5GLOGINNOV

Deliverable 1.4

Initial specification of evaluation and KPIs

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of abbreviations and acronyms

Abbreviation	Meaning
4G/5G	$4^{th}/5^{th}$ Generation (of cellular networks)
ADAS	Advanced Driver Assistance System
AI	Artificial Intelligence
API	Acceleration Performance Index
ATP	Automated Truck Platooning
CAD	Connected Automated Driving
CAN	Controller Area Network
CNF	Cloud Native Functions
CSF	Critical Success Factor
DoA	Description of the Action
E2E	End-to-End
eMBB	Enhanced Mobile BroadBand
EPI	Energy Performance Index
FTED	Floating Truck & Emission Data
GLOSA	Green Light Optimal Speed Advisory
GNSS	Global Navigation Satellite System
HMI	Human-Machine Interface
IoT	Internet of Things
ITS	Intelligent Transportation Systems
KPI	Key Performance Indicator
LCMM	Low Carbon Mobility Management
LL	Living Lab
MANO	MAnagement and Network Orchestration
MCA	Multi Criteria Analysis
MEC	Mobile Edge Computing
ML	Machine Learning
MNO	Mobile Network Operator
NFV	Network Functions Virtualization
NSA	Non-Standalone (5G network operation)
OEM	Original Equipment Manufacturer
ORDP	Open Research Data Pilot
SA	Standalone (5G network operation)
SDK	Software Development Kit
TEU	Twenty-foot Equivalent Unit
TOS	Terminal Operating System
UC	Use Case

UHD	Ultra-High Definition
WLTP	Worldwide-harmonized Light vehicles Test Procedure
WP	Work Package
STS	Ship to Shore

EXECUTIVE SUMMARY

This deliverable presents the evaluation methodology that will be carried out to evaluate the impact of the use cases that will be demonstrated in the context of 5G-LOGINNOV. The proposed approach consists of an Action Plan that specifies the list of actions and a qualitative and quantitative analysis. The quantitative analysis consists of the procedure to identify the KPIs which also includes the verification of their correspondence with the measurable objectives set up by the 5G-LOGINNOV project. The qualitative analysis aims to fill the gaps by considering the objectives that cannot be measured by the KPIs. More specifically, the use cases are evaluated with reference to different areas of impact. The output of the analysis is a set of scenarios, each consisting of a rank of use cases, in which the first position is occupied by the use cases with the highest impact. This document also proposes a procedure to assess the importance of Critical Success Factors for port operations optimization. Similarly, the output of this analysis is a ranking of Critical Success Factors based on their importance for the optimization of port operations from the different points of views of the respondents. In the last part of the document, a preliminary analysis of the requirements of the tool for data collection is presented.
Chapter 1 introduces the 5G-LOGINNOV project, the objectives of the deliverable and the intended audience. The evaluation methodology, consisting of the Action Plan set up and the procedure to perform the qualitative and quantitative analysis, is presented in Chapter 2. Chapter 3 describes the results of the qualitative-quantitative evaluation of the Critical Success Factors for the port operation optimization and Chapter 4 describes the KPIs for the quantitative analysis. Finally, Chapter 5 is dedicated to the requirements of the data collection tool and Chapter 6 summarizes the main conclusions.

1 INTRODUCTION

1.1 Project Intro

5G-LOGINNOV will focus on seven 5G-PPP Thematics and support to the emergence of a European offer for new 5G core technologies in 11 clusters of use cases. 5G-LOGINNOV's main aim is to design an innovative framework addressing integration and validation of Connected Automated Driving/Mobility (CAD/CAM) technologies related to the industry 4.0 and port domains by creating new opportunities for LOGistics value chain INNOVation. 5G-LOGINNOV is supported by 5G technological blocks, including new generation of 5G terminals notably for future Connected and Automated Mobility, new types of Internet of Things (IoT) 5G devices, data analytics, next generation traffic management and emerging 5G network architectures for city ports, to handle upcoming and future capacity, traffic, efficiency, and environmental challenges. 5G-LOGINNOV will deploy and trail 11 clusters of use cases targeting beyond TRL7, including a GREEN TRUCK INITIATIVE using CAD/CAM & automatic trucks platooning based on 5G technological blocks. Thanks to the new advanced capabilities of 5G relating to wireless connectivity and Core Network agility, 5G-LOGINNOV ports will not only significantly optimise their operations but also minimise their environmental footprint to the city and the disturbance to the local population. 5G-LOGINNOV will be a catalyst for market opportunities build on 5G core technologies in the logistics and port operation domains, thus being a pillar of economic development and business innovation and promoting local innovative high-tech SMEs and start-ups. 5G-LOGINNOV will open SMEs' and start-ups' door to these new markets using its three Living Labs as facilitators and ambassadors for innovation in future European ports. 5G-LOGINNOV's promising innovations are key for the major deep-sea European ports in view of the mega-vessel era (Hamburg, Athens), and are also relevant for medium sized ports with limited investment funds (Koper) for 5G[1].

Chapter 1 introduces the 5G-LOGINNOV project, the objectives of the deliverable and the intended audience. The evaluation methodology, consisting of the Action Plan set up and the procedure to perform the qualitative and quantitative analysis, is presented in Chapter 2. Chapter 3 describes the results of the qualitative-quantitative evaluation of the Critical Success Factors for the port operation optimization and Chapter 4 describes the KPIs for the quantitative analysis. Finally, Chapter 5 is dedicated to the requirements of the data collection tool and Chapter 6 summarizes the main conclusions.

1.2 Purpose of the Deliverable

The objective of this deliverable is to set up a methodology to evaluate the impact of the use cases tested in 5G-LOGINNOV Living Labs on several aspects such as port operations optimization and social and environmental aspects.
The objectives related to this deliverable have been achieved in full and as scheduled.

1.3 Intended Audience

This deliverable aims to set up the evaluation methodology to be adopted and agreed by Living Labs Leaders and participants. This document is firstly addressed to the project partners and to the reviewers who will have to verify that the expected impacts of the 5GLOGINNOV have been fulfilled, thanks to the activities carried out in the context of the project. Finally, the deliverable is public as such and the evaluation methodology can be taken as an example and implemented to evaluate the use cases of other similar European research projects.

[1] https://5g-loginnov.eu/

2 5G-LOGINNOV EVALUATION METHODOLOGY

2.1 Purpose of the 5G-LOGINNOV Evaluation

The main objective of task T1.4 is to set up the evaluation framework of 5G-LOGINNOV. More specifically, the evaluation aims to assess the impact of 5G-LOGINNOV on port operations (T3.5) and on the society, economy, and environment (T3.6), based on the data collected by the tool developed in the context of the project (T2.2).

5G-LOGINNOV consists of three Living Labs (LLs), where a set of use cases (UC) will be demonstrated and for which their impacts will be assessed. The evaluation process is of vital importance for the success of the project, highlighting how the UCs are important to reduce the impact on the environment, to improve the social and working conditions or to optimize port operations.

The main difficulty related to the set-up of an evaluation framework for the UCs demonstrated in the context of European projects is related to the need to measure the impact of a technology that is not fully operational, but it is only tested on a limited area and for a limited period. For this reason, the real impact of a service or a technology introduced by a research project is difficult to assess on a larger scale and on a longer time period; hence, the evaluation framework is based on the quantitative and qualitative assessment.

As previously mentioned, the purpose of the evaluation methodology is to assess the impact of the use cases and Living Labs on several aspects: technical, operational, environmental, societal, and based on the possibility to transfer the results obtained in 5G-LOGINNOV to other hubs. For this reason, the evaluation methodology proposed in the context of 5G-LOGINNOV consists of the following components:

1) An Action Plan to assist, step by step, the Living Labs Leaders and the project partners in the evaluation process.
2) A quantitative analysis, which consists of a set of KPIs that are measured based on data collected during the UCs demonstration. The objective of the indicators is to measure the impact of the UCs on:
    a) Technical and operational aspects (T3.5).
    b) Societal and environmental aspects (T3.6).
3) A qualitative analysis that aims to:
    a) Evaluate the most important Critical Success Factors (CSF) for port operations optimization (T1.4).
    b) Evaluate the impact of 5G-LOGINNOV use cases according to a set of Macro and Micro-Criteria (T1.4).

In the next section, the overall evaluation framework and the Action Plan are described in detail.

2.2 The Evaluation Framework

The evaluation framework aims to identify a set of actions and procedures to assess the impact of the UCs demonstrated in the context of 5G-LOGINNOV and thanks to the introduction of the 5G network in the port areas. These impacts concern several areas and can be measured quantitatively, others can only be assessed qualitatively.

For this reason, the evaluation framework consists of three main layers: the first layer aims to define an Action Plan in which the main activities to be performed to successfully complete the evaluation are planned and the main workflow is described. The other two layers concern the evaluation methodology itself, which consist of two main approaches: quantitative or qualitative.

