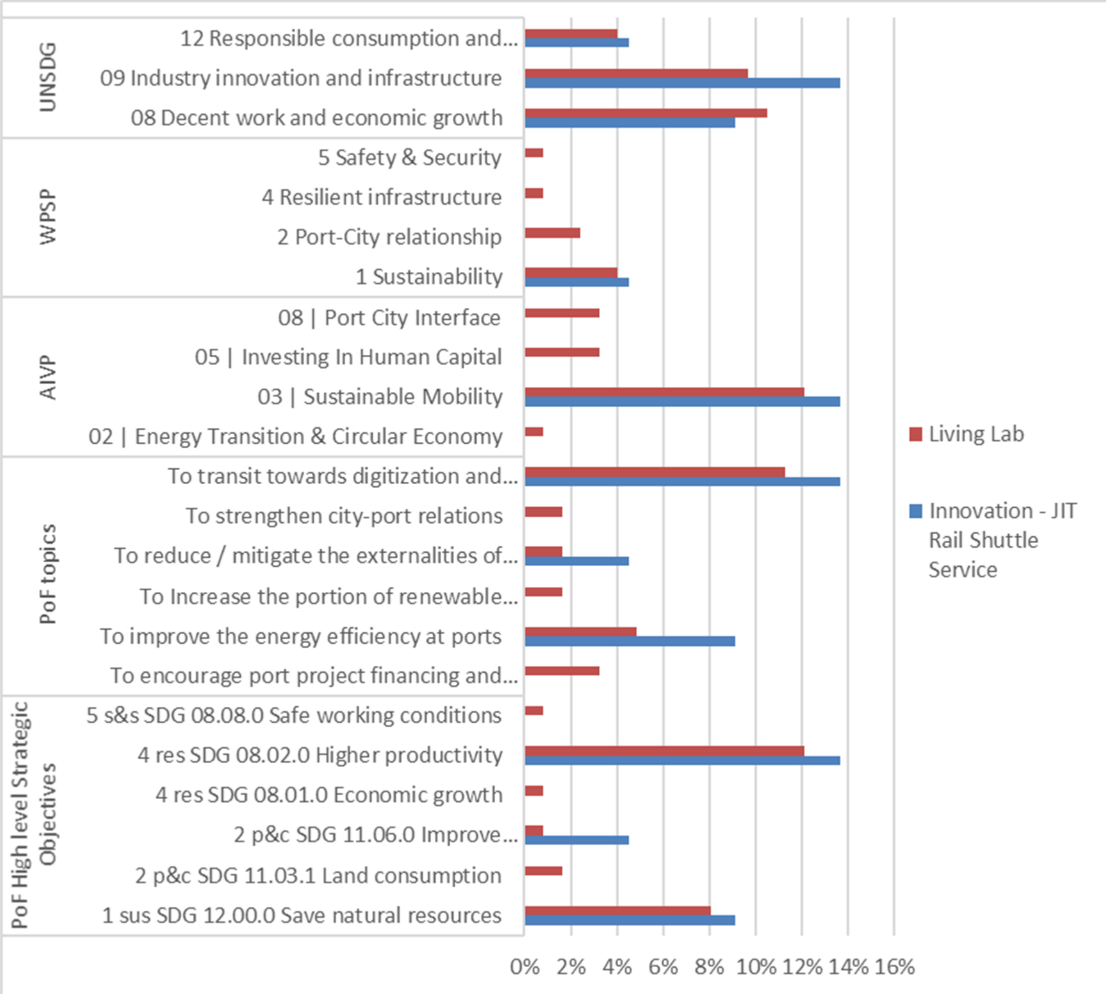

Figure 20: JIT Rail Shuttle Services and Living Labs relative importance of the strategic objectives from external programs.

For the JIT Rail Shuttle Service almost a perfect alignment is visible (Figure 20). Almost all major priorities are aligned. This means that the JIT Rail Shuttle Services fits perfectly well with the strategic objectives of all ports in COREALIS. We cannot assume a perfect representation of other ports but when targeting similar ports, the JIT Rails Shuttle Service should fit the main strategic objectives of those targeted ports.

5.5.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of the JIT Rail Shuttle Services in relation to competing projects are presented in below figure. It shall be noted that the number of projects and targeted PoF TO's and DtF Measures far exceeds the amount targeted by a single innovation. Also note that all COREALIS' innovations can only target a measure once (hence the 1).

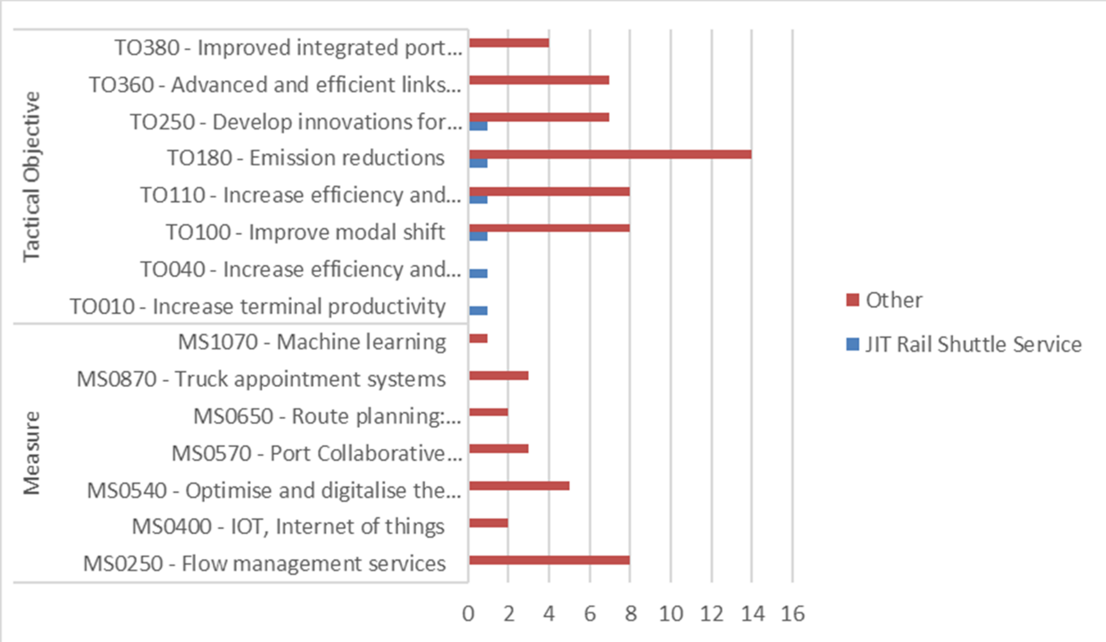

Figure 21: JIT Rail Shuttle Services targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects.

Figure 21 shows that apparently the JIT Rail Shuttle Service does not implement any of the DtF Measures, which is actually strange. This might indicate an omission in either the data or the list of measures.

When looking at the full list of Measures in Annex 1, one can conclude that rail has been ill-represented by DtF. This means that the use of rail and JIT services can be definitively seen as USPs within DtF.

When targeting other ports, the benefits increased efficiency and terminal productivity should be highlighted, as these are not targeted by other projects within the DtF database.

5.5.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 6 targeted Strategic Objectives and Measures, the JIT Rail Shuttle Service has a consolidated PCI-score of 3.3 built up of:

- 4 measures with PCI-3;
- 2 measures with PCI-4.

The innovativeness of 3.3 in combination with the targeting discussed in section 5.5.2 are an interesting combination. Apparently, the JIT Rail Shuttle Service is existing technology that is being improved and made ready for transferability, while at the same time this technology is not available in the DtF data. This makes it more likely that the measures related to the JIT Rail Shuttle Service are an omission by DtF. Which only underlines the uniqueness of the solution.

Given that, the technology is being improved and made ready for transferability indicates a unique position of the JIT Rail Shuttle Service, which should be capitalised before more competitors offer similar services.

5.5.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 6 targeted Strategic Objectives and Measures, the JIT Rail Shuttle Service has a consolidated TA-score of 4 built up of:

- 2 measures with TA-3;
- 2 measures with TA-4;
- 2 measures with TA-5.

This score and the composition are similar to the one of the Brokerage platform. On the one hand, there is a part that is being implemented only in single ports where on the other hand there are parts that have been deployed widely. This could be proof of a product (development cycle) that is (becoming) mature: where on the one hand there are new, local innovations, that are on the other hand transferred as part of business as usual to other ports. This could also clarify the difference in positioning: the product (marketing) is serving a broader purpose than only that of the individual deployments and innovations made within COREALIS. Potentially this broader purpose also involves other actors than are available within the COREALIS ports.

The combination with the PCI-score and the targeting analysis may mean that the market is relatively unaware if the existence of the JIT Rail Shuttle Service. Changing this can be done by targeted marketing.

5.6 Cargo Flow Optimiser

5.6.1 Link with external programs

The links of Cargo Flow Optimiser with external programs and the fit with the COREALIS Living Labs is indicated in the figure below. Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

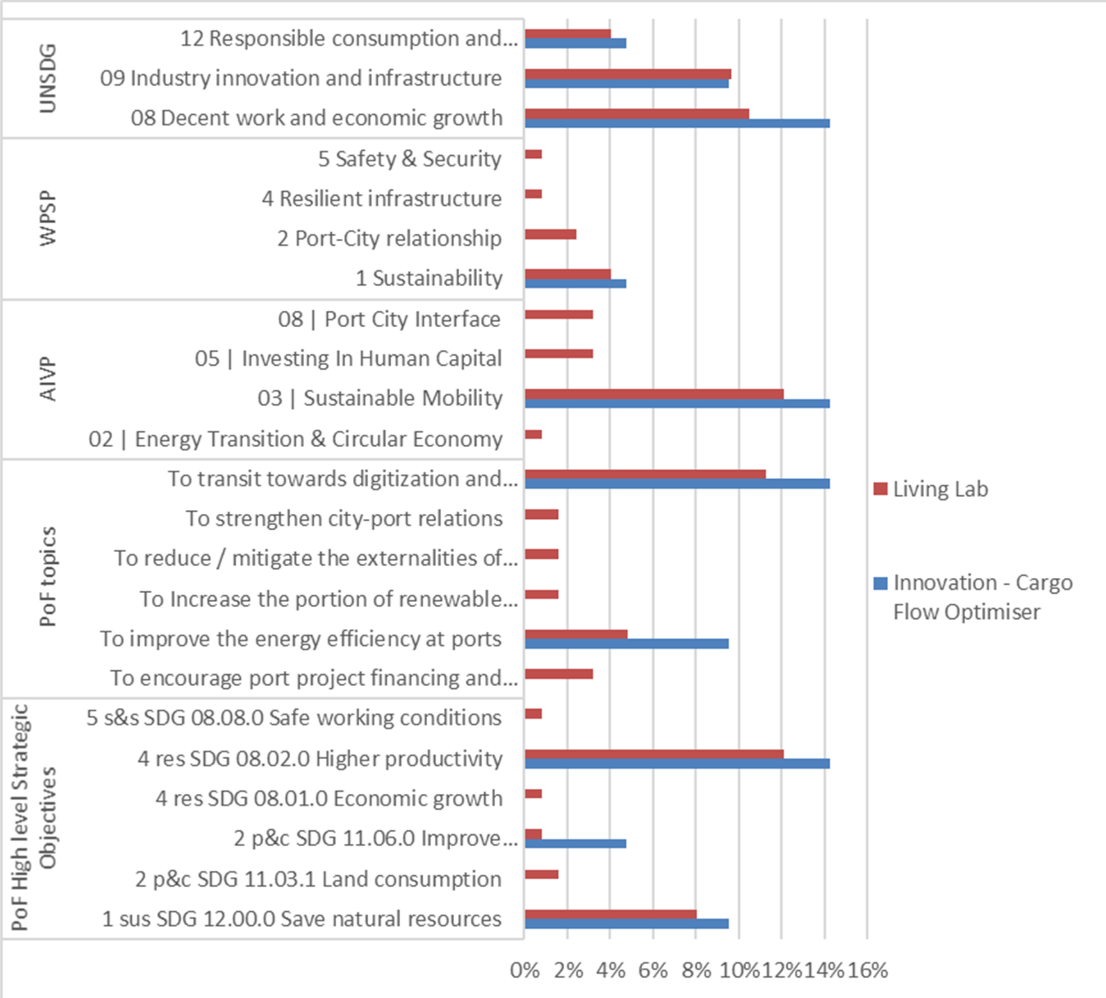

Figure 22: Cargo Flow Optimiser and Living Labs relative importance of the strategic objectives from external programs

For the Cargo Flow Optimiser almost a perfect alignment is visible as well (Figure 22). Almost all major priorities are aligned. This means that the Cargo Flow Optimiser fits perfectly well with the strategic objectives of all ports in COREALIS. We cannot assume a perfect representation of other ports but when targeting similar ports, the Cargo Flow Optimiser should fit the main strategic objectives of those targeted ports.

The main (minor) difference is visible in the PoF HLSO's, here the Living Labs mar Land consumption with a higher priority where the Cargo Flow Optimiser aims for improving the environmental quality.

5.6.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of the Cargo Flow Optimiser in relation to competing projects are presented in below figure. It shall be noted that the number of projects and targeted PoF TO's and DtF Measures far exceeds the amount targeted by a single innovation. Also note that all COREALIS' innovations can only target a measure once (hence the 1).

