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

COREALIS
THE PORT OF THE FUTURE

D.6.1: Impact assessment methodology for technical, operational, environmental and societal impacts and list of KPIs

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List of Acronyms

Abbreviation / acronym	Description
CFO	Cargo Flow Optimizer
CO2	Carbon Dioxide
CT	Container Terminal
D1.1	Deliverable number 1 belonging to WP 1
DoA	Description of Action
EC	European Commission
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
ETA	Estimated Time of Arrival
FEEM	Fondazione Eni Enrico Mattei
IAIA	International Association for Impact Assessment
ICT	Information, Communication Technology
JIT	Just-In-Time
KPI	Key Performance Indicator
LL	Living Lab
PCS	Port Community System
PoFSG	Port of the Future Serious Game
SDG	Sustainable Development Goal
SDG-SP	Sustainable Development Goals and Smart Port
SDSN	Sustainable Development Solutions Network
SP	Smart Port
STS	Ship-To-Ship
TAS	Truck Appointment System
TEU	Twenty-foot container Equivalent Unit
TOS	Terminal Operating System
UN	United Nations
UN SDG	United Nations Sustainable Development Goals
UN SDSN	United Nations Sustainable Development Solutions Network
WP	Work Package

Executive Summary

COREALIS proposes a strategic, innovative framework, supported by disruptive technologies, including Internet of Things (IoT), data analytics, next generation traffic management and emerging 5G networks, for cargo ports to handle upcoming and future capacity, traffic, efficiency and environmental challenges. It respects the limitations that many European ports are facing concerning the port land, intermodal infrastructure and terminal operation. It proposes beyond state of the art innovations that will increase efficiency and optimize land-use, while being financially viable, respecting circular economy principles and being of service to the urban environment. Through COREALIS, ports will minimize their environmental footprint to the city, they will decrease disturbance to local population through a significant reduction in the congestion around the port. They will also be a pillar of economic development and business innovation, promoting local start-ups in disruptive technologies of mutual interest. COREALIS innovations are key both for the major deep sea European ports in view of the mega-vessel era, but also relevant for medium sized ports with limited investment funds for infrastructure and automation.

The purpose of the D6.1 "*Impact assessment methodology for technical, operational, environmental and societal impacts and list of KPIs*" is to provide an overview of the evaluation methods used to assess the operational, technical and social impact of COREALIS innovations. Additionally, it describes the scenarios of each living lab and the relative operational, technical, environmental and social KPIs, giving the current baseline and setting the result target.

The reader of the document should gain an understanding of the methodologies followed to measure the impact of COREALIS innovations as well as the extend of the tests that will take place. Test scenarios are described for each one of the projects living lab sites and relative KPIs are given.

Section 1 of the deliverable describes the purpose of the document, the intended readership and the relation of the current deliverable with other COREALIS deliverables completed so far.

Section 2 of the deliverable describes the impact assessment framework addressing it around three main pillars, in order to ensure that the measurable objectives of the project and the corresponding expected impact is achieved. The three evaluation pillars are i) Operational and

Technical assessment ii) Impact Assessment to future port and supply chain operations and to the environment/climate and iii) Societal Impact Assessment within a port-city context.

Section 3 lists the Key Performance Indicators for COREALIS Innovations. Performance indicators can be quantitative or qualitative indicators, can be derived from one or several measures, and they can be expressed as a ratio, percentage, index or other value. COREALIS KPIs are categorized in accordance to the evaluation pillars of the project.

Finally, Section 4 describes the list of test scenarios per living lab, sets the research hypotheses for each one and lists the relative KPIs and targets per case.

1. Introduction

Deliverable D6.1 introduces the work carried out in Task 6.1, which aims at defining the evaluation methodology and collect, consolidate and document the metrics and Key Performance Indicators (KPIs) to evaluate (within T6.2-T6.5) the COREALIS innovations demonstrated in the LLs.

KPIs will be driven by the measurable objectives of COREALIS. The KPIs will include ones of a technical and operational nature relevant to the COREALIS high-level objectives (i.e. move to the circular economy, improvement of multimodality, increase of the CT efficiency and capacity); moreover, the KPIs set will comprise environmental and climate-change related indicators and indicators for measuring the societal impact for the port personnel, the surrounding urban area residents and city authorities.

1.1 Purpose of the Document

The purpose of this document is to present and discuss the methodology for the technical, operational, environmental and societal impact assessment in the project. In addition, it aims to further refine and categorise specific metrics and KPIs for the assessment of the impacts spanning all COREALIS LLs.

1.2 Intended readership

The deliverable is addressed to any interested reader since the document's dissemination level is public. The work presented in this document addresses the needs of the COREALIS consortium including both technical and non-technical partners who will have a reference on the operational, environmental and societal impact of the COREALIS technologies.

1.3 Relation with other COREALIS deliverables

This deliverable is linked to Deliverables D5.1-D5.5 Scoping Documents of WP5. These deliverables include the final versions of the LL chosen scenarios and document the technical specs for innovations implemented within each LL.

2. COREALIS Impact Assessment Framework

2.1 Operational and Technical Assessment

The impact assessment methodology of COREALIS is addressed around three main pillars, in order to ensure that the measurable objectives of the project and the corresponding expected impact is achieved. This includes i) Operational and Technical assessment ii) Impact Assessment to future port and supply chain operations and to the environment/climate and iii) Societal Impact Assessment within a port-city context.