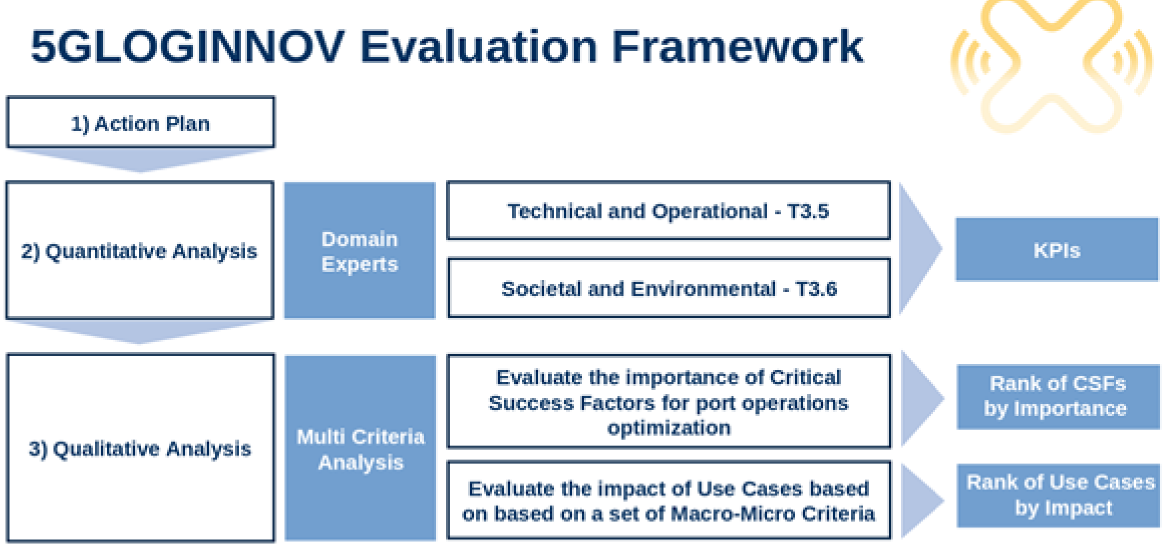

Figure 1 5G LOGINNOV evaluation framework, authors' elaboration

The diagram above provides an overview of the workflow based on which the evaluation is carried out. From the left to the right, it shows that the first step consists in setting up an Action Plan that should be agreed with all project participants involved in the evaluation. In 5G-LOGINNOV, the Action plan has been shared among all project participants because the consortium was small, all the partners were involved in the LL demonstrations and most of them had to collect/provide data for the evaluation.

Besides the definition of the Action Plan, the evaluation framework consists of two main approaches. The output of the quantitative approach is a set of KPIs related to technical, operational, societal and environmental aspects. The KPIs are identified based on the planned demonstrations and thanks to the collaboration of the LL Leaders, who provided information on the type of data collected during the demonstration. With reference to the qualitative approach, there are two main outputs consisting of an evaluation of the importance of Critical Success Factors for the optimization of port operations and of the evaluation of the use cases based on a set of Micro-Criteria.

2.2.1 The Action Plan

The Action Plan aims to detail the steps needed to successfully carry out the evaluation of the 5G-LOGINNOV UCs and of the overall project. The Action Plan includes actions that have to be carried out; these actions include the identification of the KPIs, data collection, the KPIs measurement and the qualitative assessment.

2.2.1.1 Step 1: Definition of the Macro and Micro-Criteria

The first step of the Action Plan is to identify and agree on the Macro-Criteria reported in the Description of the Action (DoA) and the corresponding Micro-Criteria identified by the project participants. The Micro-Criteria have been identified during the definition of the KPIs with the aim to classify them. More specifically, the Micro-Criteria define the areas of impact of the use cases. The idea is to evaluate the 5G-LOGINNOV use cases based on their capability of having an impact on several areas (the Micro-Criteria). The Macro-Criteria, therefore, represent the macro-categories based on which the Micro-Criteria (micro-categories) are defined to evaluate the 5G-LOGINNOV use cases and LLs. The Macro and Micro-Criteria have two main functionalities:

- First of all, the identified KPIs are classified based on the Macro and Micro-Criteria.
- Secondly, a qualitative evaluation of the use cases is performed based on the Micro-Criteria.

The first functionality refers to the need of classifying the identified KPIs into categories to ensure a correct balance among quantitative indicators and to have an idea of which areas can be covered thanks to their measurement. With reference to the evaluation of the impact of the use cases, a survey is carried out to assess the importance of each Micro-Criterion with reference to each use case. The questions related to the CSFs have been added to the survey prepared in the context of WP4 and filled in by 5G-LOGINNOV stakeholders. The questions of the survey related to the evaluation of the use cases are reported in Annex 1. Based on the DoA, the stakeholders involved in the Athens, Hamburg and Koper LLs are the following:

- Port Authority Terminal Operators.
- Rail Operators.
- Transport Operators.
- Truck Drivers.
- Regional Authorities.
- Local Industries & Associations
- Customs Authorities.

The preliminary results of the evaluation of the impact of the use cases with reference to the Macro and Micro-Criteria is presented in Chapter 3.1.

2.2.1.2 Step 2: Identification of CSFs through survey

This step is dedicated to the preparation of the questionnaire addressed to the stakeholders of the LLs to identify and assess the Critical Success Factors (CSFs) for optimization of port operations. This survey has been carried out in conjunction with the survey presented in this chapter. The survey consisted of a multiple-choice questionnaire that gave the possibility to the respondents to add additional CSFs that were not listed in the survey. A first list of CSFs has been identified based on the work of Parola et al. (2017). The study was focused on the drivers of port competitiveness and on their measurement; most importantly, the authors performed an analysis of existing literature to identify the Critical Success Factors related to five trends:

1) Economies of scale in shipping.
2) Governance changes.
3) Competition among ports in proximity.
4) Inter-firm networks.
5) Green and sustainable challenges.

The list of the CSFs has been discussed with project partners and WP4 leader. Once the final and agreed version of the questionnaire was ready, it was delivered to the stakeholders identified by the LLs representatives to collect their opinion on the importance of each CSF. The results of the survey have been analysed and a scenario analysis has been performed based on the multi criteria approach. The survey is reported in Annex 1 and the results of this analysis are described in the dedicate chapter of this deliverable (see Chapter 3.1).

2.2.1.3 Step 3: KPIs and data needed for their measurement

A preliminary list of KPIs has been created by ICOOR and shared with T1.4, T2.2, T3.5, T3.6 participants and LLs representatives. The KPIs have been selected based on the analysis of existing projects.

The template deployed for the collection of KPIs is reported in the table below.

Fields	Description
Living Lab	Name of the Living Lab where the use case is tested
Use case	Use case identification number
Measurable objectives and indicators	Measurable objectives and indicators as per DoA
KPI	Name of the KPI selected
KPI Measurement	When the KPI will be measured. It could be either before, after, or during the test (or a combination)
Data needed	List of data needed to compute the KPI
Owner	Name of the partner providing the data

Table 1 Fields to be collected for each KPI, authors' elaboration

The KPIs have been reviewed and selected by the responsible of the LLs based on their capability of measuring the impact of each use case and the possibility to calculated them. It was indeed discussed about the type of data needed to measure the selected KPIs with the partners involved in the evaluation task and with the partners involved in the LLs demonstration who are in charge of data collection and of measuring the KPIs. Finally, the objectives of the LLs stated in the DoA have been associated to the selected KPIs. In case of 5G-LOGINNOV, the proposal included a table that specified for each LL and UC, the *Measurable objectives and Indicators*, which have been revised and updated in the context of D1.1 5G-enabled logistics use cases; the field *Measurable objectives and indicators* (Table 1) is meant to trace back each KPI to the objectives described in D1.1.

Overall, the approach to identify the KPIs has been the following:

1) Preparation of the preliminary list of KPIs based on existing literature.
2) Review and integration of the list by project participants.
3) Selection of the KPIs by the LLs.
4) Provision of information about the data needed to calculate the KPIs.
5) Final selection of KPIs based on the availability of data to calculate them.
6) Review of KPIs based on the project objectives.

The KPIs are discussed in Chapter 4 of the deliverable.

2.2.1.4 Step 4: Develop the tool for data collection

With reference to the data collection, the requirements of the tool for the data collection had to be defined. It was agreed that some data needed to be collected prior the implementation of the 5G-LOGINNOV use cases, to assess the baseline scenario and quantify the "before" situation. The initial idea was to collect data three months before the execution of the demonstration; every LL, depending on their readiness level, should have performed this activity. Eventually, it was clarified that some data were already collected by the LLs, so that there was no need to perform additional activities. Chapter 5 describes the requirements of the tool for data collection and specifies the type of data that will be collected by the LLs during the demonstrations.

2.2.1.5 Step 5: Update of the Quantitative and Qualitative indicators

The KPIs that have been selected for their measurement (see Chapter 4) will be revised and updated in the context of T3.1 Trial Methodology, Planning and Coordination, which according to the DoA includes the specification of the data collection process and assessment with relation to defined KPIs and evaluation requirements by T1.4. More specifically, the plan is to update the KPIs during the demonstration, because it could happen that some data are not available but others will be. However, it has to be pointed out that the update of the KPIs in the context of T3.1 should be minimised, so that the tool for data collection developed in the context of T2.2 does not need major updates.

Furthermore, the Micro-Criteria will also be updated by considering these KPIs, to evaluate the impact of the use cases that can only be measured qualitatively.

2.2.1.6 Step 6: Quantitative and Qualitative analysis

In this step, the selected KPIs are calculated to perform the impact assessment of the demonstrated use cases and of 5G-LOGINNOV project. Data analyses need to reveal the changes / improvements among the two phases ('before' and 'after'), thus providing the necessary evidence regarding the success of each LL based on the expected objectives. In the qualitative framework described in Chapter 3, the new Micro-Criteria identified in 2.2.1.5 are considered, a new survey is performed and the Multi Criteria Analysis provides a final ranking of use cases based on their capability to have an impact on the corresponding Macro and Micro-Criteria.