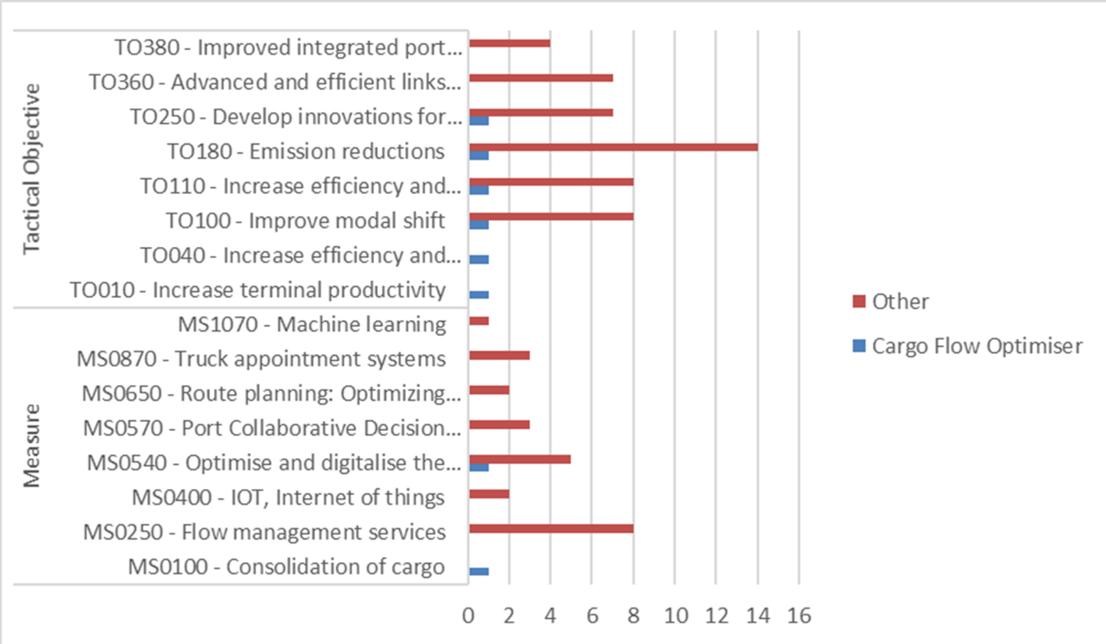

Figure 23: Cargo Flow Optimiser targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects

Figure 23 shows that most of the tactical objectives served by the Cargo Flow Optimiser are covered by multiple other projects. When targeting other ports, the benefits for efficiency and capacity of hinterland connections and the terminal productivity should be highlighted. The main USP of the Cargo Flow Optimiser lies within the consolidation of cargo, no other project in the database offers that measure.

Another thing that stands out is the total targeting of 8 TOs and Measures. Of the 135 projects there are only 4 with 8 or higher targeted TOs and Measures. The average is 3.9. Either this could mean an innovation with many benefits or that the message may be focused more.

5.6.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 8 targeted Strategic Objectives and Measures, the Cargo Flow Optimiser has a consolidated PCI-score of 3.4 built up of:

- 5 measures with PCI-3;
- 3 measures with PCI-4.

This score means a focus on moving towards full-scale deployment while at the same time using proven technology. The benefit of this lies in being able to both show proof of ability while at the same time showing innovation.

Another reason for this mix could lie in the number of measures targeted. If the Cargo Flow Optimiser were (would be) developed as part of a mature product development cycle, it is to be expected that there is a mix of proven technology (part of the mainstream of the product development cycle) and innovative technology (part of the R&D stream of the product development cycle).

5.6.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 8 targeted Strategic Objectives and Measures, the Cargo Flow Optimiser has a consolidated TA-score of 3.9 built up of:

- 3 measures with TA-3;
- 3 measures with TA-4;
- 2 measures with TA-5.

TA-3 means that the measure is applied in a single port and that the barriers for transferability are known. TA-4 means that the measure is applied in at least 3. TA-5 means that there are joint forces to apply the measure in at least 5 ports. This spread in TA scores of the measures applied by the Cargo Flow Optimiser underlines the earlier remark on the mature product development cycle.

The combination of the PCI and TA scores show that on the one hand there are innovations on measure being realised, these are most likely being performed in single port environments, and on the other hand, there are measures being applied more widely in cooperation with the ports. This would mean that the Cargo Flow Optimiser innovations realised in COREALIS would very most likely be easily transferable.

5.7 Predictor / Asset Management

5.7.1 Link with external programs

The links of Predictor / Asset Management with external programs and the fit with the COREALIS Living Labs is indicated in the figure below. Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

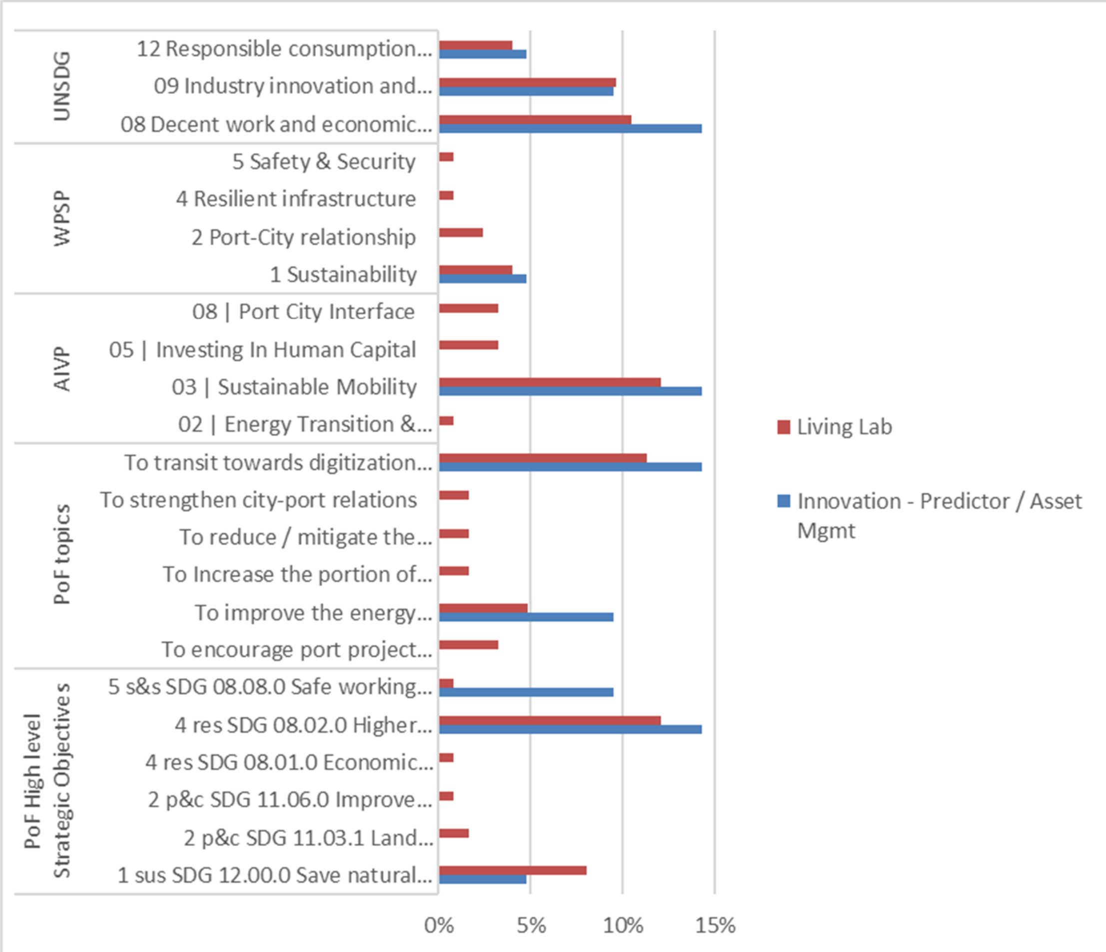

Figure 24: Predictor / Asset Management and Living Labs relative importance of the strategic objectives from external programs

For the Predictor / Asset Management almost a perfect alignment is visible as well (Figure 24). Almost all major priorities are aligned. This means that the Predictor / Asset Management fits perfectly well with the strategic objectives of all ports in COREALIS. There is one exception and that is on the PoF HLSOs. The Predictor / Asset Management marks Safe working as the second highest priority. This is not the case for the Living Labs.

When looking for target ports for transferring the innovation similar ports, as the COREALIS Living Labs will most likely be interested in the Predictor / Asset Management as well. It may be relevant to re-assess the fit with the PoF HLSOs and change the message accordingly.

5.7.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of Predictor / Asset Management in relation to competing projects are presented in below figure. It shall be noted that the number of projects and targeted PoF TO's and DtF Measures far exceeds the amount targeted by a single innovation. Also note that all COREALIS' innovations can only target a measure once (hence the 1).

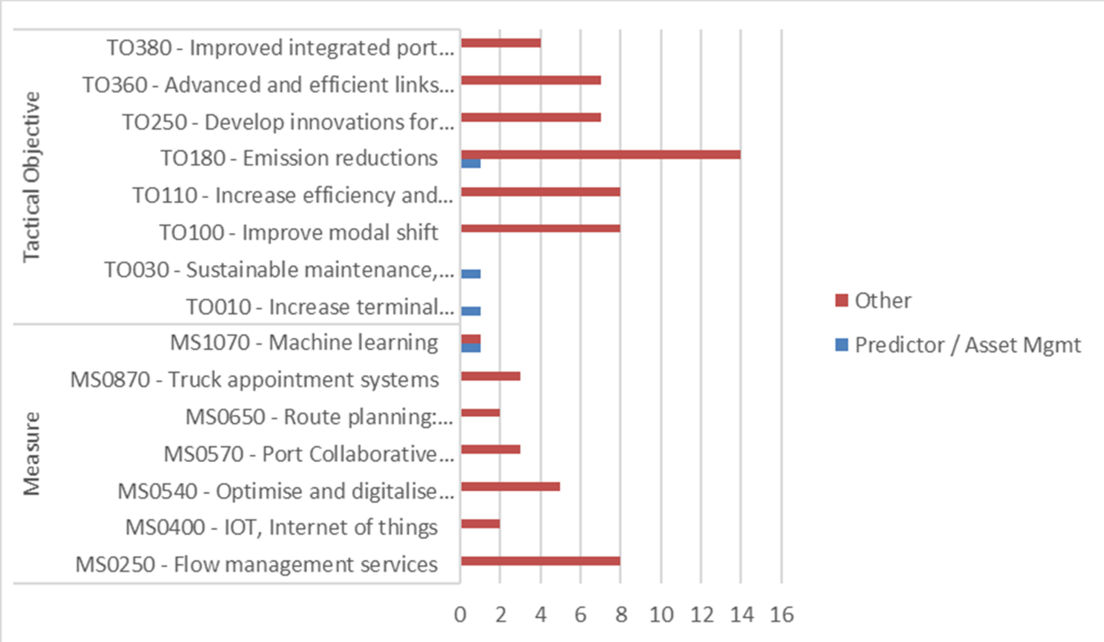

Figure 25: Predictor / Asset Management targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects

Figure 25 shows that the Predictor / Asset Management targets some unique tactical objectives in relation to the other DtF projects: sustainable maintenance and increased terminal productivity. It is also visible that the key measure Machine Learning is also implemented by 1 other project. For Predictor / Asset Management this means a clear message of USPs and used measure to achieve this.

5.7.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 4 targeted Strategic Objectives and Measures, the Predictor / Asset Management has a consolidated PCI-score of 3.5 built up of:

- 2 measures with PCI-3;
- 2 measures with PCI-4.

This score means a focus on moving towards full-scale deployment while at the same time using proven technology. The benefit of this lies in being able to both show proof of ability while at the same time showing innovation.

One thing that stands out in relation to the applied measure Artificial Intelligence is that this measure is relatively new. One would assume a higher score for this measure, however when looking at the options it becomes visible there is no score associated with 'applying new technology.'

5.7.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 4 targeted Strategic Objectives and Measures, the Predictor / Asset Management has a consolidated TA-score of 4 built up of:

- 2 measures with TA-3;
- 2 measures with TA-5.

This TA score is an interesting one as it has a gap between TA-3 and TA-4. This indicates both a single port implementation as well as joint forces between at least 5 ports skipping application in at least 3 ports. An explanation could lie in the application of AI within a single port in COREALIS in combination with Asset Management in more ports.

This score and spread could mean an addition of a new technology (AI) within an established field (Asset Management). If this indeed is the case, sales channels should be known and the innovation from within COREALIS should be relatively easy to transfer to other ports (of existing customers).