The overall evaluation framework of COREALIS is presented in the following figure:

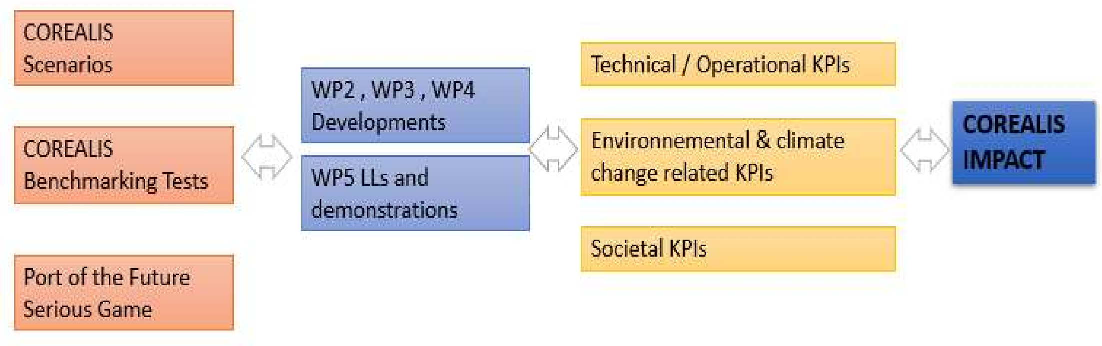

Figure 1: COREALIS Impact Assessment Framework

The COREALIS scenarios developed in T1.3 as well as the benchmarking tests defined in T6.2, will be driving the validation phases of the user/system requirements as well as the technical, operational and environmental impact assessment. Furthermore, the PoFSG in accordance with desk research methods will be the main tool to validate the societal impact as it is described in the section 2.3. Finally, the complete list of KPIs is associated and validated against the expected COREALIS Impact as it is described in the part B of the DoA.

2.1 Operational and Technical Assessment

The aim is to technically evaluate the deployment of innovations across all 5 LLs within the third phase of the LLs. Benchmarking tests per innovation and per LL shall be defined with reference to specifications within the scoping documents of WP5 and the technical KPIs documented in this deliverable. The tests will be run and measured using existing port IT infrastructure and legacy systems to the extent possible in order to ensure that they are interoperable with the former and that innovations have been properly integrated to the port operations.

Operational and capacity/efficiency improvements will be measured using the defined tests directly on the port IT systems such as their PCS/TOS and ERP or other asset management solution so that the direct benefits to their daily operations may be assessed. The evaluation will include datasets from the deployment of components in a period of 7 months (M25-M31), so that the improvement may be profiled and assessed for different periods and cargo volumes.

2.1.1 Description of Methodology

The validation of the Technical and Operational components of COREALIS is based on the initial list of scenarios that were created in T1.3. Based on these scenarios it is developed a methodology to ensure that the User requirements , are mapped to the system requirements as it is seen in the scoping documents developed in WP5 and consequently the tests performed correspond to the expected KPIs , that will be developed in this deliverable .

More specifically, the starting point is represented by the User Requirements collected within the D1.3 – Port of The Future Needs and Requirements. It has been possible to extract and define the System Requirements for each scenario to be implemented in all Living Labs. System Requirements can be discriminated based on their priority (MUST/SHOULD) and first, the focus on functional testing for MUST requirements for the alpha versions will be considered. Then, even non-functional testing will be performed in order to achieve the expected behaviour of the specific non-functional system requirement.

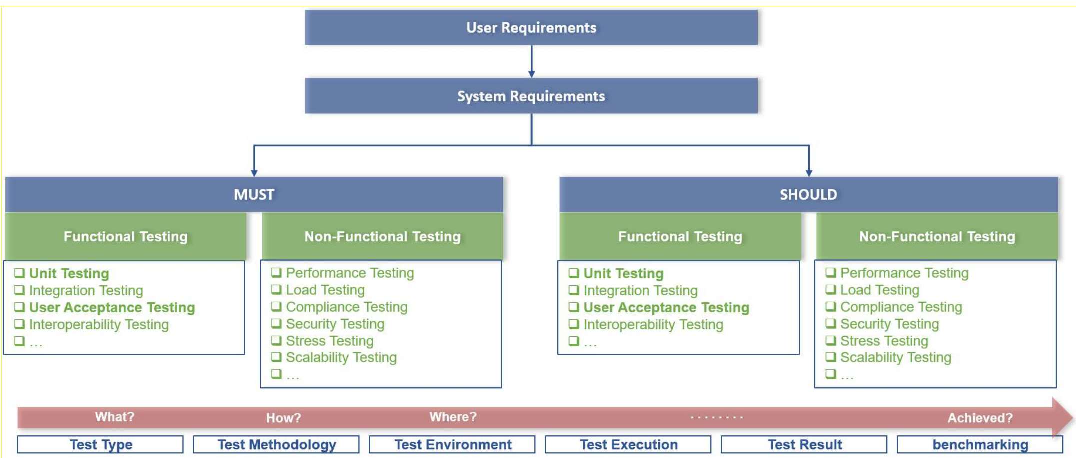

Figure 2: Benchmarking Methodology

The whole benchmarking methodology (shown in the figure above), could be described following the bullet points below:

1. For each requirement it is necessary to identify the type of test to be executed (Functional or Non Functional). Functional Tests will be executed before the Non Functional Tests, since they are related to the functional aspects of the requirement. Examples of Functional Testing could be: unit testing, integration testing, user acceptance testing, interoperability testing, and so on. For the case of Non-Functional Testing we could consider: performance testing, load testing, compliance testing, security testing, etc.