2.2.2 Macro and Micro-Criteria

According to the Description of the Action (DoA), five Macro-Criteria have been considered together with a preliminary list of Micro-Criteria. These Macro-criteria are:

- Technical
- Operational
- Environmental
- Societal
- Transferability

The Transferability Macro-Criterion is considered apart, in the context of T5.3 Exploitation. In that task, a transferability analysis will be developed for the solutions validated at the three Living Labs.

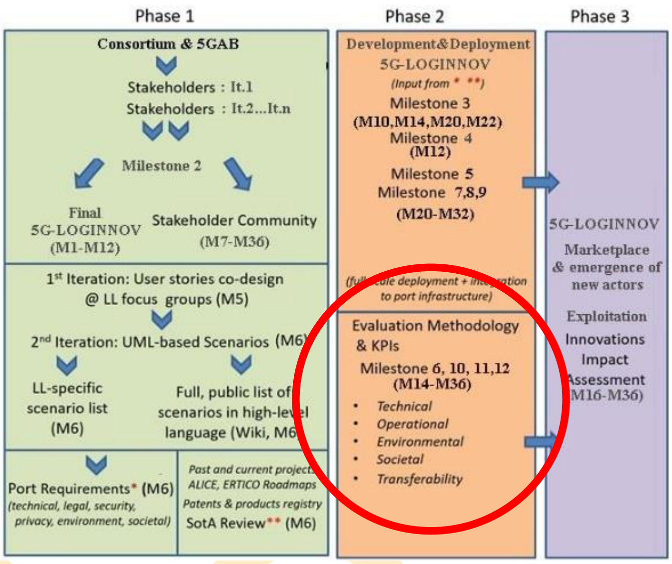

Figure 2 Participatory approach and methodology

For what concerns the other Macro-Criteria, the corresponding Micro-Criteria and KPIs are complemented thanks to the identification of Critical Success Factors (CSF) for the optimization of port operations, as explained in Step 1 (see Section 2.2.1.1). The preliminary list of Macro- and Micro-Criteria technical, operational, societal and environmental has been shared with the participants of T1.4 and a survey for Micro-criteria (see Annex 1) has been delivered to the actors operating in the 5G-LOGINNOV LLs to ask their opinion on the importance of each Micro-Criterion.

2.2.3 Qualitative and Quantitative Analysis

2.2.3.1 Quantitative Analysis

With reference to the Quantitative Analysis, this is mainly addressed to identify and define the KPIs based on the existing literature and the use cases defined in the context of WP1. The KPIs will be measured thanks to the data collected during the 5G-LOGINNOV demonstrations. The first step for the definition of the KPIs consisted in the review of existing projects dealing with 5G and maritime transport. More specifically, a set of KPIs have been selected from the deliverable *D1.2 Personas and Stakeholder classification of COREALIS project*. The deliverable considered a set of KPIs based on their capability of measuring the impact on climate change, infrastructural costs and logistics efficiency. One of the purposes of the deliverable was to understand which KPIs were considered important by the stakeholders that constituted the ecosystem of a smart port and its surroundings urban space. These KPIs have been presented to the LLs participants. Some of them were relevant to the use cases demonstrated in 5G-LOGINNOV, therefore, they have been selected by the LL participants. The list of KPIs included in the deliverable D1.2 of COREALIS is reported below.

KPIs related to climate change
- KPI related to CO_2 emissions.
- Noise-related KPI.
- KPI evaluating the modal transport split.
- KPI evaluating the introduction or use of smart grids and/or green energy technologies and services.
- KPI evaluating the introduction or use of sustainable energy resources.

KPIs related to infrastructural cost
- Reduction in the number of empty container runs (Container runs).
- Better use of the yard due to improved stacking (Stacking).
- Reduction of false-positives/negatives in regard to replacement/renewal decisions for assets (Assets).
- Reduction of operational and maintenance costs of the port spare parts, including tyres (Spare parts).
- Reduction in the trucks and yard equipment idling for more than one shift (Equipment).

KPIs related to the logistics efficiency
- Reduction of the time a container stays in the port prior to being handed over to another transport mode.
- Lower unit cost in the end-to-end supply chain due to a better estimated time of arrival.
- Improvement of modal split to rail.
- Improvement of modal split to inland waterways.

Another deliverable from which KPIs have been selected was the *Deliverable D6.1 Documentation of Requirements and KPIs and Definition of Suitable Evaluation Criteria* of the **5G-Monarch** project. From this document, a set of KPIs related to the performance of the 5G network have been proposed to LLs:

- Area traffic capacity.
- Availability.
- Bandwidth.
- Coverage area probability.
- End-to-end latency.

Overall, the end-to-end latency will be measured by all three LLs. Some LLs, such as Koper, are more focused on the implementation of 5G network; in this case, the list of selected KPIs is more related to the performance of the network. Other LLs are focused on the operations such as Athens.

2.2.3.2 Qualitative-Quantitative Analysis

The KPIs have been identified thanks to the preliminary definition of Macro/Micro-Criteria and of Critical Success Factors (CSFs). The former leverage a business strategic approach that breaks down the goals of the project (i.e. Macro-Criteria) into measurable objectives (i.e. Micro-Criteria) that can be then evaluated using selected metrics (KPIs), while the latter extracts knowledge from port managers, employees and other stakeholders to understand whether the technologies introduced by 5G-LOGINNOV project improved the previous operations.

The quali-quantitative analysis is performed based on a Multi Criteria approach. The first analysis consists of a procedure that allows to evaluate the importance of Critical Success Factors (CSF) for the optimization of port operations based on the different respondents' point of views. A detailed presentation of the methodology and of the results is reported in Chapter 3.2.

Finally, the quali-quantitative analysis aims to evaluate the impacts of the use cases according to a set of criteria that cannot be measured quantitatively. To perform the analysis, a set of areas of impact (or criteria) for the use cases have been defined and a survey enabled collecting personal opinions on the degree of impact of each UC with reference to each Micro-Criterion, as defined in chapter 2.2.1.1. Thanks to the Multi Criteria Analysis, a ranking of use cases according to different scenarios is obtained as described in Chapter 3.1.

According to the DoA, the evaluation framework includes the assessment of transferability of solutions proposed by 5G-LOGINNOV to other hubs. This activity is performed in T5.3 Exploitation. However, that task should take into account the Micro-Criteria to evaluate the impact of the UCs, because they could provide useful information to assess whether it will be possible to transfer the 5G-LOGINNOV solutions to other hubs or not. Furthermore, the transferability assessment should take into account the requirements for the implementation of the use cases that are defined by T1.3 (Living Labs infrastructure requirements).

3 QUALI-QUANTITATIVE ANALYSIS

3.1 Evaluate the Impact of use cases based on Macro and Micro-Criteria

3.1.1 Use cases and Criteria for the Evaluation

The current work is aimed at evaluating the use cases (UC) implemented by the Living Labs involved in the 5G-LOGINNOV project. The specific goal of the evaluation is to assess which UC has the highest impact, according to different scenarios. A UC is considered to have the highest impact with respect to the evaluation criteria if it places itself at the first position of the rank generated based on experts' domain knowledge. Table 2 reports the complete list of all UCs implemented within 5G-LOGINNOV and the name of the Living Lab in charge for it (for more detailed information on use cases description see Chapter 4).

Living Lab	UC	UC Name
Koper	1	Management and Network Orchestration platform (MANO)
Athens	2	Device Management Platform Ecosystem
Athens	3	Optimal Selection of Yard Trucks
Athens	4	Optimal Surveillance Cameras and Video Analytics
Athens, Koper	5	Automation for Ports: Port Control, Logistics and Remote Automation
Koper	6	Mission Critical Communications in Ports
Athens	7	Predictive Maintenance
Hamburg	8, 9	Floating Truck & Emission Data
Hamburg	10	5G GLOSA & Automated Truck Platooning (ATP)
Hamburg	11	Dynamic Control Loop for Environment Sensitive Traffic Management Actions (DCET)

Table 2 Use cases and Living Labs, authors' elaboration

The rank has been created based on experts' answers collected via the online survey (see Annex 1). The criteria used for the evaluation are the Micro-Criteria that have been defined based on the literature and on the identified KPIs (see chapter 2.2.1.1 for the definition of Macro and Micro-Criteria). The macro areas of interventions, called Macro-Criteria, have been identified during the proposal preparation. More specifically, there are three macro areas of impacts: 1) Operational and Technical, 2) Societal, and 3) Environmental. Table 3 reports the list of the Macro-Criteria and the corresponding Micro-Criteria based on which the ranking of UCs has been created (see chapter 2.2.2 for a more comprehensive discussion on Macro and Micro-Criteria).