5.8 PORTMOD

5.8.1 Link with external programs

The links of PORTMOD with external programs and the fit with the COREALIS Living Labs is indicated in the figure below. Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

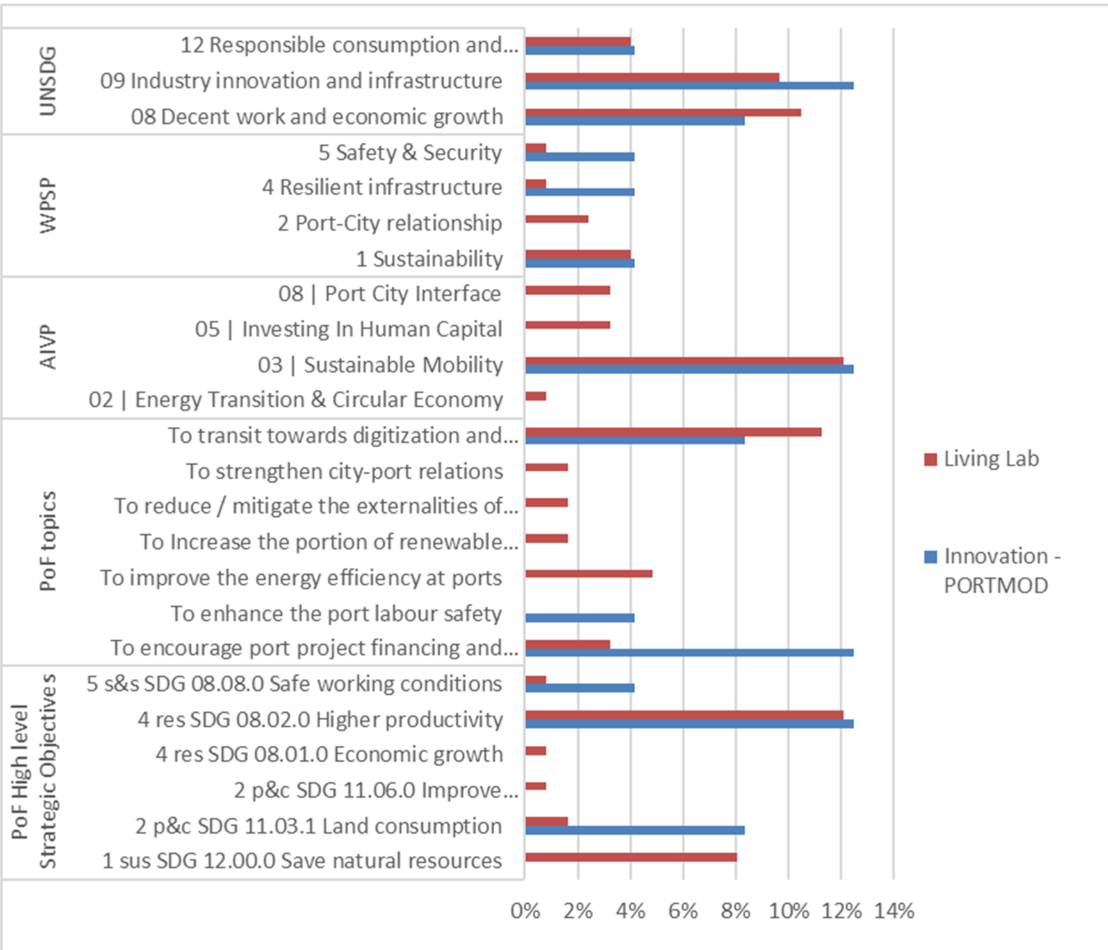

Figure 26: PORTMOD and Living Labs relative importance of the strategic objectives from external programs.

Figure 26 shows a good alignment of PORTMOD with the priorities of the Living Labs. The main differences lie with:

- The WPSP focus areas where PORTMOD ticks Safety & Security and Resilient infrastructure whereas the Living Labs ports see the Port-City relationship as more important.
- The PoF topic encourage port project financing that PORTMOD addresses as main priority, while this is the third priority of the Living Labs.
- The PoF topic enhance port labour safety that PORTMOD addresses, while this is not a priority for any of the Living Labs.
- The PoF HLSO land consumption that PORTMOD addresses as second priority, while the second priority of the Living Lab ports is on saving natural resources.

When looking for other ports for the PORTMOD innovation this means that either ports that have these issues should be found, or the message should be changed when addressing similar ports as the COREALIS Living Lab ports.

5.8.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of PORTMOD in relation to competing projects are presented in below figure. It shall be noted that the number of projects and targeted PoF TO's and DtF Measures far exceeds the amount targeted by a single innovation. Also note that all COREALIS' innovations can only target a measure once (hence the 1).

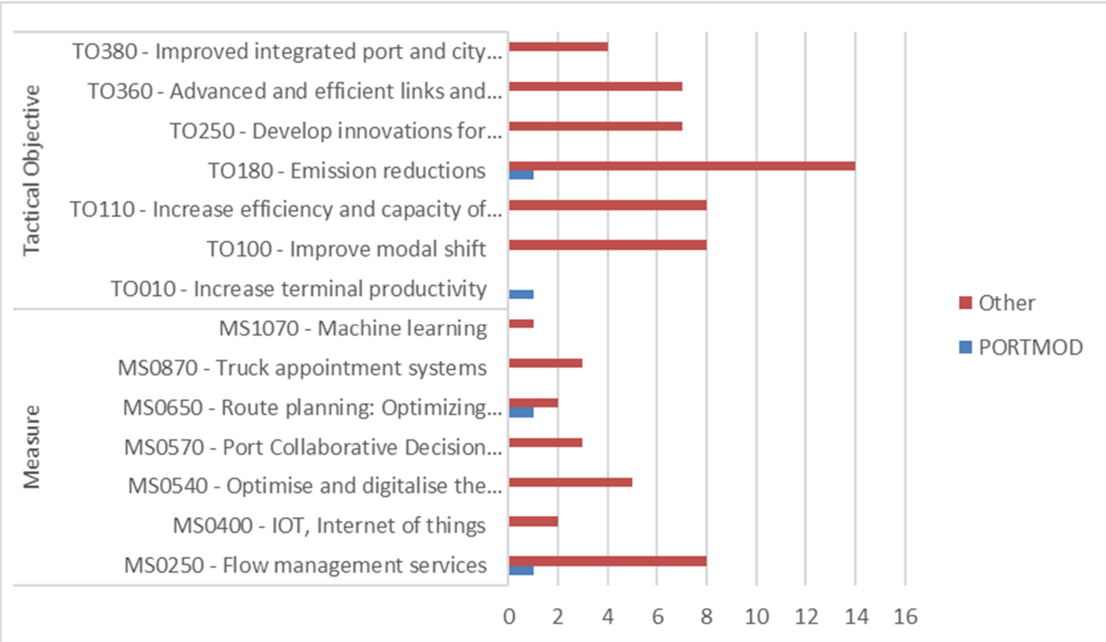

Figure 27: PORTMOD targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects.

In figure 27 it can be seen that of the 2 addressed tactical objectives, 1 is actually targeted very much by other DtF projects. Using this tactical objective in commercial outings would mean proof is necessary and the benefits should be large. The other tactical objective has not been addressed by other DtF projects meaning it is easier to show the benefits of PORTMOD on that objective. The measures implemented to realise the tactical objectives are being implemented by several other projects as well.

Summarising the targeting of PORTMOD implies that there is quite some competition on the market offering similar solutions on the one hand. On the other hand, that apparently multiple parties see this as an opportunity, which is an indication for an actual market.

5.8.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 4 targeted Strategic Objectives and Measures, PORTMOD has a consolidated PCI-score of 3.3 built up of:

- 3 measures with PCI-3;
- 1 measure with PCI-4.

The score of 3.3 and the spread of scores show a focus of PORTMOD on improving current technology and working towards transferring of the solution. This is indicative for a novel solution that is about to be rolled out widely.

5.8.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 4 targeted Strategic Objectives and Measures, PORTMOD has a consolidated TA-score of 4 built up of:

- 2 measures with TA-3;
- 2 measures with TA-5.

The TA scores associated with PORTMOD show something interesting. Where in the previous section it seemed that the innovation in COREALIS was mainly local, now it seems there already is an established link with ports.

Looking into the data shows that the higher scores are linked to TOs that are served by almost all COREALIS innovations while the Measures are only implemented by PORTMOD. This would indicate that the TOs are well known amongst other ports (and thus easily transferred resulting in TA-5) while the solution offered by PORTMOD is relatively new (PCI-3 and TA-3) and about to be transferred to other ports.

5.9 RTPORT

5.9.1 Link with external programs

The links of RTPORT with external programs and the fit with the COREALIS Living Labs is indicated in the figure below. Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

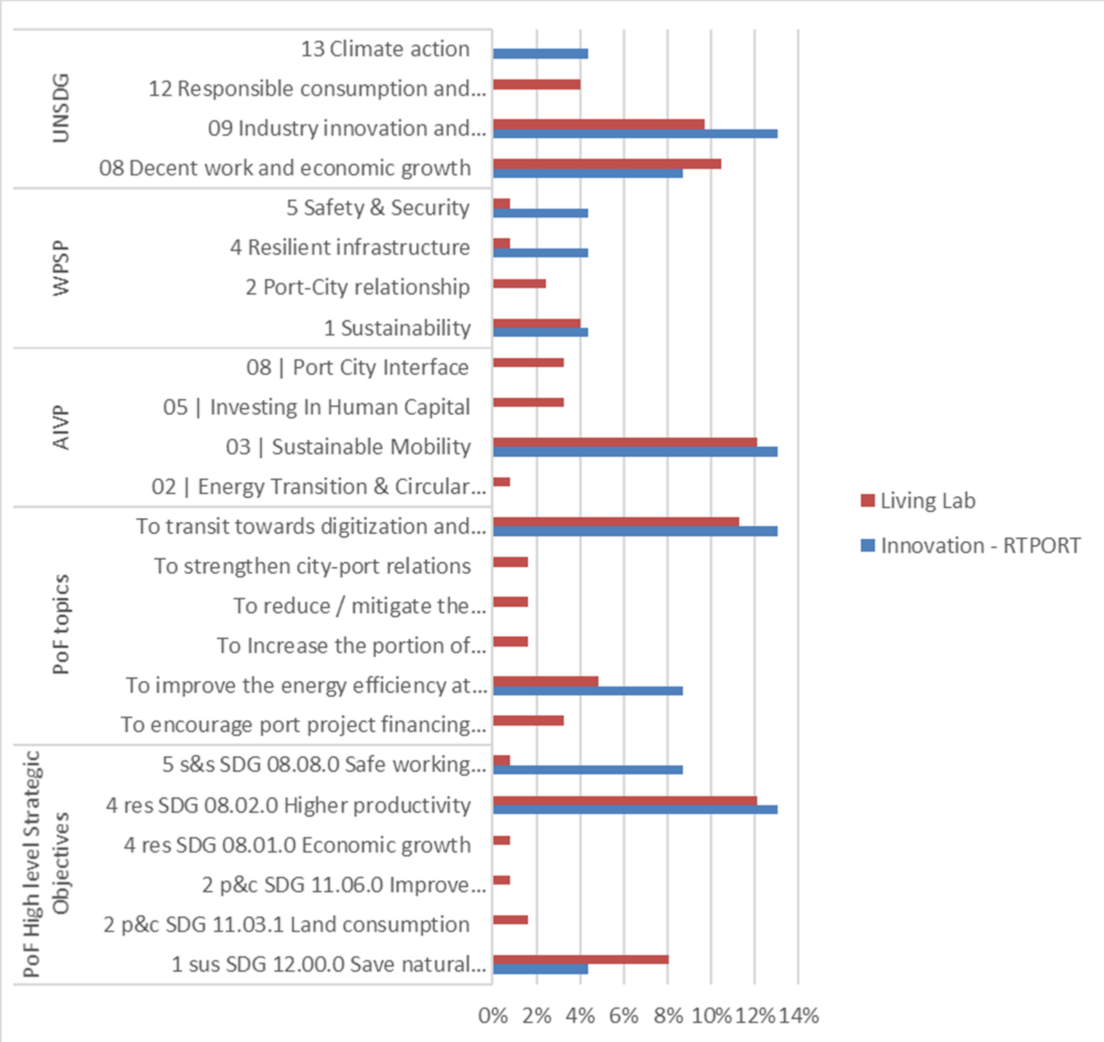

Figure 28: RTPORT and Living Labs relative importance of the strategic objectives from external programs

The link with external programs in above Figure 28 shows that in general the priorities of RTPORT overlap with those of the Living Labs. However, there are some interesting differences.

In the UNSDGs RTPORT has a priority on Climate action where this is a priority in none of the Living Labs. This is quite interesting given the expectation if rising sea levels. One might assume a priority at the Living Labs on this topic. It could mean RTPORT is well positioned for future issues.

A similar assumption can be seen at the WPSP focus area resilient infrastructure. This is addressed by RTPORT, however prioritised relatively low by the Living Labs. This mismatch is also present with Safety & Security. Apparently, the Living Labs do not see that as a priority.

This Safety & Security mismatch is also visible at the PoF HLSOs. Safe working is addressed as second priority by RTPORT by as one of the lowest by the Living Labs. When looking for other ports/terminals, high value trans-shipment locations/operators may be more interested in the solutions.

5.9.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of RTPORT in relation to competing projects are presented in below figure. It shall be noted that the number of projects and targeted PoF TO's and DtF Measures far exceeds the amount targeted by a single innovation. Also note that all COREALIS' innovations can only target a measure once (hence the 1).