2. Once the type of test has been identified, the methodology for the specific test to be performed will be defined for each scenario (it depends on the context since the same test could be executed in different ways). This methodology will allow to define how the specific test will be executed. Depends on the scenario, but in any case the methodology could be both automatic (using specific tool) or manual (ad-hoc setup).

3. Once the methodology has been defined, the relative environment in which the specific test is expected to be executed will be specified as well. The tests will be run and measured using existing port IT infrastructure and legacy systems to the extent possible in order to ensure that they are interoperable with the former and that innovations have been properly integrated to the port operations.

4. The test is performed with the specific result that will allow to execute the benchmarking analysis using the description of the specific system requirement as a reference metric. The tests' results will be collected into a specific Performance Report, shown below:

Test Scenario ID	
Test case description	*A small description of the test case*
Input to the system	*What will be the input to the system to test the use case , reference to the persona that may trigger/involved in the test case is expected*
Output of the system	*What will be the response of the system ? Please specify the expected output in order to be compared with the output of the system during the test*
System requirements covered	*Provide the list of system requirements that are covered by the test scenario*
Success Criteria	*Which are the success criteria of the use case ? It can be used when the expected output field can't be predicted*
KPIs	*Reference to the relevant KPIs of the test case .*

Figure 3: Test Scenario Template

5. After this first phase, it will be necessary to proceed with the technical assessment (second phase) to be performed on the definitive KPIs list for each Living Lab, in order to assess whether they have been achieved or not. This will be done by the M24, as expected by the project (figure below).

Figure 4: Opeational & Technical Assessment Plan

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

This task quantifies the impact of applying the project innovations to (i) port terminal internal operations, (ii) seamless cargo transport from ocean to truck/rail/barge and vice-versa, (iii) 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 impact assessment regarding emissions and environmental footprint and the climate change impact will consider existing comprehensive emissions databases, e.g. Lipasto (lipasto.vtt.fi) database from VTT and will use PoFSG scenario building capacity and established impact assessment tools for climate change for benchmarking, e.g. the free

CLIMSAVE Integrated Assessment Platform, adapted to the port-city environment and out-scoping domains not relevant (eg. agriculture).

2.2.1 Description of Methodology

In order to evaluate the effect on COREALIS innovations to the environment and climate, it is necessary to know the current situation. This requires the knowledge of the following information of the current vehicles or equipment in use:

- Equipment type (truck, forklift, straddle carrier, crane);
- Usage time;
- Driven kilometers;
- Fuel type (diesel, electricity, other);
- Fuel/electricity consumption in different situations (in work, lifting, idle, other), or at least total amount of fuel used in current operations.

In addition, if possible, the following information will improve the impact assessment:

- Euroclass of vehicle, or other information about the emissions;

The more information is available, the better is. To calculate the environmental impact, there is a need to know the effect of COREALIS innovations to the port and supply chain operations. The following information is needed:

- Change of equipment type in a situation when e.g. diesel-driven equipment are changed to electricity-driven equipment or equipment is replaced by another type of equipment;
- Changed usage time (or number of changed vehicles/equipment);
- Change of driven kilometers;
- If vessel turnaround time can be decreased, then the information (size, type) about the vessel and saved time.

The main result of environmental impact assessment is the information about the amount of decreased CO2 emission (in figure and in percentage). The calculations are made by using the information in LIPASTO database as a basis. The database does not include all the port equipment, but it is possible to find equipment that have e.g. similar fuel consumption. When the fuel consumption and type is known, it is possible to calculate CO2 emissions. Additional information about the emissions (e.g. equipment’s Euroclass) will enable the calculation of other forms of emissions.

2.3 Societal Impact Assessment within a port-city context

This task aims to act 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. Assessing the societal impact is in general more complex and less tangible than evaluating operational and environmental aspects.

A combination of methods shall be used, both participatory and desk-based, such as tree-diagrams analysis, adopted into the project context from recommended guidelines/handbooks of recognised stakeholders, as is the International Association for Impact Assessment (IAIA) and enriched with aspects identified in ERICSSON's Networked Society strategy .

The participatory tools used for this assessment will go beyond traditional methods of questionnaire-based evaluations which are usually rigid, one-directional and sometimes tedious to participants; rather, the PoFSG tool and the gamification strategy it entails will support the evaluation; this process shall be materialised during the COREALIS final event held in M30.

The defined societal impact related KPIs will be fed to the PoFSG and conclusions will be drawn from members of the stakeholder community regarding societal impacts to individuals. This way, the assessment will stem from rewarding participation; instead of serving as passive endpoints in the supply chain, individuals will contribute with valuable perspectives.

2.3.1 Description of Methodology

The "Sustainable Development Goals and Smart Port" model ("SDG-SP Model") aims at assessing the relationship between the smart port, as empowered by 5G networks and related applications, and the nearby area (hinterland + urban area) in terms of contribution to the UN Sustainable Development Goals (SGDs) of the 2030 Agenda. The model and the related KPIs, which are currently under development, will be validated thanks to the concrete use case provided by COREALIS activities within the living hub in the port of Livorno.

The development of this evaluation model relies on the expertise of the Livorno Port Authority, which is currently developing a "Smart Port Sustainability Index" to integrate the set of traditional KPIs (e.g. dwell time, transit time, etc.) with innovative performance indicators, by considering technology as the main lever for the sustainable and innovative development of the port.