Macro-Criteria	Micro-Criteria
Operational and Technical	Provide accurate communications and recommendations for operations
	Increase safety within port
	Increase security in port areas
	Increase efficiency of the operations

	Decrease costs for operation
	Decrease traffic and incidents
	Improve connections inside and outside the port
	Increase number of ITC services
	Degree of centralization of data and information sources
	Degree of data-driven and digitally automated processes
Societal	Improve quality of working environment
	Increase economic wealth
	Increase businesses cooperation
	Decrease health risks for workers
Environmental	Increase resilience to climate change

Table 3 Macro and Micro-Criteria association, authors' elaboration

After identifying the Micro-Criteria as main areas based on which the evaluation is performed, Multi Criteria Analytical tools were implemented to generate different ranks related to different scenarios (see chapter 3.1.3 for an explanation of the methodology and 3.1.4 for the implementation). The different ranks are then discussed in 3.1.5, which provides a comprehensive overview of the results and a conclusion on what UCs best satisfy the identified criteria that are in line with the 5G-LOGINNOV project's objectives. It is important to note here that only UCs for which answers were provided by the respondents have been ranked. See next chapter for a discussion on the considered UCs.

3.1.2 Data Description

The information was collected through a survey delivered to the stakeholders involved in the implementation of the 5G-LOGINNOV use cases (for more information about the respondents' characteristics see chapters 3.2.2). Thanks to the 47 responses collected, it was possible to analyse the respondents' preferences and rank 6 out of 10 use cases. The reason why it was not possible to rank them all was due to the lack of answers from experts involved on the remaining use cases. The number of responses received by each use case are reported in Table 4.

Living Lab	UC	Responses (n)
Koper	1	4
Athens	4	1
Athens, Koper	5	8
Koper	6	6
Hamburg	8, 9	11
Hamburg	10	11
Hamburg	11	6
Total Responses		**47**

Table 4 Number of answers collected by UC, authors' elaboration

The questions asked in the survey were aimed at assessing whether the UC would be successful if it was achieving the objective related to the Micro-Criteria, or not. Each Micro-Criterion was then mapped into a defined area of intervention within the set of three defined Macro-Criteria presented in Table 3. The participants expressed their opinions on an ordinal scale based on five classes ordered from 'strongly disagree' to 'strongly agree' which were then used to rank UC based on how much they satisfied the objectives. The methodology in the next chapter will provide more information on how UC were ranked using experts' opinions.

3.1.3 Methodology

3.1.3.1 A Comprehensive Exploration of Rankings

To compute the rank for each UC, the Multi Criteria Analytical tools that are presented in chapter 3.1.3.2 were deployed. These tools require the evaluators to assign a weight for each criterion object of the valuation (i.e., Macro-Criteria). It was not possible to extrapolate weights from the preferences since the participants did not provide this type of information in the survey. For this reason, a different set of weights have been generated to create conflicting scenarios and to explore "what if" situations to answer questions of the kind what would be the UC that best satisfy one or the other criteria as well as a combination of two. This approach does consider a multitude of scenarios that allow for understanding what objectives a UC can satisfy better as well as mapping how the UC satisfies the 5G-LOGINNOV objectives considering different criteria. The next chapter will describe the steps of the methodological approach as well as the analytical tools used to weight the three Macro-Criteria. The implementation of the methodology will be presented in chapter 3.2.3 and the results leading to a comprehensive assessment of the UCs for different scenarios in the last chapter 3.2.5.

3.1.3.2 Ranking UC for Different Scenarios

The methodology for generating different scenarios is articulated as follows. First, each Macro-Criterion is assigned to a different set of weights to account for variations in the relative importance of each criterion with respect to the other. The combination of the set of criteria and the set of weights is called *scenario*. Table 5 shows the different scenarios that will be considered. There are seven scenarios in total and they encompass a wide variety of settings considering equal weights among criteria, one criterion outweighing the other two, as well as two criteria outweighing one. The third setting is called *underweight* to focus the attention on the criterion with smaller weight compared to the other two.

Scenario/Criteria Weights	Operational and Technical	Societal	Environmental
Scenario 1 "Equal Weights"	0.33	0.33	0.33
Scenario 2 "Outweigh Technical/Operational"	0.90	0.05	0.05
Scenario 3 "Outweigh Societal"	0.05	0.90	0.05
Scenario 4 "Outweigh Environmental"	0.05	0.05	0.90
Scenario 5 "Underweight Environmental"	0.45	0.45	0.10
Scenario 6 "Underweight Societal"	0.45	0.10	0.45
Scenario 7 "Underweight Technical/Operational"	0.10	0.45	0.45

Table 5 Criteria weights set up per scenario, authors' elaboration

The role of the weights here is to simulate different scenarios which consist of giving more importance to one or the other criterion. The evaluator could decide to assign a greater weight to those objectives associated with Operations and Technical compared to those aimed at improving Societal and Environmental objectives to look at how, under a different scenario, the UCs rank would change. To reduce the number of ranks to be considered, only a limited set of scenarios have been produced. However, the approach presented here could be scaled up to all possible combination of weights.

After setting up the scenarios, the next step is to compute the average response per each Macro-Criterion and UC. To do so, for each respondent the average response by Macro-Criteria is calculated using the association between Micro-Criteria and Macro-Criteria presented in Table 3. Then, the average response for UC by Macro-Criteria is computed. Finally, the rank for each scenario is obtained using the MCA tools, combining the matrix with mean preferences for each use case and Macro-Criterion, as well as the vector with the weights defined by scenario.

To reduce the biases and limitations of the MCA tools available in the package used for calculating the rank, five different Multi Criteria approaches have been tested (see chapter 3.1.3.3). The average of the five ranks is used to obtain a unique rank for each scenario.

The output is a set of UCs ranks, one for each scenario, representative of different weights assigned by the evaluator to each of the Macro-Criteria. This output will enable comparing seven settings where the Macro-Criteria are alternatively more relevant to the others to account for differences on the UC ranks. To summarize, the methodology can be broken down in few steps listed below:

1) Set criteria weights for different scenarios.
2) Compute mean preference for each UC and for each Macro-Criteria.
    a) Compute mean preference for a subset of Micro-Criteria per respondent.
    b) Compute mean preference by Macro-Criteria per respondent of the same UC.
3) Compute ranks for each scenario using different MCA tools.
4) Average rank for each scenario.
5) Compare ranks of different scenarios.

3.1.3.3 Multi Criteria Analytical Tools for Ranking

The Multi Criteria Analytical tools used for generating scenarios are included in the Table 6, which reports a short of description for each one.

	Multi Criteria Analytical Tool	Description
1	Weighted Sum	The weighted sum model is the simplest multi criteria decision analysis for evaluating a number of alternatives in terms of a number of decision criteria. It is applicable only when all the data are expressed in exactly the same unit.
2	Weighted Product	The weighted product model is a popular Multi Criteria decision analysis method. It is similar to the weighted sum model. The main difference is that instead of addition in the main mathematical operation now there is multiplication.
3	Topsis	The Topsis method is based on the concept that the chosen alternative should have the shortest geometric distance from the ideal solution and the longest Euclidean distance from the worst solution.
4	Ref Point Moora	The Ref Point Moora method follows a multi-objective optimization on the basis of ratio analysis.
5	Fmf Moora	The Full Multiplicative Form is a method that is non-linear, non-additive, does not use weights and does not require normalization.

Table 6 Multi Criteria Analytical Tools

3.1.4 Generate UC Ranks for each Scenario

To generate and rank UCs for each scenario, the dataset was cleaned from the responses for which there were less than 4 answers. After that, there were 46 responses left referring to six UCs. Then, the data were converted into a computer readable format by recoding the answers of the respondents from string data type to numerical. For this purpose, an ordinal scale of values in the range from -2 to

+2 was deployed, where negative values encode disagreement with the statement proposed in the survey while the positive one encode agreement (see Table 7). The question presented to the respondents asked whether the subject would agree or disagree that a certain Micro-Criterion would have been achieved after implementing the use case in which he/she/they would be involved.

Respondent Answer	Ordinal Value
Strongly disagree	2
Agree	1
Neutral	0
Disagree	-1
Strongly disagree	-2

Table 7 Respondent answer conversion to ordinal values

Once the data have been processed, the mean preference for each Macro-Criterion and UC has been calculated as shown in Table 8 (for more information on the procedure followed for the computation see chapter 3.1.3.2).

UC / Macro Criteria	Operational and Technical	Societal	Environmental
Use Case 1	1.10	0.25	-0.25
Use Case 5	0.86	0.50	0.38
Use Case 6	1.02	0.75	0.00
Use Case 8	0.71	0.07	1.55
Use Case 10	0.69	0.07	1.55
Use Case 11	0.78	0.08	1.33

Table 8 Mean respondents' preference for each Macro Criteria and use case, authors' elaboration

Finally, the ranks obtained by all the five selected MCA tools for each scenario and the average of the five models' output have been computed. Table 9 shows an example for the scenario where the weights for Environment and Societal Macro Criteria are greater than the weights applied to Technical and Operational one (see Scenario 7 "Underweight Technical/Operational"). As shown for this specific scenario some models rank use case scenarios similarly (e.g., Weighted Sum and Topsis).

UC / MCA tools	Weighted Sum	Weighted Product	Topsis	Ref Point Moora	Fmf Moora	Rank (Average)
Use Case 8	1	3	1	2	3	**1** (2.0)
Use Case 11	3	2	3	1	2	**2** (2.2)
Use Case 5	4	1	4	4	1	**3** (2.8)
Use Case 10	2	4	2	3	4	**4** (3.0)
Use Case 6	5	5	5	5	5	**5** (5.0)
Use Case 1	6	6	6	6	6	**6** (6.0)

Table 9 UC average rank for Scenario 7", authors' elaboration

The same process described above was repeated for all the scenarios and the results are discussed in next chapter.