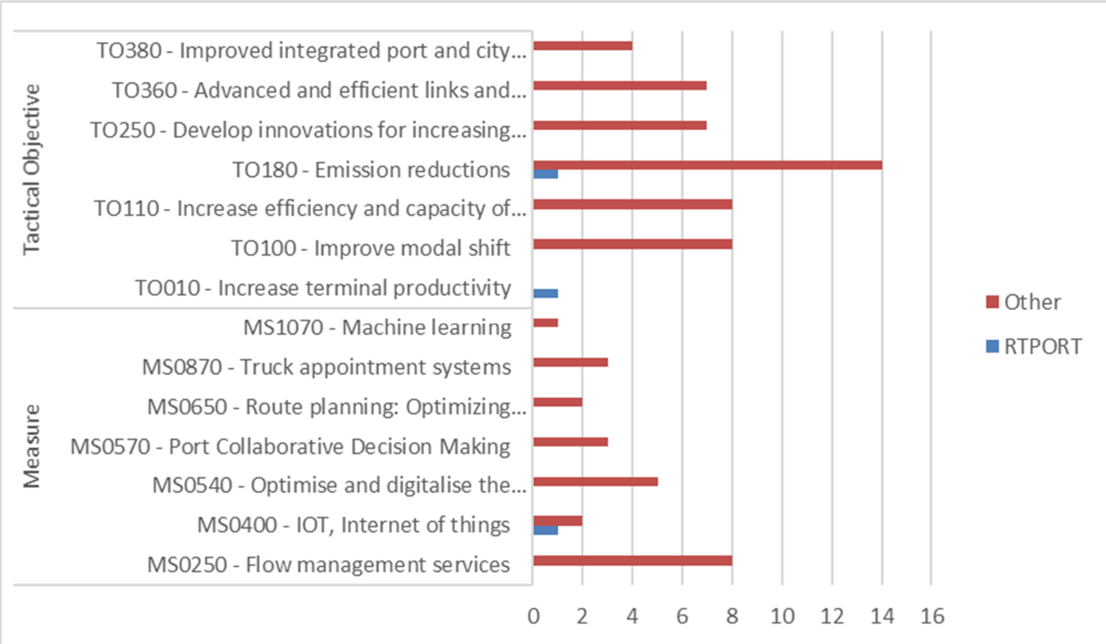

Figure 29: RTPORT targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects

In figure 29 it can be seen that RTPORT targets the two major TOs of COREALIS. Of these two, the increase of terminal productivity is the main USP. To realise this increase of productivity RTPORT implements IoT technology.

5.9.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 3 targeted Strategic Objectives and Measures, RTPORT has a consolidated PCI-score of 4 built up of:

- 1 measure with PCI-3;
- 1 measure with PCI-4;
- 1 measure with PCI-5.

The PCI score of 4 is among the highest of COREALIS. What is interesting to see is that the PCI-5 score is linked to the IoT measure meaning that RTPORT implements a completely new cross-sector technology, which IoT is. RTPORT does this while addressing the two main COREALIS TOs. This means a new solution that adds innovations that are already being improved and adapted for transferability. RTPORT thus piggybacks on already established solutions for emission reduction and increases of terminal productivity.

5.9.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 3 targeted Strategic Objectives and Measures, RTPORT has a consolidated TA-score of 4 built up of:

- 1 measures with TA-2;
- 2 measures with TA-5.

Where the innovativeness shows that a new technology is being realised and implemented, this has its downsides for transferability. The TA-2 score indicates that the barriers and constraints for transferability are unknown. The TOs associated with the TA-5 score indicate however that the potential to implement RTPORT in other locations is very well available. The actual potential of RTPORT can only be assessed when the barriers and constraints are known and an implementation in another port has been performed. The combination of PCI- and TA-score does indicate great potential.

5.10 Energy assessment & Green cookbook

5.10.1 Link with external programs

The links of the Energy assessment & Green cookbook with external programs and the fit with the COREALIS Living Labs is indicated in the figure below. Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

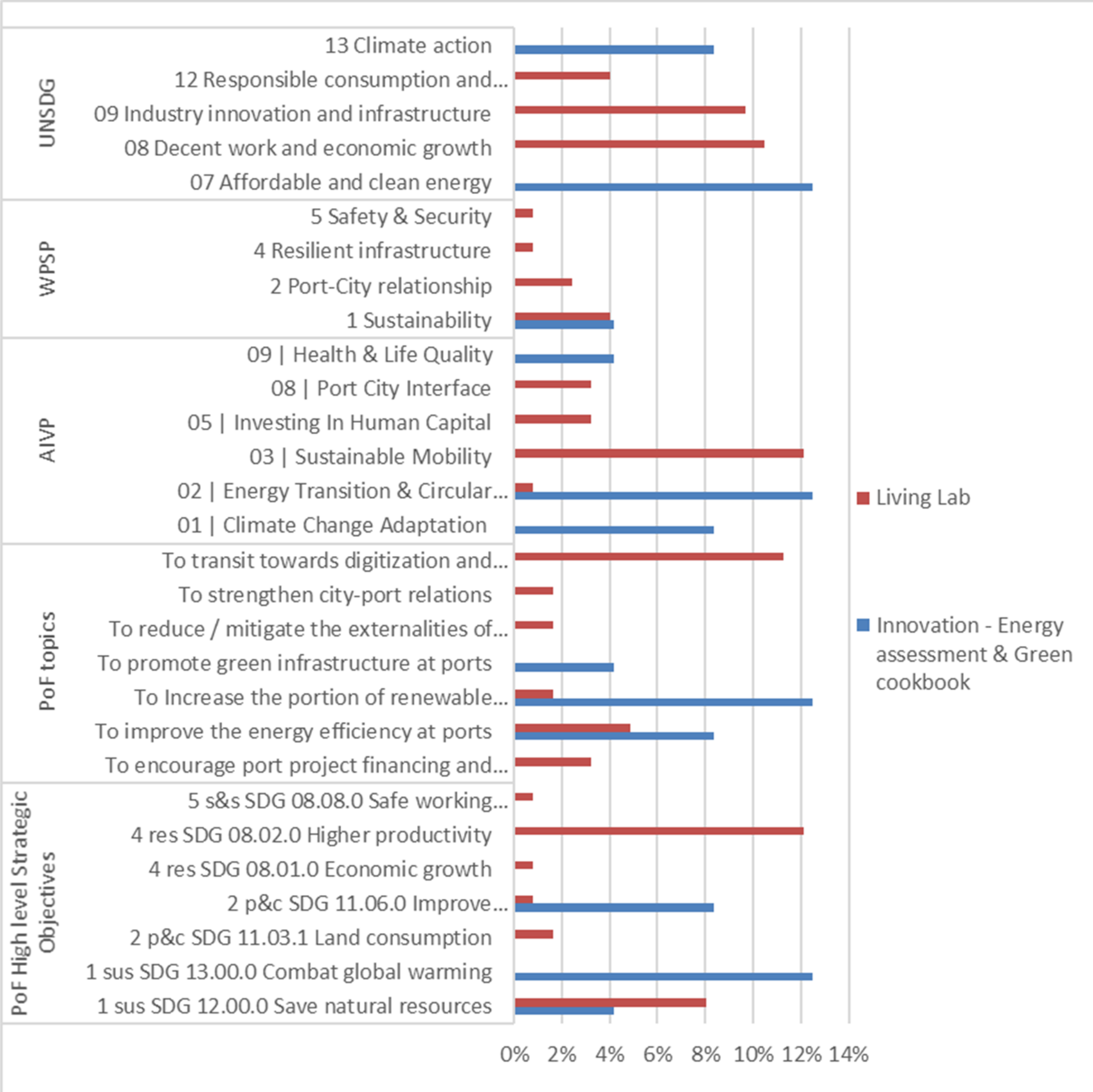

Figure 30: Energy assessment & Green cookbook and Living Labs relative importance of the strategic objectives from external programs.

Figure 30 shows a clear distinction between the priorities of the Energy assessment & Green cookbook and the priorities of the Living Labs. It is clearly visible the innovation aims at improvements on the environment while the needs of the Living Labs lie elsewhere. The exceptions to this are linked to mutual interests.

In the WPSP focus areas sustainability has the highest priority for the Living Labs and the innovation. Sustainability evolves around *People, planet, profit (and prosperity)*; this is beneficial for both the environment and the ports.

For the PoF topics, the improvement of energy efficiency also serves a mutual interest. For ports, this is directly linked to profit, for the innovation it is directly linked to energy savings and less pollution. This also holds for the PoF HLSO save natural resources.

For the Energy assessment & Green cookbook innovation, it is relevant to focus on these mutual benefits in ports as apparently the ports are more inclined to listen to the profit argument than the green argument.

5.10.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of the Energy assessment & Green cookbook in relation to competing projects are presented in below figure. It shall be noted that the number of projects and targeted PoF TO's and DtF Measures far exceeds the amount targeted by a single innovation. Also note that all COREALIS' innovations can only target a measure once (hence the 1).

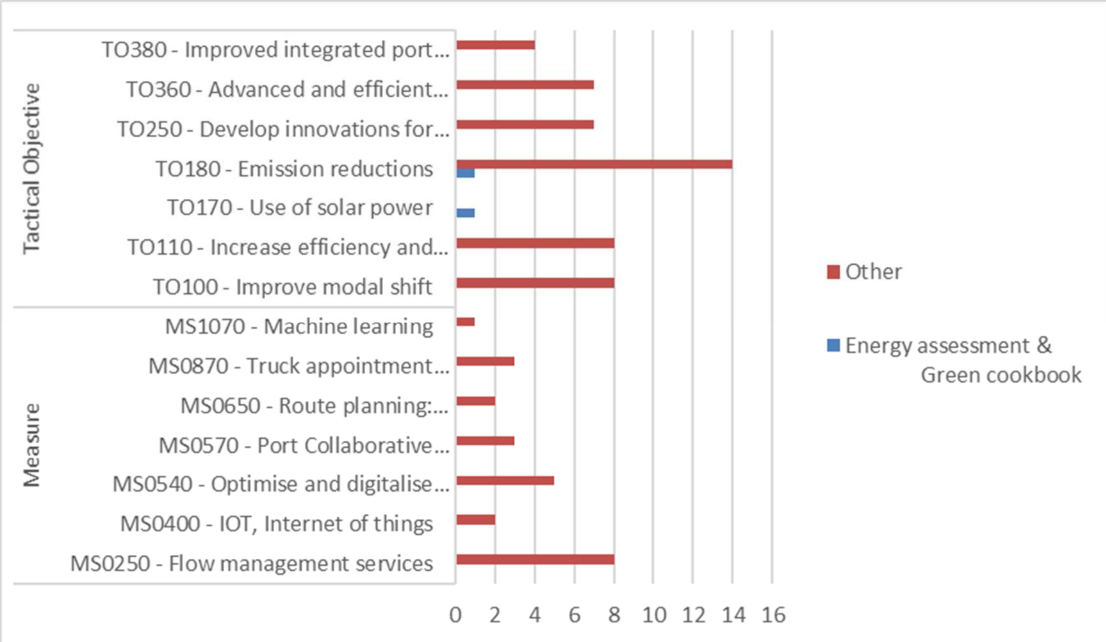

Figure 31: Energy assessment & Green cookbook targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects.

Figure 31 shows a similar picture as "Figure 21: JIT Rail Shuttle Services targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects." as in no Measures have been identified that are implemented by the Energy assessment & Green cookbook. When looking at the full list (Annex 1), this indeed is the case. However, for the Energy assessment & Green cookbook innovation, this is actually true as the 'Measure' is composed of best practices and advice on what can be done, instead of actually doing it.

5.10.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 2 targeted Strategic Objectives and Measures, Energy Assessment & Green Cookbook has a consolidated PCI-score of 2.5 built up of:

- 1 measure with PCI-2;
- 1 measure with PCI-3.

The PCI-scores indicate that the solutions available in the Energy assessment & Green cookbook are aimed at higher availability and improvements of solutions. This actually fits very well with the best practices and advice as these are typically aimed at sharing knowledge (higher availability) and improving operations with this knowledge on solutions.

5.10.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 2 targeted Strategic Objectives and Measures, Energy Assessment & Green Cookbook has a consolidated TA-score of 4 built up of:

- 1 measure with TA-3;
- 1 measures with TA-5.

This built up of the TA-score is counterintuitive. TA-3 says the innovation is a single port implementation with known barriers and constraints. TA-5 says the innovation is implemented in at least 5 ports. One would expect sharing of knowledge to be available widespread.

It actually makes sense when looking deeper into the data. The TA-3 score is linked to solar panels; these are apparently only implemented in Piraeus. This solution however will be taken into the Green cookbook and made available to numerous ports. This shows an excellent cycle of creating and sharing knowledge and best practices ensuring transferability of this COREALIS innovation.