The development of the “SDG-SP Model” is being conducted since October 2018 by a joint effort of CNIT, Livorno Port Authority and Fondazione Eni Enrico Mattei (FEEM), according to their specific responsibilities. As UN SDSN Italy branch, FEEM has been engaged by Ericsson in order to leverage on their expertise and research.

As a first step, the Livorno Port Authority has identified the port operational priority areas expected to be positively affected by the digital transformation to ensure that the model and its specific KPIs is set on the local needs of the port.

Ericsson and CNIT supported the Livorno Port Authority in the identification of the port application areas of interest due to their expertise in the ICT field. They provided a technology description and qualitative analysis of 5G technologies and relative applications (Augmented Reality/Mixed Reality, Artificial Intelligence, Internet of Things) which are relevant in terms of impact on port operational activities and integrated logistics.

FEEM relies on a deep knowledge of the UN SDGs at a global level and a well-established understanding of the related Italian sustainability strategy and agenda. Furthermore, it has recently performed a SDGs analysis declined at urban level. Drawing inspiration from such experience, FEEM intersected the international and local perspectives to support the joint identification of the specific SDGs which are positively impacted by digital transformation of the port through 5G networks and advanced ICT technologies within urban local dimension.

Prospected SDGs so far are set on different levels according to potential relevance for the Port Authority in the context of smart port empowered by 5G technologies. The most relevant SDG is that related to “Industry, Innovation and Infrastructure” (SDG 9), followed by “Growth and Decent Jobs” (SDG8), “Sustainable Cities and Communities” (SDG 11), “Responsible Consumption and Production” (SDG 12), “Climate Change” (SDG 13) and “Life below water”; lastly, “Quality Education” (SDG 4). Of course, the enabling approach reflects the “Partnership for the Goals” (SDG 17) as the overall success of this initiative relies on a cross-sectoral collaboration of different public and private stakeholders committed to accelerate sustainable progress within society. The SDGs and the specific targets addressed by the model will be detailed within the analysis process and will serve as the basis to set the Key Performance Indicators per each port application area (Livorno Port Authority and FEEM as the main drivers, Ericsson and CNIT validating in a second phase). Then, the “SDG-SP Model” will leverage on the COREALIS pilot phase with innovative logistic use cases enabled by 5G in the port of Livorno. The forecast analysis of data from real tests within the COREALIS demo pilot will set the basis for the estimation of 5G potential with respect to port performance, as well as in terms of contribution of the port system to the SDGs at local level.

The expected impact of the “SDG-SP Model” is represented by the qualitative and possibly quantitative facts and figures about how the digital transformation of port operational activities through 5G technologies contribute to the achievement of the identified needs of the Port Authorities, as well as to the societal needs and opportunities. The “SDG-SP” model is intended to be a general system of policy advise in the areas of digital transformation and integrated logistics within the port, with a set of modular KPIs that can be referred to different contexts. Furthermore, it serves as a tool for the local understanding and integration of SDGs within territorial sustainability and innovation strategies. This methodological approach may be of interest to different public stakeholders in the fields of logistics integration and optimization, smart community and city models, who are looking for an integrated approach to promote an inclusive and sustainable development. The proof point provided by the “COREALIS case study” will represent a best practice, as well as a reference to all ports within Italy, Europe and across the world.

A White Paper will illustrate both the model and the results to all relevant stakeholders. Further communication and dissemination activities will be conducted according to each partners’ responsibility and stakeholders’ engagement needs, as well as on the basis of arising opportunities and interests within public and private upcoming initiatives. The introduction of this model within the public discussion may increase awareness around the UN Sustainable Development Goals, as well as it may lead to further improvements in the commitment of public and private stakeholders to sustainable development by means of integrated strategies at territorial level.

3. Key Performance Indicators (KPIs)

Choosing the appropriate performance indicators during the process of developing hypotheses is of vital importance for the success of the project. These indicators will aim to answer the hypothesis within the budget, time and other limitations (FESTA Handbook, 2016).

Performance indicators can be quantitative or qualitative indicators, can be derived from one or several measures, and they can be expressed as a ratio, percentage, index or other value. KPIs are used to evaluate the performance of a company and can be compared with previous periods, other industry companies or even individual competitors (Krauth et al., 2005). These indicators are monitored on a regular basis, in order to prove the difference between the proposed solutions compared to the baseline scenario. There are numerous possible KPIs for the expected impacts of all Living Labs, associated however with uncertainty in relation to their implementation feasibility prior the actual execution of the LL activities.

The list of KPIs which can be used in order to assess the implementation of the Living Labs are shown in Tables 1,2 and 3.

3.1 Operational/technical KPIs

Table 1: List of Operational/technical KPIs per LL

List of operational/technical KPIs per LL	
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.
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 CO2 reduction of rail compared to truck on the requests performed with the multimodal inland planner.
	Percentage of CO2 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
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.
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 tyres.

3.2 Environmental & climate change related KPIs

Table 2: List of Environmental KPIs per LL

List of environmental KPIs per LL	
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).
Piraeus LL	Energy consumption percentage that can be replaced by renewable energy sources.
	Measure overall and per crane power consumption.

3.3 Societal KPIs

Table 3: List of 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. Research Hypothesis

4.1 Port of Piraeus hypotheses and roles

The port of Piraeus is one of the fastest growing ports worldwide during the last decade. Container traffic in PCT has been increasing significantly over the last decade reaching from 685.000 TEUs in 2010 (when PCT assumed the management of the port) to 4.403.000 TEUs in 2018. Based on the projection of Q1 2019 throughput growth data, Piraeus is expected to be the largest container terminal in the Mediterranean and the 4th largest in Europe.