3.1.5 Scenarios Analysis

From the comparison of the seven scenarios, it was possible to identify scenarios with similar rank order. There were two similar patterns, the former - called group A - presents at the first places UC8 and UC11, while at the last positions UC5 and UC1; the latter - called group B - shows UC5 and UC6 at first two places, while UC10 and UC1 at the last ones. Then, the two scenarios were split in two groups and their result combined in one rank. Table 10 shows the ranks for group A, and Table 11 those for group B.

Scenario / Rank	1	2	3	4	5	6
Scenario 1 “Equal Weights”	UC8	UC11	UC5	UC10	UC6	UC1
Scenario 4 “Outweigh Environmental”	UC8	UC10	UC11	UC5	UC6	UC1
Scenario 6 “Underweight Societal”	UC8	UC11	UC10	UC5	UC6	UC1
Scenario 7 “Underweight Technical and Operational”	UC8	UC11	UC5	UC10	UC6	UC1

Table 10 UC rank by Scenario (Group A only), authors’ elaboration

Scenario / Rank	1	2	3	4	5	6
Scenario 2 “Outweigh Technical and Operational”	UC5	UC6	UC1	UC11	UC8	UC10
Scenario 3 “Outweigh Societal”	UC5	UC6	UC11	UC8	UC1	UC10
Scenario 5 “Underweight Environmental”	UC5	UC6	UC11	UC8	UC1	UC10

Table 11 UC rank by Scenario (Group B only), authors’ elaboration

The scenarios in group A seem to be mostly associated with scenario with greater weight for the Macro-Criteria Environmental, while group B for the Technical, Operational and Societal ones. Table 12 shows the combined ranks for both groups. At first sight it is possible to notice that the two ranks show different ranks order. The combined scenario Environment placed in the first three places UC8, UC11 and UC10, while Technological, Operational and Societal one places UC5, UC6, and UC11.

Combined Scenario / Rank	1	2	3	4	5	6
A: “Environment”	UC8	UC11	UC10	UC5	UC6	UC1
B: “Technological, Operational and Societal”	UC5	UC6	UC11	UC1	UC8	UC10

Table 12 UC rank comparison by combined scenarios, authors’ elaboration

To produce a unique rank, two scenarios are combined, as reported in Table 13. In this combined scenario, UC5 and UC11 scored the same and they occupy the first positions of the rank, followed by UC8.

Use Case	Rank (Average)
Use Case 5	**1** (2.5)
Use Case 11	**1** (2.5)
Use Case 8	**3** (3.0)

Use Case 6	**4** (3.5)
Use Case 10	**5** (4.5)
Use Case 1	**6** (5.0)

Table 13 UC rank average by combined scenarios, authors' elaboration

3.2 Define Protocols for Assessing Critical Success Factors for the Optimization of Port Operations

3.2.1 Critical Success Factors for the optimization of port operations

The current work is aimed at evaluating Critical Success Factors for the optimization of port operations. The Critical Success Factors -from now on CSFs- considered in this study are related to the factors that make operations within ports more effective in the context of the use cases implemented within the 5G-LOGINNOV project (see Chapter 4 for a detailed presentation of the use cases). CSF has been defined as "those characteristics, conditions or variables that when properly sustained, maintained, or managed can have a significant impact on the success of a firm competing in a particular industry" (Leidecker and Bruno, 1984). Thus, CSFs are here considered to be those relevant factors identified by experts that allow ports to optimize their port operations.

The CSFs will be analysed and then ranked by leveraging information gathered from experts working on different positions for the three maritime hubs (Athens, Koper and Hamburg). In this context, experts are employees of companies involved in daily operations and services aimed at sustaining port operations. While Leidecker and Bruno (1984) suggest collecting the information through interviews, in this work answers have been collected thanks to an online survey delivered to all stakeholders involved in the project. To reflect the diversity of the respondents in terms of role and level of experience, the collected information is evaluated under different scenarios relating to different characteristics of the respondents namely a) years of experience and b) company sector within the logistics supply chain.

To run the experiments, data have been collected through a survey that asked opinions from experts in port operations on the CSFs, for further information on the data collection process and information gathered (see the Annex 2 for a complete list of the Critical Success Factors). The collected information has been then processed using different Multi Criteria Analytical (MCA) tools presented in section 3.1.3.3. The MCA tools used were implemented within the package scikit-criteria (Cabral, Luczywo, Zanazzi, 2016). The methodology presented in this work allows to investigate the CSFs that contribute the most to the optimization of port operations and to rank them differentiating responses among different groups of workers specialized in different activities (i.e., operation or information technology services) and have different levels of experience (i.e. less than 11 years of experience, between 11 and 21, and more than 21). One applied example is presented in chapter 3.2.4, and the results will be discussed in chapter 3.2.5.

The results of the current work could be useful to understand those aspects that are more critical for port operations. Thanks to their evaluation, it will be possible to unveil those CSFs that are more important for different groups of respondents.

3.2.2 Data description

A preliminary list of CSFs for port operations has been identified based on the work of Parola et al. (2017). The list has been integrated with additional CSFs identified by the project participants. The information was collected through a survey delivered to the stakeholders involved in 5G-LOGINNOV use cases and Living Labs. Thanks to the answers of 44 participants, it was possible to analyse the respondents' preferences on a list of 23 different Critical Success Factors (see Annex 2).

The questions asked in the survey were aimed at assessing which Critical Success Factors would ensure the greatest performance of the port and to what extent each will contribute. For each CSF, it was asked to express its degree of importance for achieving best results within a defined area of intervention. The participants expressed their preference on an ordinal scale based on five classes ordered from 'strongly disagree' to 'strongly agree' (see Table 7). In the survey, there was the possibility to add additional Critical Success Factors but none of the respondents proposed new ones.

The survey allowed to collect experts' opinions and preferences on a variety of CSFs from both managers and workers of the organizations involved in the project and specialized in some activities within the supply chain for logistics. Table 14 shows that most of the respondents are specialized in the fields of *Technology Provider* and *IT services* while a fewer are on *Shipping, Receiving* and *Warehouse* operations.

Feature	Criteria	Respondents (n)
Company Sector	Technology provider, Telco, IT	27
Company Sector	Shipping, Receiver, Warehouse	17
Total Answers for Company Sector		**44**

Table 14 Number of respondents by company sector, author's elaboration

Table 15 shows that out of 44 total respondents, the majority is *experienced*. For the purpose of this study, are considered experienced all those respondents with more than 11 years of experience. Indeed 36 respondents have more than 11 years of experience (and 15 respondents more than 21 years), while only 8 respondents have less than 11 years of experience.

Feature	Criteria	Respondents (n)
Years of Experience	Less than 11 years of experience	8
Years of Experience	Between 11 and 21 years of experience	21
Years of Experience	More than 21 years of experience	15
Total Answers for Years of Experience		**44**

Table 15 Number of respondents by years of experience, author's elaboration

The different points of view of the respondents are based on their Company Sector and Years of Experience. The motivation for grouping respondents by these two features is that different experiences and company sectors are expected to prioritize differently the CSFs. The methodology in the next chapter will provide more detailed information on how CSFs were ranked for different groups.

3.2.3 Methodology

3.2.3.1 Why we need a methodology

To identify the most important CSFs, the first simple approach was to average over the preferences given by all participants for each CSF and rank them from the one with the highest average to the lowest. As shown in Table 16, the top five CSFs ranked by average preference highlight as successful factors the development of joint-projects on R&D, green issues, safety and security, inland infrastructures and improving sea-land operations that focuses and promote new green processes. Among the others, an important factor is to promote digital innovation within the port.

Rank	Critical Success Factor	Mean Preference
1	Development of joint-projects on R&D, green issues, safety and security, inland infrastructures	1.52
2	Green innovations in processes and facilities	1.38

3	Synchronization of sea-land operations	1.32
4	Respect of international green regulations	1.31
5	Encourage digital innovation and collaboration throughout the port	1.29

Table 16 Critical Success Factors ranked by average preference, author's elaboration

Even though taking the average of the preferences for each CSF is a quite neat trick to achieve an immediate solution to rank CSFs, this approach does not consider the different point of views and characteristics of the respondents. The second approach proposed to enlighten these differences by grouping respondents for each selected characteristic and using those groups as criteria for a Multi Criteria Analysis. For clarity, in the case of the company sector feature (see Table 14), the respondents will be split in two groups: one that works on providing technology (i.e., Technology provider, Telco, IT) and the other on running port operations (i.e. Shipping, Receiver, Warehouse). Each group will be used as criterion of a Multi Criteria Analysis that will allow to obtain a rank of preferred CSFs for the corresponding feature (e.g., company sector). The Multi Criteria Analytical tools used to rank CSFs have been presented in chapter 3.1.3.3 (i.e., weighted average, weighted product, Topsis, and Moora).

The main improvement achievable following this second approach is to give a representation that considers different ways of ranking CSFs by respondents' subgroup. Each subgroup will be considered as criteria of the Multi Criteria Analysis. Criteria are defined using the characteristics of the respondents in terms of operations performed within the logistic supply chain (i.e. company sector) and on their working experience (e.g. year of experience). The methodological approach as well as the analytical tools that was used to weigh the preferences from different subgroup will be discussed in the next chapter. The implementation of the methodology will be discussed in chapter 3.2.4 and the results leading to a comprehensive assessment of the CSF for different scenarios in the last chapter 3.2.5.