5.11 PoF Serious Game

5.11.1 Link with external programs

The links of the PoF Serious Game with external programs and the fit with the COREALIS Living Labs is indicated in the figure below. Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

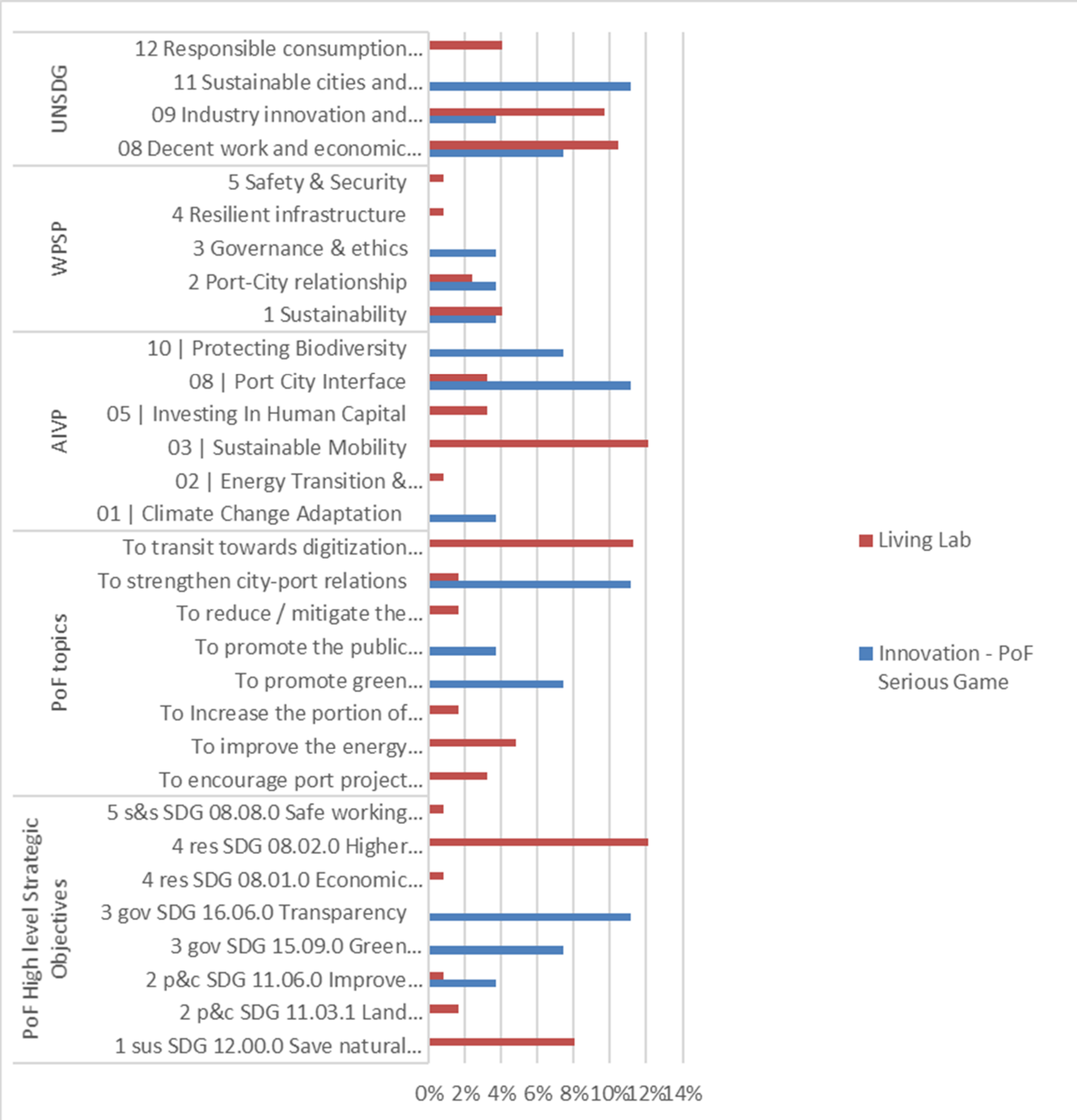

Figure 32: PoF Serious Game and Living Labs relative importance of the strategic objectives from external programs.

For the PoF Serious Game a similar view is available as for the previous innovation (Figure 32). The focus of the innovation differs from the focus of the Living Labs. The PoF Serious Game focusses on the environment and relation between the environment, city, port and citizens while the Living Labs focus on raising productivity and lowering (energy) costs. When looking for target ports it is relevant to assess if they have issues with port-city relations.

5.11.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of the PoF Serious Game in relation to competing projects are presented in below figure. It shall be noted that the number of projects and targeted PoF TO's and DtF Measures far exceeds the amount targeted by a single innovation. Also note that all COREALIS' innovations can only target a measure once (hence the 1).

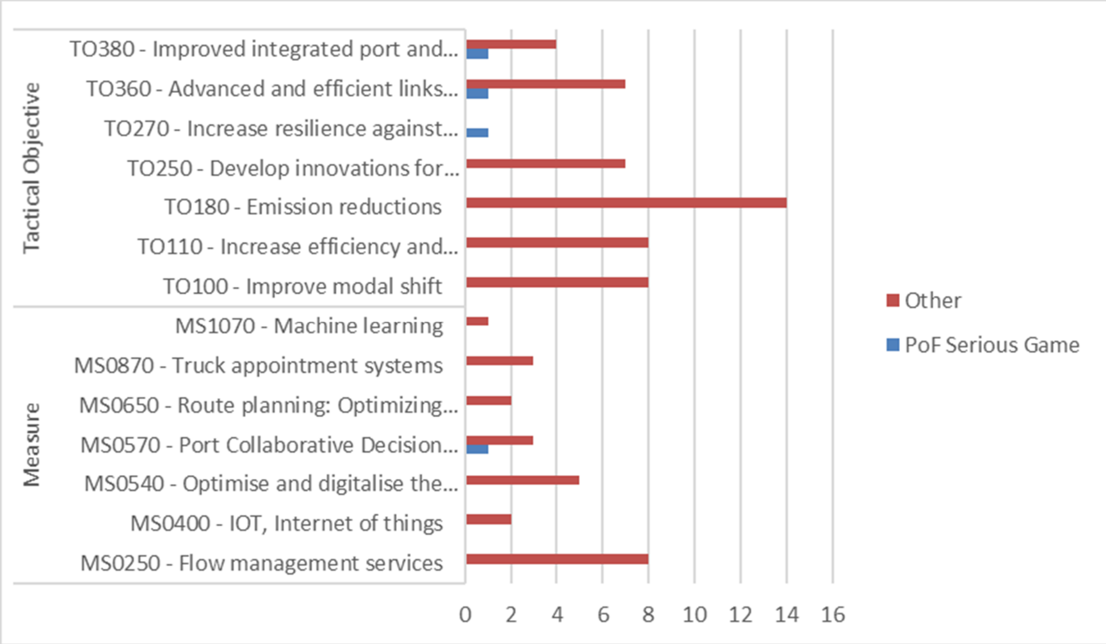

Figure 33: PoF Serious Game targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects.

From figure 33 we can see that the PoF Serious Game is uniquely targeting an increase in resilience against climate change. This increased resilience is obtained by port collaborative decision making. The measure alone is not uniquely implemented, the purpose to implement this measure is not aimed for in any of the other projects in the DtF database. When looking for other ports it may be relevant to check the current resilience against climate change and check if the port is willing to implement this collaborative decision-making.

5.11.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 4 targeted Strategic Objectives and Measures, the PoF Serious Game has a consolidated PCI-score of 3 built up of:

- 1 measure with PCI-1;
- 1 measure with PCI-3;
- 2 measures with PCI-4.

This score and spread indicate that the PoF Serious Game is being implemented using existing technologies and is extended with new concepts that are just (becoming) widely available. This positions the PoF Serious Game such that is should be usable to assess the value of these new concepts.

5.11.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 4 targeted Strategic Objectives and Measures, the PoF Serious Game has a consolidated TA-score of 3.5 built up of:

- 2 measures with TA-3;
- 2 measures with TA-4.

This TA-score means that the innovation is in a transition between a single port implementation and an implementation in at least 3 ports.

When looking at the details it becomes apparent that the decision making itself in combination with the improved port-city development planning are part of an established product/service in at least 3 ports. The lower scores are given to the resilience and links between the port and industrial and urban environment. This indicates that these latter are newer parts that are integrated in the PoF Serious Game and being made ready to be part of the standard product. This would mean the PoF Serious Game is very well transferable to other ports.

5.12 Innovation Incubator

5.12.1 Link with external programs

The links of the Innovation Incubator with external programs and the fit with the COREALIS Living Labs is indicated in the figure below (Figure 34). Note that the total amount of strategic objectives far exceeds the number of objectives targeted by a single innovation. Therefore, no innovation can cover all the Living Lab strategic objectives.

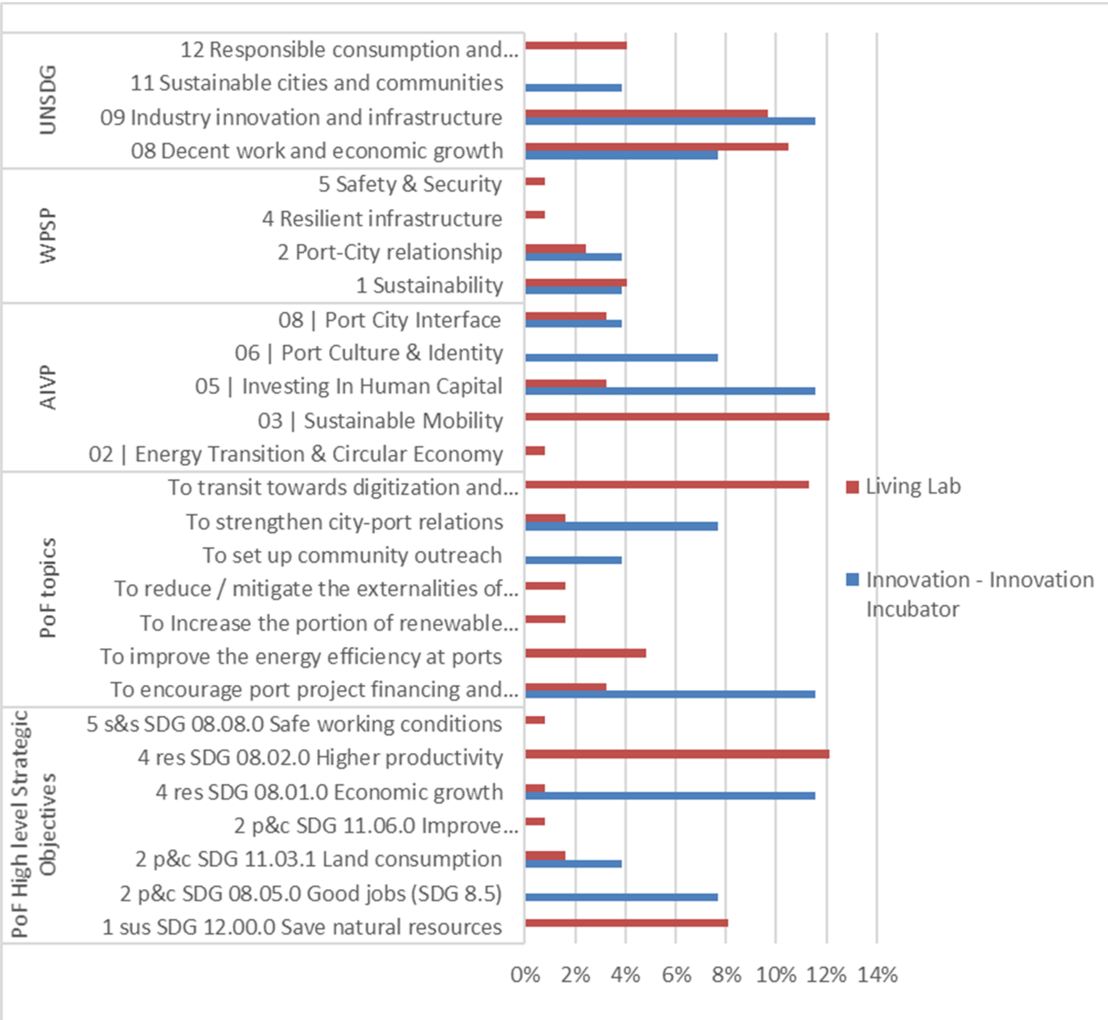

Figure 34: Innovation Incubator and Living Labs relative importance of the strategic objectives from external programs.

The link with external programs for the Innovation Incubator shows a good overlap of priorities for some programs and a mismatch on others.

For the UNSDGs, the overlap is good except for Responsible consumption and production for the Innovation Incubator versus Sustainable cities and communities for the Living Labs. These two could be considered as two sides of the same coin, however.

For WPSP the Innovation Incubator and the Living Labs are well aligned.

For AIVP there is a clear distinction in the priorities of the Living Labs (sustainability) and those of the Innovation Incubator (human capital and identify) as may be expected by a service dealing with start-ups and taking innovations to a higher level.

This is visible on the PoF topics as well. The community, project financing and city-port relations are all very relevant when dealing with start-ups and taking innovations to a higher level. For the ports, the priorities lie more on improvements of the main processes.

The view from the PoF HLSOs only underlines this. The Living Labs focus on higher productivity and lower costs (resources), the Innovation Incubator focusses on growth and jobs.

When looking for other ports to implement the Innovation Incubator it will be relevant to search for locations that are focusing on the priorities above.

5.12.2 Targeting

The targeted PoF Tactical Objectives and DtF Measures of the Innovation Incubator in relation to competing projects are presented in below figure. It shall be noted that the number of projects and targeted PoF TO's and DtF Measures far exceeds the amount targeted by a single innovation. Also note that all COREALIS' innovations can only target a measure once (hence the 1).