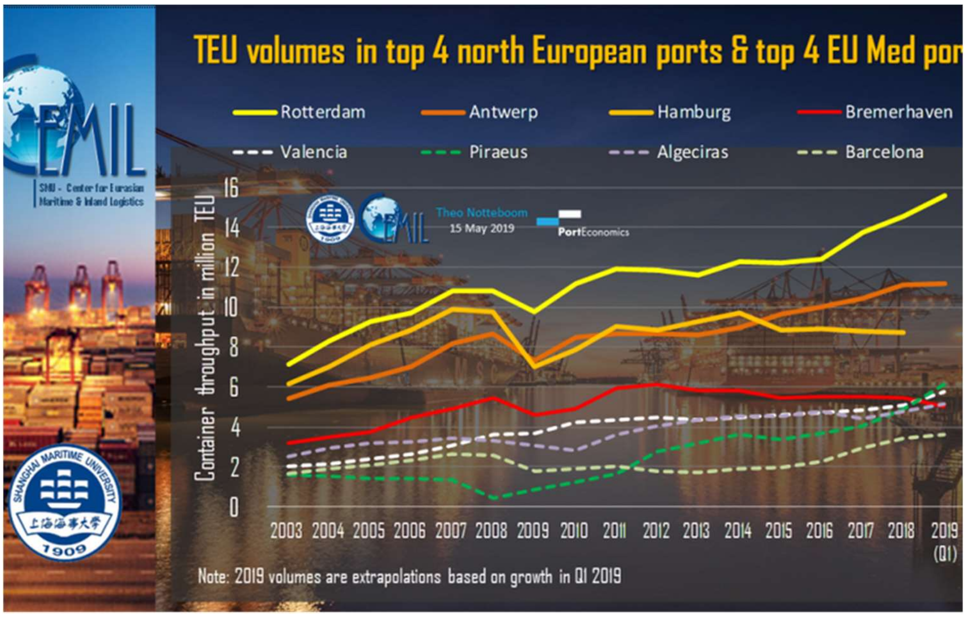

Figure 5: PortGraphics TEU Volumes

Yard equipment availability plays a significant role in modern container ports not only on operational efficiency but also on matching container traffic forecasts with port throughput capacity. With the completion of Pier III, the throughput capacity of the port will reach 6,8M TEUs and container traffic is expected to increase. Quay side length is already fully utilized making the addition of quay cranes practically impossible. Moreover, given the fact that there are already 170 trucks operating in PCT's container yard, leaves little space for an increase on the number of trucks, thus making the increase of truck availability an important factor for future growth. Last but not least, storing and managing bulky spare parts required for equipment maintenance takes up significant space of the port that could be used more efficiently.

The purpose of the Piraeus Living Lab is to improve yard equipment availability and hence container moves performed per truck by implementing an algorithm that will predict maintenance requirements for yard trucks.

Moreover, cranes operating in the Piraeus Container Terminal, both quay cranes and stacking cranes, are based on electricity thus making it a significant power consumer. An energy assessment will be carried out to determine consumption per crane and identify consumption patterns that will help determine whether the use of renewable energy sources is feasible.

Finally, a Port of the Future Serious Game will be developed with the participation of port stakeholders and the use of an extensive list of parameters including the findings of the energy assessment.

4.1.1 List of Scenarios:

Scenario 1: COREALIS Predictor.

The first scenario of the LL of Piraeus focuses on the improvement of operational efficiency through the improvement of yard equipment availability.

The user of the engineering department will be presented with a predictive maintenance schedule for yard equipment. The suggested predictive maintenance schedule will be compiled with the vessel calls schedule and yard equipment operational requirements to ensure availability.

Yard equipment maintenance list will be confirmed and maintenance operations will be planned.

Research hypotheses: 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 as regards to replacement/renewal decisions for assets;
- Reduce operational and maintenance costs of the port spare parts, including tyres.

Scenario 2: Energy Assessment.

In this scenario, the main task will be to analyze and model energy consumption and efficiency of the port of Piraeus, through measuring and collecting data from selected sources. It will explore novel and cost-effective solutions for reducing energy consumption of the terminals, as well as for improving energy efficiency in the whole network of the port and the connected port city. Furthermore, the task will investigate the option of (large-scale) use of renewable energy for the ports of the future, including costs, benefits, technical challenges and solutions.

The identification of energy consumption patterns and findings regarding replicability with renewable power sources will be presented to the facility manager of the terminal in order to support the decision-making process for possible yard equipment enhancements or replacements.

Research hypotheses: The use of COREALIS Predictor 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.

Scenario 3: Sustainable Growth (PoF Serious Game).

This scenario engages in developing green port-city connectivity. The scenario will be 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.

It will be based on an extensive list of parameters among which will be the results of the energy assessment scenario and will make an effort to incorporate the ambitions of the municipality in terms of renewable energy and cutting CO2 and how the port can play a role in that.