3.2.3.2 Methodology for ranking CSFs in different scenarios

The methodology for generating different scenarios is articulated as follows. First, the relevant features that characterize the respondents (i.e., company sector and years of experience) were identified. Depending on the selected feature, the number of criteria used to compute the rank will vary. For instance, the feature "Company Sector" has two subgroups (i.e., technology providers and operations) so the rank will be computed using two criteria, while "Work Experience" will have three (i.e. less than 11 years, between 11 and 21, more than 21). Different weights were assigned to each criterion to account for variations. A scenario is a combination of one set of criteria with a set of weights. Table 17 and Table 18 show the different scenarios that will be considered. There are seven scenarios in total, which encompass a wide variety of settings considering both equal weights among criteria as well as criteria outweighing one and the others.

Scenario / Criteria Weights	Technology provider, Telco, IT	Shipping, Receiver, Warehouse
Scenario 1 "Equal Weights"	0.50	0.50
Scenario 2 "Operational"	0.10	0.90
Scenario 3 "Technological"	0.90	0.10

Table 17 Weights by company sector criteria and scenarios, authors' elaboration

Scenario / Criteria Weights	Less than 11 years	Between 11 and 21 years	More than 21 years
Scenario 4 "Equal Weights"	0.33	0.33	0.33
Scenario 5 "Young"	0.90	0.05	0.05

Scenario 6 “Experienced 11<x<21 years”	0.05	0.90	0.05
Scenario 7 “Experienced >21 years”	0.05	0.05	0.90

Table 18 Weights by years of experience criteria and scenarios, authors' elaboration

The role of the weights here is to simulate how the rank will vary based on the decision of the evaluator of giving more importance to one or the other criterion. In the case of the criterion “company sector”, the evaluator could decide to assign greater weights to those respondents working on operations compared to those providing technology to look at how that specific group would rank the CSFs. Just to clarify, for one criterion, different scenarios can be generated by changing the weights (see tables above). To reduce the space of the solutions, in this work, only a limited set of scenarios are produced.

When the scenarios are set up, two sets of information are available: 1) a matrix with mean preferences for each criterion by CSF and 2) the weights for each criterion. The rank for each scenario is obtained using the Multi Criteria Analytical tools. Five different Multi Criteria approaches have been implemented. Then, the average of the five ranks was considered to obtain a unique rank for each scenario. The main reason for doing so is to reduce the biases and limitations of the MCA tools.

The output of the methodology is a list of ranks, one per scenario, representative of different subgroups of the respondents. The output will allow for comparing settings where the subgroups are alternatively more relevant to the others to account for differences on the CSF ranks (see chapter 3.2.5). To summarize, the methodology can be broken down in few steps listed below:

1) Set criterion (select a feature that characterizes respondents).
2) Compute mean preference for each CSF and for each criterion.
3) Create scenarios (assign different weights to each criterion).
4) Compute ranks for each scenario using different MCA tools.
5) Average ranks for each scenario.
6) Compare ranks of more diverse scenarios.

3.2.4 Generate Scenarios and Rank CSFs

To generate and rank CSFs for each scenario, it was followed a similar procedure already described in chapter 3.1.4. First, the dataset was cleaned from those respondents that did not provide an answer to the questions in the survey necessary to assess the CSFs importance. After, data were cleaned to be computer readable by converting the answers of the respondent from categorical data type to numerical (see Table 7). For this purpose, it was deployed an ordinal scale of values in the range from -2 to +2, where negative values encode disagreement with the statement and the positive one agreement. The question presented to the respondents asked whether the subject would agree or disagree that a certain CSF would have been important for the optimization of port operations.

Once the data have been processed, the mean preference for each Criterion and CSF was computed and the set of weights for each scenario were set up (see Table 17 and Table 18). The final rank was obtained as the average of the ranks obtained with all the five selected MCA approaches. Table 19 and Table 20 show respectively the ranks for the scenarios associated with company sector and with the years of experience.

3.2.5 Discuss Scenarios

Table 19 presents the rank for the three scenarios generated from the company sector criteria. From the table below is evident that the two subgroups of respondents in which the feature was split (i.e. Shipping, Receiving, and Warehouse versus Technology Provider, IT, and Telco) have different, almost opposite, perspectives on what the five top CSFs are:

Rank	Scenario 1 "Equal Weights"	Scenario 2 "Operational"	Scenario 3 "Technological"
1	*Synchronization of sea-land operations*	***Synchronization of sea-land operations***	***Development of joint-projects on R&D***
2	*Respect of international green regulations*	*Respect of international green regulations*	*Green innovations in processes and facilities*
3	*Development of joint-projects on R&D*	***Presence of dedicated terminals ensuring a stable cargo base***	***Encourage digital innovation and collaboration throughout the port***
4	*Green innovations in processes and facilities*	*Green innovations in processes and facilities*	*Respect of international green regulations*
5	*Encourage digital innovation and collaboration throughout the port*	***Sustainable port planning***	***Real-time and large-scale data processing***

Table 19 CSF rank by scenario for company sector criteria, authors' elaboration

Indeed, from the comparison between scenario 2 "Operational" and scenario 3 "Technological" (which respectively assign greater weights to Shipping, Receiving, Warehouse, and to Technology Provider, IT), it is clearly possible to see that three out five Critical Success Factors are different (written in bold in Table 19). While in scenario 2 the factors considered as more important are synchronization of sea-land operations, the presence of dedicated terminals and a sustainable approach for sustainable port planning, in Scenario 3 the favourites factors are to develop joint-projects on R&D, green issues, safety and security, inland infrastructures, to encourage digital innovation as well as to use real time and large-scale data. Indeed, while in the "Operational" Scenario the CSF named *Respect of International green regulations* is more important than the one aimed at promoting green innovation processes and facilities (respectively ranked 2nd and 4th), in the "Technological" Scenario the two CSFs are ranked in the opposite order (4th and 2nd). Table 20 shows the rank of the CSFs for the entire set of scenarios considered when assigning different weights to the criteria related to the respondents split by "Years of Experience". The most notable fact is that the four scenarios show the same CSFs within the top five positions. There are minimal differences between the pair comparison of these scenarios, and they are related to the position in the rank of two CSFs, highlighted in bold. These are real time and large-scale data processing and respect of international regulations. Other differences in the rank order are between the Scenario "Young" and "Experienced". The former gives more importance to green operation, while the latter to develop of joint-projects on R&D, green issues, safety and security, inland infrastructures. Thus, the comparison between scenarios related to different Years of Experience does not seem to yield to major differences when compared among each other.

Rank	Scenario 4 "Equal Weights"	Scenario 5 "Young"	Scenario 6 "Experienced 11<x <21 years"	Scenario 7 "Experienced x >21 year"
1	*Development of joint-projects on R&D*	*Green innovations in processes and facilities*	*Development of joint-projects on R&D*	*Development of joint-projects on R&D*
2	*Green innovations in processes and facilities*	*Development of joint-projects on R&D*	*Green innovations in processes and facilities*	*Green innovations in processes and facilities*
3	*Synchronization of sea-land operations*	*Encourage digital innovation and collaboration throughout the port*	*Synchronization of sea-land operations*	***Respect of international green regulations***
4	***Real-time and large-scale data***	*Synchronization of sea-land operations*	*Encourage digital innovation and*	***Real-time and large-scale data***

	processing		*collaboration throughout the port*	***processing***
5	*Encourage digital innovation and collaboration throughout the port*	***Real-time and large-scale data processing***	***Respect of international green regulations***	*Synchronization of sea-land operations*

Table 20 CSF rank by scenario for years of experience criteria, authors' elaboration

In conclusion, the two most different scenarios among those considered in the study are Scenario 2 “Operational” and Scenario 4 “Equal Weights” (related to the criteria Year of Experience). The CSFs in bold in Table 21 do not appear in both list and they encompass a wide variety of factors. While the CSF respect of international green regulations, the presence of dedicated terminals ensuring a stable cargo base and sustainable port planning are more important in the opinion of respondent involved in port operations, this is not the case for the scenario “Equal Weights” in which rank they do even appear. Vice versa, factors such as development of joint-projects on R&D, green issues, safety and security, inland infrastructures, real time data processing, and digital innovation are themes present in the “Equal Weights” scenario and not in the “Operational”. Another interesting difference is also the position within the rank of the two CSFs that appear in both lists. While synchronization of sea-land operations is ranked first in Scenario 2, it is not as important in Scenario 4 where it places itself third one in the rank.

Rank	Scenario 2 “Operational”	Scenario 4 “Equal Weights”
1	*Synchronization of sea-land operations*	***Development of joint-projects on R&D***
2	***Respect of international green regulations***	*Green innovations in processes and facilities*
3	***Presence of dedicated terminals ensuring a stable cargo base***	*Synchronization of sea-land operations*
4	*Green innovations in processes and facilities*	***Real-time and large-scale data processing***
5	***Sustainable port planning***	***Encourage digital innovation and collaboration throughout the port***

Table 21 Pair Comparison of the scenarios with most different CSFs rank, authors' elaboration

In conclusion, an approach that is aimed at identifying the important factors for the optimization of port operations should consider all the eight different CSFs listed in Table 21 for providing a complete overview of different perspective of workers employed in the optimization of port operations.