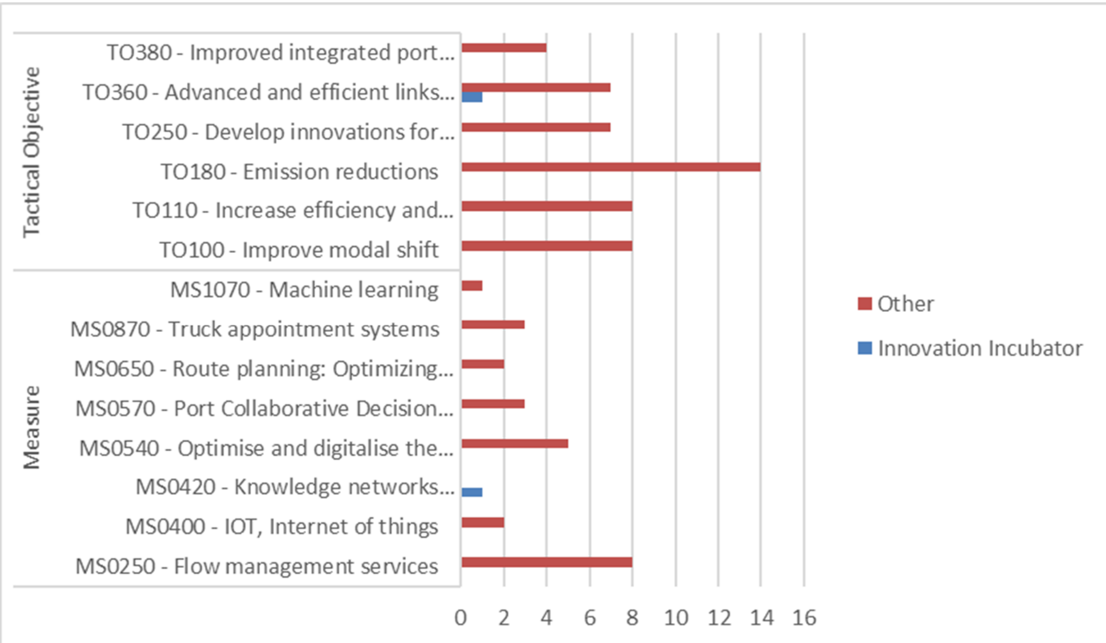

Figure 35: Innovation Incubator targeted Tactical Objectives and Measures in relation to other COREALIS' TOs and MSs targeted by DtF projects.

When looking at above figure (Figure 35) it becomes clear that the Innovation Incubator uniquely implements knowledge networks when comparing to the other projects available in the DTF database. This fits perfectly well with the positioning with respect to the external programs described in the previous section. The Innovation Incubator does this to realise the Tactical Objective on efficient links with the port externalities.

5.12.3 Innovativeness

In section 5.2.3 a description on how the innovativeness is assessed is presented. With the 4 targeted Strategic Objectives and Measures, the Innovation Incubator has a consolidated PCI-score of 1 built up of:

- 2 measures with PCI-1.

Above scores may seem disappointing however, they are logical given the nature of the Innovation Incubator. The implementation of knowledge networks for realising efficient links with surroundings on its own may have been done before. The topics that are being ‘incubated’ may very well be scored higher. The methodology unfortunately does not offer a solution to better assess the total innovativeness of the Innovation Incubator and the ‘incubated innovations’.

5.12.4 Transferability

In section 5.2.5 a description on how the transferability is assessed is presented. With the 2 targeted Strategic Objectives and Measures, the Innovation Incubator has a consolidated TA-score of 3.5 built up of:

- 1 measure with TA-3;
- 1 measure with TA-4.

The score of TA-4 has been given in relation to the creation of knowledge networks, which is in line with the PCI-1 score. The TA-3 score has been given to the links with the port surroundings. Apparently, this part is being realised within COREALIS and being taken into the solution to be transferred.

For the Transferability of the Innovation Incubator, the same holds as for the innovativeness. The methodology does not offer a solution to score transferability of the “incubated innovations”.

6. Summary of the results

6.1 Project objectives

All four project objectives were either realised during the project or proved achievable by the means of COREALIS innovations. In the following tables (Table 31), the test results from each innovation are presented in relation to the project objectives.

Table 31: Project objectives and their corresponding COREALIS solutions.

O1. Embrace circular economy models in its port strategy and operations.	
Innovation	**Comment**
Cloud Brokerage Platform	*Platforms for sharing resources like the COREALIS Brokerage Platform are promising in achieving objectives of circular economy by reducing demand for resources, thus raw materials and semi products down the supply and production chain.* *Consistent and trusted information being exchanged within community makes it possible to create value for local society, economy of the businesses as well as footprint of the whole community. The marketplace is a customizable and scalable solution, and a port authority can be a great example of maintaining it reaching its goals of its sustainability.*
PREDICTOR	*Predictive maintenance is an integral part of circular economy that aims to get more value from existing products while decoupling value creation from resource consumption, optimising resource use within industries. COREALIS PREDICTOR has proven that it is feasible to shift from standard maintenance plans that are based either on manufacturer guides or standard mileage to custom plans for each individual piece of equipment (in this case yard trucks), minimise both the amount of spare parts used and the inventory space required to store them and improve their operational availability due to the reduction of unexpected breakdowns.*
Green Cookbook	*This objective has been achieved. The innovation can be utilised to identify power consumption patterns in the container yard and to determine power consumption that can be replaced by power generated from renewable energy sources.*

O2. Reduce the port's total environmental footprint associated with intermodal connections and the surrounding urban environment for three major transport modes, road/truck, rail and inland waterways.	
Innovation	**Comment**
IoT based TAS (Truck Appointment System)	*Reducing waiting times in the port reduces the emissions when trucks are running idle less time than before.* *Using TAS has an indirect effect for transport companies when truck operations are more efficient and predictable. As*

	the waiting times are shorter, the utilisation rate increases, and the same fares can be done with a smaller number of trucks. This leads to faster renewal of trucks, which reduces environmental footprint.
Cargo Flow Optimiser	*Conclusion was that CFO MIP has added value already in this development stage. Current parameters as duration, distance, price indication and emissions are a first indicator. In order to make real decisions on the operational route also live data on closing and delivery time and actual cost is necessary.* *After testing, CFO shows the potential of achieving a modal shift from truck to barge/train.*
JIT Rail shuttle service feasibility study	*Implementing this service and shift from road to rail the intermodal transport between Zaragoza and Valencia represents a reduction of more than 35.14L/TEU, which is almost 53% in fuel savings and its associated GHG emissions. Anyhow, Just-In-Time Rail Shuttle service is not going to be implemented in the Port of Valencia in the short term. Actually, it never was foreseen in the framework of the project.*

O3. Improve operational efficiency, optimise yard capacity and streamline cargo flows without additional infrastructural investments.	
Innovation	**Comment**
RT PORT	*Through the conducted analysis, it was possible to see positive effects of 5G and digital technologies when applied to the port's operational processes in terms of efficiency, sustainability as well as economic improvements.* *The instantiation of the 5G network at the Port of Livorno, as well as the use of advanced AR/VR-based services and AI based control functions, provide optimisation of the intra-terminal operations. This means an increasing operational speed and thus the reduction of the vessels berthing time.* *The remote and automated cargo handling together with monitoring and tracking systems lower the time to find cargo, reduce operational inefficiencies and movements in cargo handling. This optimises the process and lowers fuel consumption and associated CO_2 emissions.*
PORTMOD	*FlowAnalyzer can find bottlenecks that require further investigation to improve operational efficiency. With simulation, the work can be planned to be performed more efficiently (with less driving kilometres and movements). Since PORTMOD is an analysing and simulation tool, it will only fulfil the objective when the improvements are taken in use in practice.*
PREDICTOR	*By introducing a machine learning algorithm that allows ports to deviate from general maintenance plans to plans per individual yard truck, it has been demonstrated that there is a reduction of the number of unexpected breakdowns that leads to improvement of equipment availability. Smooth container delivery and pickup to/from quay cranes is crucial for the operational efficiency of container ports since a single breakdown can delay significantly vessel operations that*

	require containers to be loaded/unloaded with a strict sequence.
IoT based TAS (Truck Appointment System)	*In Valencia, truck operations are more efficient due to the higher visibility of them and the reduction of the waiting times inside the terminal in almost 10 minutes compared to the results of 2019. This has a huge impact considering the volume of trucks that call at the port gates in daily basis in the Port of Valencia, which has an average number of 5000 trucks movements per day. The reduction of waiting times optimises the efficiency of the operations.*

O4. Enable the port to take informed medium term and long term strategic decisions and become an innovation hub of the local urban space.	
Innovation	**Comment**
Port of the Future Serious Game PoFSG	*The PoFSG can facilitate the (explorative stage of the) decision-making process and facilitate stakeholder involvement but does not provide actual (quantitative) decision information as such.* *Due to COVID-19, the PoFSG workshops had to be replaced by webinars and, hence, actual stakeholder engagement has not taken place. Anyhow, the webinars gathered also a reasonable number of external attendees.* *However, the degree to which the PoFSG meets its objectives was tested to some extent in the benchmarking game session with the consortium held in Valencia by means of a survey. The results presented in D5.6 show clear increase in the awareness of port sustainability and understanding different stakeholder viewpoints.*
Innovation Incubator (Hackathon)	*This first edition of the hackathon contributed to reach this objective by organising a one-week event where the innovation and entrepreneur ecosystem faced the challenges proposed by the port community of the Port of Valencia. On one hand, the stakeholders proposed the challenges and involved their personal to support participants through mentoring sessions with port-logistics experts. On the other hand, hackathon participants knew the main concerns of the port-logistics industry and were able to propose innovative solutions to overcome them.* *Additionally, challenge owners have shown interest in continuing development and testing some of the solutions proposed in the hackathon.*

6.2 Technology readiness levels (TRL)

A methodology of assessing technology maturity is the concept of Technology Readiness Levels (TRLs) introduced in the 1970s by the National Aeronautics and Space Administration (NASA). The main goal of the TRL scale is to assist the decision-making process regarding technology infusion in complex systems development [7]. TRL scale was modified during the last decades of its existence and the last version consists of nine discrete levels (1 to 9), where higher TRL ratings relate to more mature technologies (Figure 36). TRLs have been broadly used also by other sectors outside aerospace and they have become generally accepted method for technology maturity [8], [9], [10], [11], [12]. In 2016, Tomaschek, Olechowski, Eppinger and Joglekar [13] conducted a survey with TRL scale practitioners in different industries worldwide in order to identify the most priority challenges among the fifteen that they were already identified. The results showed that these four challenges were the representation of the integration between technologies, interfaces maturity, modifications in the system and system overall maturity.

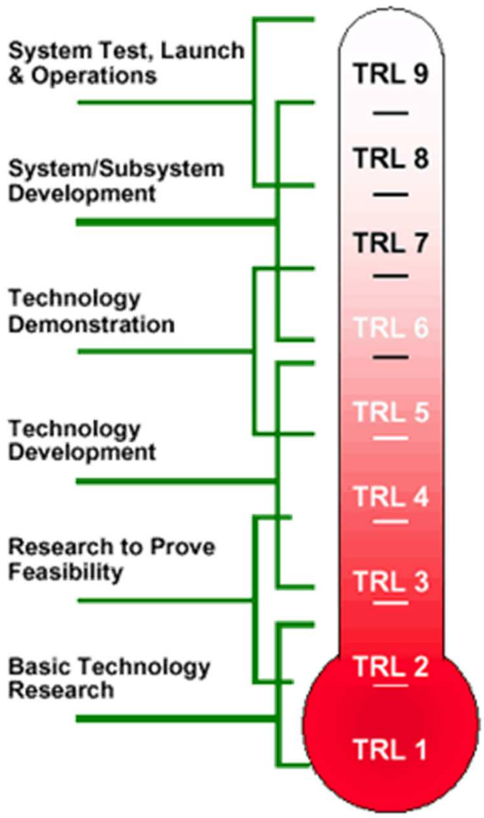

Figure 36: The TRL Scale as developed by NASA [14].

TRL concept has been expanded over the years in order to address also other risk fields, such as manufacturing readiness (MRL) or systems integration readiness, and even commercialisation readiness (CRL), etc. [15], [16], [17], [18], [19], [20], [21].

Technology readiness level (TRL) is a method of estimating technology maturity of Critical Technology Elements (CTE) of a program during the acquisition process. They are determined during a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities. TRLs are based on a scale from 1 to 9, with 9 being the most mature technology. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technology.

The assessment of the maturity of a technological product, either hardware or software, is a very complex process, mainly due to the specific characteristics that each of them often have. The tool that is used for this process is the TRL Calculator. A Technology Readiness Level

Calculator was developed by the United States Air Force [10]. This tool is a standard set of questions implemented in Microsoft Excel that produces a graphical display of the TRLs achieved. TRL calculators provide information about the maturity level of the technology in specific times of the project development. Once the questions are answered, the spreadsheets show the TRL achieved. Standardising these questions and grouping them into specific levels is what allows for a standardised, iterative process for generically evaluating the maturity of any technology product under development. The TRL scale itself does not contain any quantitative values, except for the TRL level number. The quantitative estimation of TRL levels is solved through the calculators, which provide quantitative estimates based on user responses to a number of YES/NO questions.