Research hypotheses: The use of the Port of the Future Serious Game will:

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

4.1.2 List of KPIs

Table 4: Piraeus LL KPIs

Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)
Scenario #1	Yard equipment performance (moves/week).	450	480
Scenario #1	Monthly average yard equipment breakdown hrs.	0.20	0.15
Scenario #1	Monthly average fuel and spare part consumption.	3.150,00€	3.000,00€
Scenario #1	Total container moves performed after applying the data-driven preventive maintenance schedule.	2,9M	3,1M
Scenario #1	False-positives/negatives as regards to replacement/renewal decisions for assets.	-	75%
Scenario #2	Energy consumption percentage that can be replaced by renewable energy sources.	-	10%
Scenario #2	Measure overall and per crane power consumption.	-	100%
Scenario #3	Monitor socio-economic adoption of the port in the surrounding urban environment (number of stakeholders).	-	10

4.2 Port of Valencia hypotheses and roles

The LL of Valencia mainly aims at optimising the hinterland connectivity of the port by fostering the rail transport mode to increase its model share and to streamline container delivery and pick up processes of road transport mode. To do so, a feasibility study of a JIT Rail Shuttle Service in one of the most important rail corridors of the port was carried out to assess the potential of a new rail solution for hinterland traffic. To optimize road transport processes, the implementation of an Advanced Truck Appointment System will help to reduce the impacts of container delivery and pick-up operations nearby the port area. This new solution will increase the information exchange between the actors facilitating better planning and reaction to unexpected events.

The last scenario of the Valencia LL will focus on the promotion of the innovation within the port community by organizing the Hackathon event where the innovation community (students, start-ups, etc.) will face the main problems faced by the port-logistics sector. This event will help to put on the table current problems, new technologies and ideas that may result in new business models or solutions for the main challenges to be faced by the Port of Valencia.

4.2.1 List of Scenarios:

Scenario 1: Implementation of an Advanced Truck Appointment System.

The first scenario of the LL of Valencia will test the implementation of an Advanced Truck Appointment System (TAS) in the Port of Valencia aiming at optimizing road transport processes and ensuring optimal operations with predefined time slots for container delivery/pick-up operations. On one side, with the new TAS, terminal operators will be able to set the capacity of land operations thanks to the implementation of a time slot-based system. On the other side, logistics operators, shipping agents and truck companies will be able to plan their operations and select the most suitable time slot to perform them. Additionally, an Estimated Arrival Time (ETA) to port premises will be calculated to inform container terminals about the compliance or not with the pre-selected delivery or pick-up schedule.

Research hypotheses: 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.

Scenario 2: Just-In-Time Rail Shuttle service feasibility study.

The second scenario comprises the realization of a Just-In-Time Rail Shuttle service feasibility study for a key port-hinterland corridor of the port of Valencia (Valencia-Zaragoza) to boost the rail transport mode and increase its modal share. The solution aims to minimize the container movements in the terminal and optimize the loading/unloading operations and it includes the design of the physical and operational solution (service characteristics), the information system requirements and the definition of the business models for its implementation.

Research hypotheses: The use of COREALIS Just-In-Time Rail Shuttle service will:

- Increase collaboration and information exchange between the actors of the container supply chain;
- Optimize 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.

Scenario 3: Hackathon in the Port of Valencia.

The third scenario of the LL of Valencia consists of the organization of a 2-day event where students, professionals, start-ups & scale-ups will face some of challenges of the port community of the Port of Valencia. During these days, the hackers will have to team up and propose innovative and feasible solutions including technologies to be used and/or business models to be applied. To do so, they will go from ideas to working concepts, together with coaching of experts within the industry. Finally, the best projects for each of the challenges will be voted and chosen by the jury, selecting a winner for each category.

Research hypotheses: The COREALIS hackathon will:

- Increase collaboration between the port industry and the entrepreneur community;
- Facilitate digitalization of port processes;
- Promote innovation among the port community.

4.2.2 List of KPIs

Table 5: Valencia LL KPIs

Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)
Scenario #1	Average Estimated Time of Arrival (ETA).	-	2h
Scenario #1	Number of slots per hour.	N/A	1000
Scenario #1	Maximum number of bookings per hour.	Maximum of 500 trucks per hour in an average day.	-
Scenario #1	% use of the time slots preselected.	N/A	95%
Scenario #1	Number of cancellations.	N/A	1%
Scenario #1	Number of bookings changed.	N/A	4%
Scenario #1	External systems connected to the TAS.	N/A	1

Scenario #2	Number of daily roundtrips.	-	2-3
Scenario #2	Composition characteristics: Composition TEU Capacity.	-	73 TEU
Scenario #2	Composition characteristics: Composition ITU Capacity.	-	43 ITU
Scenario #2	Composition characteristics: Composition length.	-	495m
Scenario #2	Composition characteristics: Composition maximum load.	-	1.935 tones
Scenario #2	Cost per Unit transported (€/TEU).	-	93.29-95.37€/TEU
Scenario #2**	% of containers delivered on time.	-	-
Scenario #2**	Turnaround time.	-	-
Scenario #2**	Average number of handling movements per container.	-	-
Scenario #2**	Minimum time required for booking.	-	-
Scenario #3	Number of Hackers (Participants).	-	100
Scenario #3	Number of Sponsors.	-	4
Scenario #3	Number of Stakeholders involved.	-	10
Scenario #3	Number of challenges.	-	5
Scenario #3	Number of solutions.	-	10
Scenario #3	Number of publications in social media.	-	500
Scenario #3	Number of projects with scalability.	-	3

** Currently there is not TAS implemented in The Port of Valencia so there is no baseline to compare the KPIs.*

*** These KPIs were not calculated in the feasibility study. However, their analysis will be useful during the operational phase once the Just-In-Time Rail Shuttle service is implemented.*

In reference to the Just-In-Time Rail Shuttle service feasibility study, the results of the study will be used to set some of baseline KPIs. Later on, once the shuttle starts to operate in the corridor Valencia-Zaragoza, the KPIs set during the study will be compared to the measured ones during the operational phase. Finally, for the hackathon organization, there is no baseline as the COREALIS Hackathon to be organized in Valencia will be the first one.