4 QUANTITATIVE ANALYSIS

The quantitative analysis is mainly focused on the definition of the KPIs for each use case and Living Lab. The objective of the KPIs is to provide a measure of the impact of each use case based on the data collected during the demonstrations; furthermore, the KPIs are defined according to the outcomes of 5G-LOGINNOV. For this reason, each KPI is mapped to the measurable objectives and indicators that are reported in deliverable D1.1. This approach allows to verify that each objective can be measurable quantitatively. In case it cannot be measured quantitatively, it will be measured qualitatively in the framework of the MCA.

In the next sections, an overview of 5G KPIs measured in the three LL is provided. Furthermore, each Living Lab is briefly introduced and the measurable objectives and indicators are associated to the KPIs. Successively, each use case and the related 5G technologies are briefly described as well as each KPI; the description of the KPIs includes the information on the type of data needed to calculate them and the information on the owner of the data.

4.1 5G KPIs

In this section, we present an overview of the KPIs related to 5G network and functioning. The objective is to measure the impact of the 5G network on the use cases demonstrated in the LLs.

LL	UC	UC Name(s)	Measurable Objectives and Indicators	Validation/Measurable Outcomes	KPI(s)
Athens	2,3,4	Device Management Platform Ecosystem Optimal Selection of Yard Trucks Optimal Surveillance Cameras and Video Analytics	5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements	Deployment and validation of the 5G network and services in Athens LL. Support for the operation of use cases.	• End-to-end Latency • One-way Latency.
Athens	3,4,5,7	Optimal Selection of Yard Trucks Optimal Surveillance Cameras and Video Analytics Automation for Ports: Port Control, Logistics and Remote Automation Predictive Maintenance	5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements	Deployment and validation of the 5G network and services in Athens LL. Support for the operation of use cases.	• Connection Density • Reliability
Athens	4,5	Optimal Surveillance Cameras and Video Analytics Automation for Ports: Port Control, Logistics and Remote Automation	5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements	Deployment and validation of the 5G network and services in Athens LL. Support for the operation of use cases.	• Area Traffic Capacity • Bandwidth • User Experienced Data Rate
Athens	4,5	Optimal Surveillance Cameras and Video Analytics Automation for Ports: Port Control, Logistics	Novel surveillance technologies and mechanisms (pioneering portable 5G-IoT device, AI/ML based video analytics) with MANO orchestration Support	Development and deployment of novel 5G-IoT devices to support UC4 and UC5 in Athens LL.	Deployment Time (NFV-MANO service)

		and Remote Automation			
Hamburg	8,9,10,11	Floating Truck & Emission Data 5G GLOSA & Automated Truck Platooning (ATP) - under 5G-LOGINNOV Green initiative Dynamic Control Loop for Environment Sensitive Traffic Management Actions	Support the 5G next generation network architecture to deploy use case	5G communication systems will be able to support dedicated bandwidths (per user) over 500MBit/s - depending on deployed network structure. LL Hamburg will use the production network of T-Mobile with 5GNR (in 3.5 GHz spectrum) to get this high capacity	Extended cellular band-width on urban roads by 5G network
Hamburg	8,9,10,11	Floating Truck & Emission Data 5G GLOSA & Automated Truck Platooning (ATP) - under 5G-LOGINNOV Green initiative Dynamic Control Loop for Environment Sensitive Traffic Management Actions	Support the 5G next generation network architecture to deploy use case	The product solution of Deutsche Telekom with the partner Skylark will provide a precision level on 10 cm (comparable with 3 - 10 m for uncorrected GNSS signal. This solution will be integrated in the LL Hamburg use cases to increase the precision by factor 10 and to reduce the complexity of the solution (map matching will be much simpler)	Positioning quality on ur-ban road networks with 5G by 10 cm
Hamburg	8,9,10,11	Floating Truck & Emission Data 5G GLOSA & Automated Truck Platooning (ATP) - under 5G-LOGINNOV Green initiative	Support the 5G next generation network architecture to deploy use case	Signal latency in the 5G environment will be reduced thru Mobile Edge Computing (MEC). The signal transfer time and the stability of the transmission will be improved. The signal transfer delay (latency) can come down near to 10 ms	Average signal latency in the 5G environment will be reduced thru Mobile Edge Computing (MEC) near to 10 ms during vehicle trips

		Dynamic Control Loop for Environment Sensitive Traffic Management Actions			
Hamburg	8,9,10,11	Floating Truck & Emission Data 5G GLOSA & Automated Truck Platooning (ATP) - under 5G-LOGINNOV Green initiative Dynamic Control Loop for Environment Sensitive Traffic Management Actions	Support the 5G next generation network architecture to deploy use case	Mean PER in the 5G environment is an indication of 5G the network performance. The PER will be monitored on the IP layer. Reduction or PER by 10%.	Packed Error Rate (PER) in 5G NSA production network
Koper	1	Management and Network Orchestration platform (MANO)	Enhancing 5G IoT backend system elements with new NFV functionalities and MANO orchestration support - Remote network monitoring (OSM-CNF/rMON) IoT platform	Deployment and validation of the 5G IoT backend system components in LL Koper to support operation of the UC1	• Components Onboard-ing and Configuration (Backend) • Deployment Time (Backend) • Time to Scale (Backend) • Service Availability (Backend) • Components Onboard-ing and Configuration (Agent) • Deployment Time (Agent)
Koper	1,5, 6	Management and Network Orchestration platform (MANO)	Dedicated private mobile system that will be built as standalone and self-operated 5G network and services platform infrastructure - VNF network	Deployment and validation of the 5G network and services in LL Koper to support operation of the UC1, UC5 and UC6	• Components Onboard-ing and Configuration (Backend) • Deployment Time

			(OSM-VNF) Private 5G network		(Backend) • Time to Scale (Backend) • Service Availability (Backend) • Slice Reconfiguration (Backend)
Koper	1,5, 6	Management and Network Orchestration platform (MANO)	Private 5G-based mobile services provided by the national MNO (Mobile Network Operator), tailored to the needs of port operation, will be provisioned and operated over the public MNO infrastructure	Deployment and validation of the 5G network and services in LL Koper to support operation of the UC1, UC5 and UC6	• Area Traffic Capacity • Availability • Bandwidth • Connection Density • Coverage Area Probability • End-to-End Latency • Reliability

4.2 Athens LL

The Athens LL is located at the port of Piraeus in Greece. Piraeus Container Terminal (PCT), wholly owned by COSCO Shipping Ports Limited (former COSCO Pacific Limited "CPL"), is currently ranked 4th among the busiest European Ports of 2020 in terms of container throughput, moving about 5.5 million TEUs on an annual basis. With the completion of Pier III, the throughput capacity of the port will reach 6,8M TEUs and container traffic is expected to increase. The Company's main activities are the provision of loading/unloading and storage services for import and export containers handled via the Port of Piraeus, including cargoes which use Piraeus only as an intermediary station of transport (transhipment cargo). The strategic location of Piraeus makes it an ideal port to be used as a hub for destinations in the Central and Eastern Mediterranean, as well as the Black Sea.

Overall, 5G-LOGINNOV at Athens LL will optimise various port operations through a diverse set of use cases including: (i) the optimal assignment of container jobs based on localisation (and other sensor) data of yard trucks; (ii) coordination with external truck operations; (iii) improvement of personnel safety; (iv) automation for ports: port control, logistics and remote automation through analytics of 4K video streams (enabled as a far-edge computing services based on computer vision and machine learning techniques); and (v) predictive maintenance service in port assets (i.e., yard trucks). The project's goals will be achieved by the deployment of 5G network at PCT premises, and the installation of several 5G-connected end devices: 5G access points installed on trucks connected to several data sources, the deployment of the envisioned 5G-IoT devices (and video analytics services) as well as the deployment of 4K surveillance cameras at specific areas of interest.

The described use cases (as explained in detail in D1.1) will exploit low latency communications and the enhanced Mobile Broadband (eMBB) service of 5G technology to address several challenges of daily port operations also considering the environmental footprint (and societal impact) of port activities in the nearby area. For the evaluation of the use cases several KPIs are selected and are explained below. All necessary data for the evaluation procedure of the KPIs will be collected (and pre-processed following the privacy/security regulations of the Piraeus port) at PCT and sent (at specific intervals) to the data collection tool that will be developed in deliverable D2.2.