The degree of TRL of a service/function certainly depends on the stage of development it is in. For example, if a service is still in the development phase, the TRL degree can be between 2 and 4. The list below shows the levels and the description according to the European Commission [22]:

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

The European Association of Research and Technology Organisations (EARTO) [23] has published a detailed report about TRLs. Nowadays, TRL are globally harmonised due to the publication of the International Standard ISO 16290 in 2013 [24]. In any project like COREALIS where new technologies are intended to be used, or existing technologies are used in extended ways, it is important to understand the risks associated with technology maturity. TRL is one factor for the evaluation of risks due to technologies. Amongst the other factors, complexity is also an important one and gives a qualitative evaluation of risks versus TRL and complexity. TRL provide a commonly accepted structure for the assessment of such risks by setting criteria to be met for each level.

The original algorithm for quantifying the level of TRL (graphical form), developed by William Nolte 46 [10], used in these tools is shown in Figure 37.

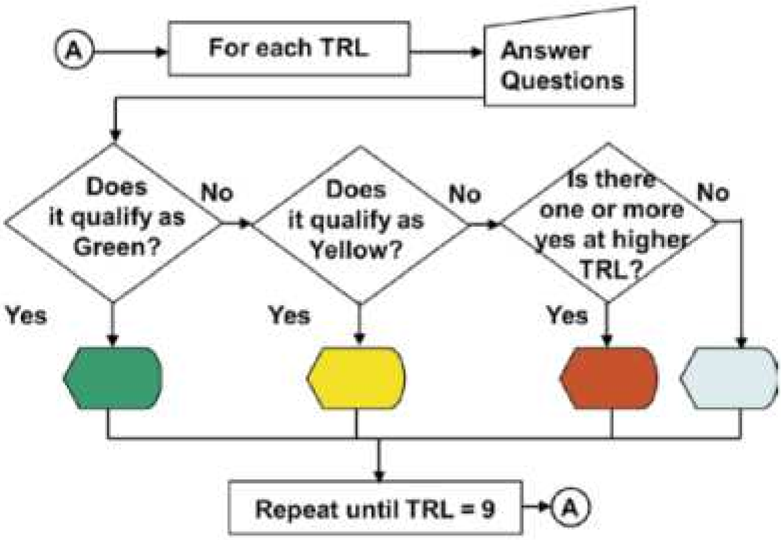

Figure 37: Algorithm for estimating the TRL level.

In COREALIS, the start and target TRLs for the main technological components are presented in Table 32, as well as the achieved TRL in 2021 during which the project ends:

Table 32: TRL development of the COREALIS innovations

Innovation	TRL in 2018	TRL target	TRL in 2021
Cloud Brokerage Platform	3	6	6
PREDICTOR Asset Management	3	6	8
IoT based TAS (Truck Appointment System)	4	7	8
Cargo Flow Optimiser	2	5	5
RT PORT	3	5	6
PORTMOD	3	5	5
Port of the Future Serious Game PoFSG	4	7	6

Cloud Brokerage Platform

The Cloud Brokerage Platform was demonstrated at the Port of Antwerp. The tests provided by the Port of Antwerp have proven its functional targets. Despite of the fact that big terminals like BASF or EVONIK have devoted to access the project in its course the Port and its stakeholders had realised this will challenging to test it in the pandemic times as well as the tools already adopted within the port servicing equipment for particular branches (trains, warehouse etc.). Having realized the potential of the platform companies have started to protect their businesses by keeping their equipment for themselves. The marketplace however has been also tested in several other environments i.e. company offices where they can exchange equipment within one company or multiple companies sharing the same location. These tests prove the target TRL6 reached.

PREDICTOR Asset Management

PREDICTOR Asset Management was demonstrated at Port of Piraeus. Even though the targeted TRL was the demonstration of the innovation in a relevant environment, the early stages of testing revealed that the predictive maintenance algorithm that was based on two years of historical data was performing above expectations. After a series of tests, PCT decided to focus on the prediction of fast-moving parts such as engine filters and tyres that would allow to reduce inventory storage space and achieve cost savings. Since November 2020, PREDICTOR has been used to predict maintenance schedules for the entire fleet of yard trucks of PCT thus successfully achieving TRL 8.

IoT based TAS (Truck Appointment System)

Truck Appointment System was demonstrated at Port of HaminaKotka and Port of Valencia. Even though the original plan was to achieve TRL 7 in both Living Labs, the extensive adoption of the innovation at the Port of HaminaKotka has initiated the process of implementing TAS in all five terminals of Steveco in Port of HaminaKotka and Port of Helsinki, thus successfully achieving TRL 8.

Cargo Flow Optimiser

Cargo Flow Optimiser has been validated at the Port of Antwerp and it has clearly achieved TRL 5. The prototype of the innovation has been validated using historical data form the Port of Antwerp and EUROSTAT in order to determine optimal route selection based on a number of parameters including TAT, cost and CO_2 emissions.

RT PORT

RTPORT was validated at the Port of Livorno and it has clearly achieved TRL 6. A 5G network has been deployed covering the designated part of the port yard where tests have been carried out.

PORTMOD

PORTMOD has clearly achieved TRL 5 and it has been validated at the Port of HaminaKotka and the Port of Livorno. Historical data of container movements of both terminals have been used to reveal optimal stack locations based on several what-if scenarios.

Port of the Future Serious Game PoFSG

The final version has been tested with existing users of the PoFSG (outside of the COREALIS consortium) with a positive result (final version, February 2020). The initial plan was to apply the PoFSG in the associated LLs in dedicated (live) demonstration workshops with LL stakeholders in the course of 2020, using the cause-and-effect physical cards of the game. However, due to the COVID-19 pandemic, these live demonstration and verification sessions were first postponed and later replaced by webinar sessions. The PoFSG was presented in the webinars of all five COREALIS LLs, i.e. Piraeus (June 4th, 2020), Livorno (June 19th, 2020), HaminaKotka (October 21st, 2020), Valencia (October 27th, 2020) and Antwerp (November 10th, 2020). Although these webinars allowed us to disseminate the final product to the COREALIS stakeholders, it was unfortunately not possible to integrate the PoFSG in the actual LL context thus limiting the achieved TRL level to 6 instead of the planned 7.

7. Conclusions

Despite the challenges caused by COVID-19 pandemic that arrived in Europe in February 2020, COREALIS innovations were successfully tested in the Living Labs with only minor modifications in the test plans.

The COREALIS innovations matured during the execution of the project from lower Technology Readiness Levels (TRL) to higher TRL in the end of the project, even more than it was anticipated in the Description of Action. The development work in the beginning of the project started between levels 2-4 depending on the innovation and reached levels 5-8 by the end of the project.

COREALIS innovations were tailored to realise the project four main objectives:

Objective 1. Embrace circular economy models in its port strategy and operations.

Objective 2. Reduce the port's total environmental footprint associated with intermodal connections and the surrounding urban environment for three major transport modes, road/truck, rail and inland waterways.

Objective 3. Improve operational efficiency, optimise yard capacity and streamline cargo flows without additional infrastructural investments.

Objective 4. Enable the port to take informed medium term and long-term strategic decisions and become an innovation hub of the local urban space.

All four objectives were either realised during the project or proved achievable by the means of COREALIS innovations. Since some innovations are more decision support tools, the final results are or course dependant on whether the actions are taken into use. The innovations used for the feasibility studies clearly indicated the achievable benefits.

The majority of the COREALIS innovations proved to be so useful and effective that Living Lab ports have decided or already started the deployment of the innovations after the project-related test period. Below, the description of how the innovations are planned to be utilised in the future is presented:

Cloud Brokerage Platform: Port of Antwerp does not have plans for future use of Brokerage Platform. Although the Port saw an opportunity to strengthen the collaboration between the different Community players, the assumption that a far-reaching cooperation and exchange of tools, equipment and people was possible turned out to be wrong.

PREDICTOR: Since November 2020, PREDICTOR has been used and verified for 10 fast moving spare part types and monitored for the entire spare parts range and the full yard truck fleet of PCT in Piraeus.

IoT based TAS (Truck Appointment System): Good results were achieved in the COREALIS innovation pilot and TAS is planned to be taken in use for general cargo trucks in Kotka Container Terminal and Hietanen terminals in Port of HaminaKotka before the end of COREALIS project, and in three other terminals during 2021-2022. In Valencia, there is no plan to use TAS in the port after the COREALIS project.

Cargo Flow Optimiser: The CFO built in the Antwerp LL is a prototype to investigate the usability of such a tool in a broader port community. As it was a prototype, it will not be used live 'in its current form' as built within the scope of the LL, but it will be further integrated within the Connectivity Platform that will be implemented within PoA.

RT PORT: CT Lorenzini in Livorno will assess the possibility to use this solution in their daily operations once COVID-19 pandemic is over; unfortunately, due to this issue, RTPORT was not possible to be fully tested. For this reason, CT still needs to assess this solution's capabilities in a real operational environment.

PORTMOD: In the beginning of year 2021, Steveco has gradually started to implement machine pooling in production use at HaminaKotka. PORTMOD FlowAnalyzer will be utilised in cost-benefit assessments. In Livorno, some tests were performed with the tool at the CT Lorenzini (FlowAnalyzer and CT's layout implications). In the future, the intention is to explore the possibility to use the tool in another context (another Container Terminal from Livorno seaport), so that the tool's capabilities could be exploited similarly as for the case of HaminaKotka.

Port of the Future Serious Game PoFSG: Due to COVID-19, the software could not be fully tested. Once the pandemic is over, at least Port of Livorno is considering the possibility to arrange a PoFSG session with stakeholders from the port community so that PoFSG capabilities can be assessed.

JIT Rail Shuttle: Just-In-Time Rail Shuttle service is not going to be implemented in the Port of Valencia in the short term.

Hackathon (Innovation Incubator): Valencia Port is planning to repeat the hackathon in 2021. It would preferred to be conducted as a face-to-face event, but it can also be online if COVID-19 is still limiting the events organisation.

Green Cookbook: The Green Cookbook is merely a feasibility study with potential results not tested neither validated. PCT will use it as input for the Master Plan of the port development, but no investment is currently planned in this area.

The transferability of the COREALIS project and individual innovations has been analysed using the PoF TA methodology. This analysis shows:

- (Alignment of) the priorities of the innovations and Living Labs with respect to the external programs. UNSDG, WPSP, AIVP, PoF Topics and PoF HLSO. All innovations are aligned to at least some programs, which is logical given the broad nature of a Living Lab and a more targeted nature of an innovation. These priorities can be used to identify relevant targets for deployment of the COREALIS innovations.
- The USPs of COREALIS and the PoF Tactical Objectives and DtF Measures that are widely targeted. These USPs can be used to better frame the message when targeting other ports for deployment.
- The innovativeness of COREALIS measured using the PCI-score. COREALIS' scores range from 1 to 5 with the consolidated score being 3.1. This shows that the innovations are well aligned with needs of ports and a potential market.

- The relevancy of the innovations of COREALIS measured with the Consolidated Objectives Score. COREALIS scores 4.26 on a scale ranging to 5 meaning the relevancy of the COREALIS project is high.
- The transferability of the COREALIS innovations measured using the TA-score. COREALIS' scores range from 2 to 5 with a consolidated score of 3.4. This shows that the innovations are becoming mature from being implemented in a single environment towards wider deployment.