4.3 Port of Livorno hypotheses and roles

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 pervasive and low-latency 5G network. Moreover, 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 (in terms of benefits and financial investments). Lastly, the third innovation, namely PORTMOD, will be tested in the Livorno Living Lab in order to analyze the current container flows at CT Lorenzini, identifying where possible, operational inefficiencies.

The main aim of the development activities at the Port of Livorno is to increase the operational efficiency of the intra-terminal operations.

4.3.1 List of Scenarios

The main scenarios that will be instantiated at the Livorno Living Lab, are summarized below:

Scenario #1 – General Cargo Management System: this scenario is focused on the implementation of the full automated system for the management of the general cargo (RTPORT), both during the unloading phase (from the truck) and the loading phase (on the vessel). The general cargo will be handled in an efficient way (optimal storage, optimal taking, etc.). This will be achieved through the deployment of the prototyping 5G network that enables VR/AR services provided to the forklift driver (who will be assisted, through a tablet, during his daily operations).

Research hypotheses: The use of 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.

Scenario #2 – Yard Vehicles Management System: this scenario is strictly linked to the previous one and represents an additional module for the management of the general cargo (RTPORT). It is based on the usage of the Port Monitoring System (called MonI.C.A) for the virtual representation of all available forklifts. Through this platform it will be possible to track all yard vehicles (mainly forklift) with their current status (available/busy) and position in reference to the general cargo storage area. This will optimize the vehicle-call process.

Research hypotheses: The use of this COREALIS 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.

Scenario #3.1 – Innovation and Digitalization: : 5G applications in ports is regarded as an advanced tool for terminal operations, with numerous potential benefits and applications.

However, due to a lack of data and uncertainties of 5G development, there is still work required to assess the impacts of adopting 5G in ports.

Research hypotheses: The use of COREALIS PoFSG is expected to:

- Investigation of the transferability of new technological solutions to other ports;
- 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: from the climate change adaption point of view, the impacts of new infrastructures in the port are going to be considered as well. The new infrastructures includes extension of berth, hinterland connections as well as the ICT installations.

Research hypotheses: The use of COREALIS PoFSG is expected to:

- Investigate the effects of climate change over a certain period;
- Facilitate a dialogue between stakeholders on development of climate-related master plans;

Scenario #4 – process Modelling for Vessel Pit-Stop Operations: this scenario focuses on the efficient management of the container flows at CT Lorenzini. It allows to describe in detail the container placements within the container movement chain.

Research hypotheses: 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.

4.3.2 List of KPIs

***Table 6:** Livorno LL KPIs.*

Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)
Scenario #1	Vessel operation completion time.	18 h	16 h
Scenario #1	Loading (on the ship)/Unloading (from a single truck) operations completion time.	18 h/40 min	16 h/30 min
Scenario #1	Time to find a pallet on the yard.	8 min	7 min
Scenario #1	Occupied space during the storage phase.	5000 m^2	4500 m^2
Scenario #1	Vessel idle time at berth.	36 h	34 h

Scenario #1	Amount of data related to the cargoes.	90%	95%
Scenario #1	Cargoes registration completion time.	3 min	2 min
Scenario #1	Average operation execution time (by forklift).	8 min	7 min
Scenario #2	Average time of activity/inactivity of the forklift.	60%/40%	65%/35%
Scenario #2	Total number of movements per cargo unit.	4	3
Scenario #3	Awareness on the impacts in investments in new technologies as well as their impacts on port operational and environmental parameters.	N/A	N/A
Scenario #4	Driving distance per productive container move inside of the container terminal.	N/A	N/A

4.4 Port of Antwerp hypotheses and roles

Firstly the Port of Antwerp Living Lab aims at introducing and testing a Cargo Flow Optimizer that will improve the organization of pickup and delivery of containers at the terminals in function of availability, commercial release and customs status in order to reduce the dwell time of cargo in the port and give an accurate prediction of the best way of transport, considering sustainability, the cost, the time and the equipment needed to handle and transport of one or more containers passing through the Port of Antwerp. In a broader sense the Cargo Flow Optimizer aims at improving the modal split from truck towards rail and barge.

Secondly a Market Place & Brokerage platform will be made available for testing with which services and equipment can be booked or made available for booking by and to other terminal and railroad operators in order to optimize the management, ownership and the use of this equipment and the services. Linked with arrival and departure data of ships and trains the Market Place & Brokerage platform will result in an optimization of turnaround times of equipment and the usage of yard equipment and/or transportation means necessary in order to reduce the container stay time at the container terminal and thus a better use of port infrastructure.

4.4.1 List of Scenarios:

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

The goal of this scenario is to achieve a smart organization 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.

Research hypotheses: The use of COREALIS Cargo Flow Optimizer will:

- 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 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 optimizer in this scenario outputs the recommendation of the best transport option.

Research hypotheses: The use of COREALIS Cargo Flow Optimizer will:

- Result in a number of companies that will use the application per month;
- Result in a number of successful transactions per month;
- Reduce the $CO2$ consumption per connection;
- Increase the percentage of transport shifted to rail and barges;

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

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.

Research hypotheses: The use of COREALIS Cargo Flow Optimizer will:

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

Scenario 4: Marketplace and chassis brokerage platform.

This scenario aims at information sharing on available equipment that can be shared between stakeholders. Equipment is owned by many stakeholders of the port and to increase its utilization it is necessary to set conditions to share it between terminals.

A booking function is made available so that users (terminal, port and transport operators) can make an offer, making it available for other terminals to book the equipment and services.

Research hypotheses: The use of COREALIS Marketplace and chassis brokerage platform will:

- Result in a number of companies that will use the application per month;
- Result in a number of successful transactions per month;

4.4.2 List of KPIs

Table 7: Antwerp LL KPIs

Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)
Scenario #1	Number of terminals that reduced the number of handlings (data to be provided by the terminal operator).	0	2
Scenario #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
Scenario #2/3	Number of active uses of the application per month (Active user > 3 logins).	0	10
Scenario #2/3	Number of cargo routes requested per month	0	150
Scenario #2/3	Number of different locations/destinations chosen per month(locations within 20km distance are considered the same)	0	20
Scenario #2/3	Percentage of locations/destination chosen that have an available train route	0%	70%
Scenario #2/3	Percentage of locations/destination chosen that have an available barge route	0%	30%
Scenario #2	Percentage of CO2 reduction of rail compared to truck on the requests performed with the multimodal inland planner	0%	85%
Scenario #2	Percentage of CO2 reduction of barge compared to truck on the requests performed with the multimodal inland planner	0	70%
Scenario #2/3	Number of successful transactions per month.	0	2
Scenario #2/3	Percentage of transport shifted to rail and barge.	0%	50%
Scenario #2/3	Number of new "shared" on-demand transport services that could be created.	0	2
Scenario #4	Number of uses/logins of the application per month.	0	5
Scenario #4	Number of successful transactions per month.	0	2
Scenario #4	Number of offerings by a supplier per month	0	5
Scenario #4	Number of demands per month	0	5
Scenario #4	Number of assets added per month	0	5

Scenario #4	Saved idle time of assets per month	0	24 hours
Scenario #4	Number of asset categories used per month	0	3

4.5 Port of Haminakotka hypotheses and roles

4.5.1 List of Scenarios:

Scenario 1: PORTMOD

PORTMOD is a modelling tool that aims to find improvements to Container Terminal (CT) operations by simulation. PORTMOD aims to improve the CT operations in the following three closely related goals:

1) Optimize stacking height and location of container stacks;

2) Evaluate new equipment solutions;

3) Evaluate container yard area layout changes.

Research hypotheses:

The use of PORTMOD is expected to:

- Increase productivity of container operations in container yard;
- Increase equipment 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.

Scenario 2: COREALIS Light-TAS

The purpose of the Truck Appointment System (TAS) is to allow trucking companies to indicate when they intend to pick up or deliver cargo at the port and in which area. The volume of booking should serve as an information to the terminals to adjust their operation to the expected volume of activity.

Currently the cargo data exchange between the terminal, the shippers and the land transporters are Electronic Data Interchange (EDI)-based. For example, when a truck is entering the port gate, the cargo will be identified by truck plate number and all cargo information will be available from STEVECO FLOW resource operating system. This information has been sent by an EDI message to the terminal, after the loading is completed at a mill.

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 .

Scenario 3: COREALIS Port of Serious Game (PoFSG)

HaminaKotka LL will assist in developing one scenario whereby it will be possible to assess how well the energy transition measures manage to mitigate CO2 and other environmental emissions, i.e. transferring from traditional high-polluted energy to renewable energy /electrification. PoFSG is a tool for creation of common strategies roadmaps for port decision makers, including the possibility of quantification of port decisions influence for mid-/long-term. Through the complete analysis of the energy transition scenario that is based on HaminaKotka LL, the PoFSG will be able to assess energy-related measures and incorporate some or all of them into the new version of the game.

Research hypotheses: In this scenario, HaminaKotka LL can provide assistance in one or more measures. In the following, we give examples of possible measures:

- 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.

4.5.2 List of KPIs

Table 8: Haminakotka LL KPIs

Scenario	KPI (Description)	KPI (Baseline)	KPI (Target)
Scenario #1	Equipment usage time: equipment usage time / possible usage time.	3,407	3,237
Scenario #1	Lifts/hours per crane.	20	21
Scenario #1	Vessel turnaround time: Arrival - Departure time from port.	29 h 25 min	27 h 57 min
Scenario #1	Loading & unloading efficiency: number of containers / vessel turnaround time.	2.36	2.24
Scenario #2	Temporal distribution of terminal/port gate operations.	56%/38%/6%	56%/38%/6%
Scenario #2	Average time of gate-in/out operations (All trucks incl warehouses)	32 min	30 min
Scenario #3	Average time of gate-in/out operations (Stuffing warehouse Pilot 1)	31 min	29 min

5. Conclusions

In the context of the CORALIS project vision to enable sustainable port development, this document has presented the evaluation methodology that will be followed to assess the results of the COREALIS innovations. The overall drivers, targets and scope of the Living Labs have been outlined, and the expected innovation agenda has been mapped to the stakeholders' ambitions.

An innovation management framework, including specification of KPIs has been defined to support the evaluation and development of invention in these areas within the project. However, due to the dynamic and iterative nature of innovation and research, and the evolving business landscape, it is likely that the concepts and ambitions will be refined as the Living Labs progress and more data become available.

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