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Annex 1: Full lists of goals, focus areas, goals, strategical/tactical objectives and measures

Program	Goal / focus area / goal / topic / objective
UN Sustainable Development Goals	01 No poverty
	02 Zero Hunger
	03 Good health and well-being
	04 Quality education
	05 Gender equality
	06 Clean water and sanitation
	07 Affordable and clean energy
	08 Decent work and economic growth
	09 Industry innovation and infrastructure
	10 Reduced inequalities
	11 Sustainable cities and communities
	12 Responsible consumption and production
	13 Climate action
	14 Life below water
	15 Life on land
	16 Peace, justice and strong institutions
	17 Partnerships for the goals
WPSP Focus Areas	1 Sustainability
	2 Port-City relationship
	3 Governance & ethics
	4 Resilient infrastructure
	5 Safety & Security
AIVP Agenda 2030 goals	01 | Climate Change Adaptation
	02 | Energy Transition & Circular Economy
	03 | Sustainable Mobility
	04 | Renewed Governance
	05 | Investing In Human Capital
	06 | Port Culture & Identity
	07 | Quality Food For All
	08 | Port City Interface
	09 | Health & Life Quality
	10 | Protecting Biodiversity

Program	Goal / focus area / goal / topic / objective
PoF topics	To improve the energy efficiency at ports
	To transit from fossil/based economy to bio-based economy
	To Increase the portion of renewable energy in port
	To promote green infrastructure at ports
	To provide systematic incentives for clean ships
	To deploy alternative transport fuels
	To have transition towards circular economy
	To transform the port governance into stakeholder management
	To set up community outreach
	To strengthen city-port relations
	To promote spatial planning
	To promote the public awareness and port culture
	To publish annual port sustainability report
	To increase the share of nature areas in ports
	To reduce / mitigate the externalities of port operations
	To improve employment conditions in the port
	To enhance the skills and education of port labour
	To transit towards Transparency and integrity in policy
	To have policies with equal rights and opportunities
	To set fair trade regulations for ports or by ports
	To put anti-corruption regulations
	To establish a Governance towards responsible supply chains
	To consider resilience in port planning and design
	To encourage port project financing and investments
	To have effective public-private partnerships
	To transit towards digitization and automation in port activities
	To have working with nature
	To take adaptive measures for climate resilience
	To put in place ecosystems management
	To establish cyber-security for port data network and platforms
	To optimise protection of critical infrastructure
	To comply with ISPS code
	To improve nautical safety
	To enhance the port labour safety
	To set responsible care Safety and Security

Program	Goal / focus area / goal / topic / objective
PoF High level Strategic Objectives	1 sus SDG 12.00.0 Save natural resources
	1 sus SDG 13.00.0 Combat global warming
	2 p&c SDG 08.05.0 Good jobs (SDG 8.5)
	2 p&c SDG 11.03.1 Land consumption
	2 p&c SDG 11.03.2 Inclusive cities
	2 p&c SDG 11.06.0 Improve environmental quality
	3 gov SDG 05.05.0 Gender equality
	3 gov SDG 10.03.0 Equal opportunity
	3 gov SDG 15.09.0 Green governance
	3 gov SDG 16.05.0 Restrict corruption
	3 gov SDG 16.06.0 Transparency
	4 res SDG 08.01.0 Economic growth
	4 res SDG 08.02.0 Higher productivity
	4 res SDG 09.01.0 Resilient infrastructure
	4 res SDG 13.02.0 Account for resilience
	5 s&s SDG 08.08.0 Safe working conditions
	5 s&s SDG 16.01.0 Reduce crime

ID	PoF Tactical objective
TO010	Increase terminal productivity
TO020	Improve design and maintenance of the port infrastructure to increase overall resilience
TO030	Sustainable maintenance, repair and reconfiguration
TO040	Increase efficiency and capacity of hinterland connections
TO050	Realise the TEN-T infrastructure network
TO060	Implementation of the TEN-T Core Network Corridors
TO070	Work Plans for Ports and of the Motorways of the Sea Detailed Implementation Plan
TO080	Improve smart traffic and mobility management inbound / outbound.
TO090	Improve digital support for route efficiency Sea Traffic Management
TO100	Improve modal shift
TO110	Increase efficiency and capacity of hinterland connections
TO120	Multi-modal optimised cost-effective and flexible operations inside the terminal and in the wider port area
TO130	Develop a synchro-modal transport system
TO140	Realize LNG Infrastructure
TO150	Stimulate the use of bio-fuels
TO160	Increase the use of cold ironing electrification
TO170	Use of solar power
TO180	Emission reductions
TO190	TO190: Define environmental thresholds

TO200	Energy transition towards new energy store facilities
TO210	Optimise renewable energy use including smart grids
TO220	Increase efficiency in industrial processes
TO230	Create innovative energy storage systems
TO240	Support circular economy schemes
TO250	Develop innovations for increasing sustainability in all transport modes
TO260	Harmonise safety regime
TO270	Increase resilience against climate change
TO280	Increase resilience against and terrorism
TO290	Optimise and digitalise the logistic chain sharing data between all stakeholders in secure way, with usage of IT data security technology from other sectors.
TO300	Harmonisation of ports processes and of the related data exchange
TO310	Identification of real-time indicators to improve the quality of services provided.
TO320	Harmonisation of port services
TO330	Encourage harmonised data sharing.
TO340	ICT and communication: data sharing between all stakeholders including G2B (gov. to business), roadmap to fully deploy reporting directives further (waste reporting, SECA reporting, …)
TO350	Realise uniform systems on all European rail and waterways close to ports
TO360	Advanced and efficient links and integration in the socio-economic industrial and urban surrounding environment
TO370	Improve the quality of public space in the port
TO380	Improved integrated port and city common development planning
TO390	Improve recreational facilities in the port surrounding
TO400	Organise events to introduce the port to young people
TO410	Develop tailor human resources management to the age of workers
TO420	Monitor and forecast the development of port labour market
TO430	Improve the visibility of port related business in the education
TO440	Develop harmonised professional and vocational training packages
TO450	Increase harmonization between EU and non EU ports in terms of common approach to the Port of the Future Topics
TO460	Develop and efficient links between TENT network and non EU transport networks
TO470	Develop transferability mechanisms to facilitate the application of H2020 results in CEF projects

ID	DtF Measure
MS0010	AEO
MS0020	Alternative fuels
MS0030	Ballast water management system
MS0040	Beacons
MS0050	Big data
MS0060	Blockchain
MS0070	Cargo logistics system in urban areas
MS0080	Clearance procedures, cargo clearance procedures for short sea services
MS0090	Collaborative network of ICT platforms

MS0100	Consolidation of cargo
MS0110	Cranes Outreach of container gantry cranes
MS0120	Create innovative energy storage systems
MS0130	Customs and phytosanitary controls, customs fast corridors
MS0140	Cyber security. Industry guidelines for cyber security on board vessels. Adequate training on how to respond to cyber security incidents
MS0150	Develop dynamic lighting for ports and terminals;
MS0151	LED lighting
MS0160	Developing governance structure
MS0170	Digital Corridor Information Management Systems
MS0180	e-Learning tools on MSP
MS0190	Electrical charging stations in the ports
MS0200	e-Manifest
MS0210	Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP)
MS0220	Environmental compensation measures
MS0230	e-Seals
MS0240	e-Signature
MS0250	Flow management services
MS0260	Fuel types (new)
MS0270	Funding and financing: Encouraging financing actions, European Ship Plan, Joint Industry Plan, multi financing platforms, financial blending, financing the environmental part of the investment, Eco bonus (incentive for transport buyer) to use climate efficient sea alternatives
MS0280	Gates
MS0290	Global Navigation Satellite System (GNSS) to improve positioning at sea
MS0300	Harmonization of administrative procedures
MS0310	Harmonization of taxes on clean fuel
MS0320	Higher co-funding rates for outermost regions and islands, EIB new financial instruments, EFSI, Project Bond Initiative, Public private partnerships
MS0330	Hub for bunkering in Scandinavia
MS0340	Hydrogen
MS0350	Hydrographic information, Hydrographic surveys
MS0360	Ice breaking capabilities (develop)
MS0370	Incentives for off-peak traffic
MS0380	Information sharing platforms
MS0390	Inspections (Appointment systems for all inspections)
MS0400	IOT, Internet of things
MS0410	ITS
MS0420	Knowledge networks (creation of, investment in)
MS0430	Legislation for a common framework for maritime spatial planning
MS0440	LNG bunkering, supply and distribution chain
MS0450	Maritime simulator networks
MS0460	Maritime spatial planning
MS0470	Methanol
MS0480	Mobile (Use of mobile technologies and apps)

MS0490	Off shore wind farms
MS0500	Offload black and grey water in tanker trucks and barges
MS0510	Offshore renewable energy
MS0520	On shore power supply
MS0530	Optical character recognition
MS0540	Optimise and digitalise the logistic chain
MS0550	Optimise renewable energy use including smart grids
MS0560	Places of refuge
MS0570	Port Collaborative Decision Making
MS0580	Port ship interface
MS0590	Processes, integration of business processes
MS0600	Reefers, Refrigerated cargo, reefer block trains
MS0610	Re-fuelling (barges, facilities)
MS0620	Reliable online real-time information
MS0630	RIS
MS0640	Robotics, autonomous ground vehicle
MS0650	Route planning: Optimizing routing with the support of digital systems, standards for route exchange, Application services such as route optimisation services
MS0660	RTMS
MS0670	Safe procedures for shore power supply
MS0680	Safety data sheet for handling scrubber additives and chemicals
MS0690	Safety training
MS0700	Scanners, new scanning technologies
MS0710	Scrubbers, closed loop scrubbers
MS0720	Seals for containers
MS0730	Sewage water. Facilities available in ports for receiving sewage waters
MS0740	Sharing data about accidents and incidents
MS0750	Ship building (Standardization of the construction process of new ships and ship equipment)
MS0760	Ship to shore information exchange
MS0770	Shore supply, cold ironing, Universal standard for shore supply is
MS0780	Single window, single window for trade and transport, exchange of data with public authorities
MS0790	Situational awareness
MS0800	Support services such as authentication, authorization and service discovery
MS0810	System Wide Information Management (SeaSWIM) Data sharing in the maritime cloud
MS0820	Technological innovations: scanners, weighbridges, tracking technology, sensors
MS0830	Track and trace. Automated vessel tracking services to retain community status of goods
MS0840	Trade facilitation
MS0850	Traffic management using new technologies including digitalisation can reduce the risk of grounding and collision
MS0860	Training schemes, Educational and professional training, Adequate training on how to respond to cyber security incidents, dedicated training for personnel handling migrants search and rescue

MS0870	Truck appointment systems
MS0880	Upgrade VTMS system
MS0890	Voyage management services, voyage planning
MS0900	VTMS systems contribute to safer navigation, efficient traffic flow, protection of the environment
MS0910	VTS systems: VHF, AIS, radar, CCTV
MS0920	Waste water reception facilities
MS0930	Wave Energy systems
MS0940	Weighbridges
MS0950	Wind energy systems
MS0960	High pressure steam networks
MS0970	Pipelines
MS0980	Cycling infrastructure
MS0990	Public and collective transport, bus lanes
MS1000	Water bus
MS1010	Empty container management
MS1020	Air emission charts
MS1030	Noise level maps
MS1040	Energy management system
MS1050	Energy recovery from sea locks
MS1060	Augmented reality
MS1070	Machine learning
MS1080	Drones
MS1090	Carbon storage and recovery systems

Annex 2: Potential Contribution to Innovation score

Score	Potential Contribution to Innovation	Description of the score
PCI-1	No innovation	The project implements existing technology.
PCI-2	Low innovation	The project innovates by adapting existing technologies to become more accessible.
PCI-3	Improvements	The project improves a current solution.
PCI-4	Adaption for transferability	The project adapts a solution or technology to enable it to be transferred (to other sectors).
PCI-5	New concepts	A completely new (cross-sector) solution is being created

Annex 3: Full list of KPIs from the PCI-Tool

	KPI	Unit
1 Sustainability (Climate and Energy)		
	Reduction or compensation of port-related CO_2 equivalents emissions/year	tons (equivalent units)
	Waste reduction/year • Dredging material • Waste (plastic + general)	Aggregated: • m^3 • tons
	Fresh water saved	litres
2 Port-City relationships		
	To which extent does this action foster the port acceptance in terms of the port-city dialogue?	score, no unit
	Former port area dedicated to alternative urban use	m^2
	Reduction of emissions in port: • noise: reduction of noise emissions • air: reduction of air emissions • water: reduction in water pollution as change in additional, effective emissions	Aggregated: • dB/period/persons/km^2 • kg/particle type • score, no unit
	To which extent does this action promote the income development in port-related jobs?	score, no unit
3 Governance and ethics		
	To which extent does this action contribute to transparency in port governance?	score, no unit
	To which extent does this action promote and increase the share of women in upper management of port-based enterprises? To which extent does this action promote and increase the overall share of women in port-based enterprises?	score, no unit
	Does this action reduce direct or implicit obstacles for third party operators? (beyond respective applicable legislation only)	score, no unit
	To which extent does this action contribute to the goal of fighting corruption?	score, no unit
	Is this action linked to fulfilling all requirements for a classification according to ISO 14001?	score, no unit
4 Resilient infrastructure		
	Growth in port's throughput capacities due to new constructions or constructional or organizational optimizations	TEU
	Savings of optimizations due to digitization and automation in port activities	€ / year
	To which extent does this action improve the infrastructure's resilience regarding the threats of climate change?	score, no unit

	KPI	Unit
5 Safety and Security		
	To which extent does this action prevent the harmful consequences of criminal and terroristic actions?	score, no unit
	To which extent does this action prevent the harmful consequences of criminal and terroristic actions?	score, no unit

Annex 4: Proof-of-Transferability score

Score	Potential Contribution to Transferability	Definition of transferability contribution
TA-1	ZERO-weight	Transferability NOT measured: project has an innovative aspect, but is only applied to a single port, OR similar solution(s) already implemented in other ports AND/OR has no horizontal applicability (no efforts undertaken to peering the solution in other ports – by either donor or adaptor port(s))
TA-2	LOW	No to low support or high constraint for transferability: project supports an innovative aspect, is applicable to other potential ports identified, but no barriers/constraints considered or investigated for implementation in other ports OR barriers/constraints for transferability have identified impossibility or high risk to apply solution in other ports
TA-3	MEDIUM	Modest support for transferability: project supports an innovative aspect, is applicable to targeted ports, has identified constraints/barriers and suggested resolutions, but NO peered resources to implement the solution in other ports
TA-4	HIGH	Limited potential for transferability: project supports an innovative aspect, is applicable at some (1 to 4) targeted ports, has identified constraints/barriers and suggested resolutions, AND has peered resources across a minimum of 3 ports to implement the solution (simultaneous project through port peering and/or assistance in transfer from donor to adaptor port(s))
TA-5	STRONG	Wide support for transferability: project supports an innovative aspect, is applicable at multiple targeted ports (5 or more), has identified constraints/barriers and suggested resolutions and risk management provisions established AND has peered resources across many ports (3 or more) to implement the solution(simultaneous project through port peering and/or assistance in transfer from donor to adaptor port(s)