4.2.1 Athens LL: Use Case, Measurable Objectives and KPIs

UC	UC Name(s)	Measurable Objectives and Indicators	Validation/Measurable Outcomes	KPI(s)
2,3,4	Device Management Platform Ecosystem Optimal Selection of Yard Trucks Optimal Surveillance Cameras and Video Analytics	5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements	Deployment and validation of the 5G network and services in Athens LL. Support for the operation of use cases.	• End-to-end Latency • One-way Latency.
3,4,5,7	Optimal Selection of Yard Trucks Optimal Surveillance Cameras and Video Analytics Automation for Ports: Port Control, Logistics and Remote Automation Predictive Maintenance	5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements	Deployment and validation of the 5G network and services in Athens LL. Support for the operation of use cases.	• Connection Density • Reliability
4,5	Optimal Surveillance Cameras and Video Analytics Automation for Ports: Port Control, Logistics and Remote Automation	5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements	Deployment and validation of the 5G network and services in Athens LL. Support for the operation of use cases.	• Area Traffic Capacity • Bandwidth • User Experienced Data Rate

4,5	Optimal Surveillance Cameras and Video Analytics Automation for Ports: Port Control, Logistics and Remote Automation	Novel surveillance technologies and mechanisms (pioneering portable 5G-IoT device, AI/ML based video analytics) with MANO orchestration Support	Development and deployment of novel 5G-IoT devices to support UC4 and UC5 in Athens LL.	• Model Accuracy/ Reliability • Model Inference Time • Deployment Time (Human Presence and Container Seal)
7	Predictive Maintenance	Improve utilisation of the port warehouses and storage spaces by at least 15%	Development and deployment of predictive maintenance service of UC7.	Parts in Stock
7	Predictive Maintenance	Reduce total cost of spare parts and tyres annually by at least 10%	Development and deployment of predictive maintenance service of UC7.	• Parts in Stock • Vehicle Breakdowns • Vehicles Under Maintenance • Vehicles Unexpected Breakdown • Maintenance Costs of Vehicles
2	Device Management Platform Ecosystem	Reduce percentage of empty container runs by 15%	Development and deployment of device management platform ecosystem service of UC2 at Athens LL.	Percent of Empty Containers Runs
5	Automation for Ports: Port Control, Logistics and Remote Automation	Reduce vessel operation completion times by at least 5%	Development and deployment of UC5 automation for ports: port control, logistics and remote automation.	Vessel Operation Completion Time
2	Device Management Platform Ecosystem	Traffic redistribution in port operations based on real-time truck localization data	Development and deployment of device management platform ecosystem of UC2 at Athens LL.	Mean time of container job
2	Device Management Platform Ecosystem	Reduced time for a device to connect to the network in comparison to existing 3G / 4G based devices	Development and deployment of device management platform ecosystem service of UC2 at Athens LL.	Time needed the device to open network connection

2,3	Device Management Platform Ecosystem Optimal Selection of Yard Trucks	• Extrapolation of the potential CO_2/NO_X savings based on the real traffic volume to the port terminals. • Reduce emissions produced by trucks delivering/picking up containers at least 15%	Development and deployment of optimal selection of yard trucks services of UC3 and device management platform ecosystem service of UC2 at Athens LL.	• CO_2 Emissions • Fuel Consumption • Truck Travel Distance
3,7	Optimal Selection of Yard Trucks Predictive Maintenance	Minimise percentage of yard equipment assets idling for more than one shift	Development and deployment of optimal yard truck selection service of UC3, and predictive maintenance service of UC7 at Athens LL.	Assets Idling
4,5	Optimal Surveillance Cameras and Video Analytics Automation for Ports: Port Control, Logistics and Remote Automation	Optimise the use of human resources in yard equipment port operations	Development and deployment of UC4 surveillance cameras and video analytics, and UC5 automation for ports: port control, logistics and remote Automation.	Human resource optimization (person hours)

Table 22 Athens LL: Use case, Measurable Objectives and KPIs

4.2.2 LL Athens 5G Network and Services

In the port of Piraeus, Living Lab of Athens, the 5G network following the NSA option of Release 15 will be established at the port premises, provided by the MNO Vodafone, to facilitate the requirements of the use cases, and address the KPIs for evaluation as explained in the following sub-sections. Figure 3 depicts at a high-level the overall architecture of the use cases targeting 5G connected yard/external trucks and distributed 5G-IoT devices. 5G technologies will enable the use case innovations exploiting the eMBB service, low latency transmissions and enhanced localization services of the cellular infrastructure at the port premises, including MANO-based services and orchestration, pioneering far-edge computing services, computer vision and AI/ML video analytics.

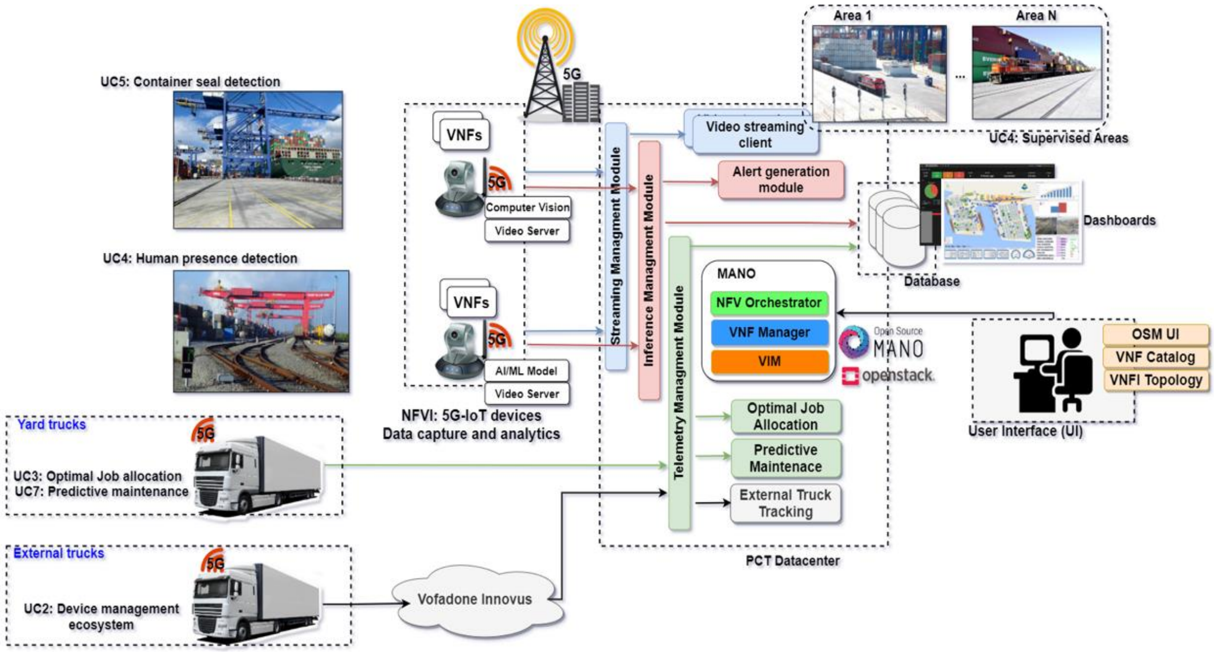

Figure 3: Use case architecture and layout overview, Athens Living Lab

Particularly an NFV-MANO platform will be deployed targeting service orchestration and life-cycle management to distributed 5G-IoT devices within the port premises (tailored to respective video analytics scenarios, i.e., human presence detection (UC4) and container seal detection (UC5)), targeting port operations optimization, safety of personnel, and security with coordinated UHD video surveillance. In more detail, a set of 25 STS cranes are currently operational at the quay side at PCT premises, and an additional 5 (adding up to a total of 30) cranes will be installed in July 2021. Given budget constraints of the 5G-LOGINNOV project, a set of 5G-IoT devices will be deployed on STS cranes targeting UC5, whereas additional 5G-IoT devices will be deployed for UC4. Both use cases, will employ computer vision techniques tailored to the respective analytics task (please refer to D1.1 and D1.3 for more details) at particular areas of interest, and transmit voluminous UHD video streams towards PCT management platform. The requirements of these services are mostly focused on uplink traffic. Such uplink-data-intensive applications call for enhanced capacity than cannot be served with legacy LTE networks. Hence, 5G-NSA cellular communications exploiting the eMBB service of 5G technology are needed to ensure the successful operation of the envisioned use cases.

For the use cases that employ 5G connected yard-trucks (UC2, UC3 and UC7) we target the low latency transmissions and, in some cases, the enhanced localization services of 5G technology. At PCT about 170 yard trucks are operational within the port area of about 2 square kilometres. In addition to this fleet of yard trucks, external truck visits rise up to about 1100 trucks in a daily basis, adding up to increased traffic within the port premises. Efficient management and coordination of port operations is thus of paramount importance, as delays on truck operations will pose delays also in several work chains (i.e., dependent operations) at the port of Piraeus. Particularly, current accuracy of GPS system combined with (average) trucks speed of 35Km/hr often results in feeding the container job assignment algorithm (UC3) with truck positions that are more than 50 meters away (or about 20 containers away) from the actual truck location, hence providing a sub-optimal allocation of container jobs. This results in truck drivers performing a number of manoeuvres (in a relatively limited space, which as described hosts a fairly significant number of trucks on a daily basis), potentially causing traffic incidents, increased fuel consumption (and CO2 emissions), as well as causing additional delays, e.g., in the loading/unloading process of vessels, hence, extending the vessel stay at the port premises. Near real time situational awareness achieved through low latency transmissions of 5G and precise positioning of yard vehicles is key enabling solution to address the needs of the use case, whereas adding information from external vehicles towards the port of Piraeus (UC2, using anonymized data from live vehicles) will further improve the coordination of operations. Finally, telemetry data will be exploited from several data source on-board yard trucks (CAN-Bus, custom sensors etc.) that will be used by the predictive maintenance algorithm (UC7) where 5G technology will be exploited providing a flexible, reliable and predictable environment to remotely keep track of the connected assets on a real time basis, i.e., end-to-end monitoring of assets performance in all phases of daily port operations.

The following subsections list the selected KPIs per use case including also the 5G and technical KPIs that will be exploited by Athens LL.

4.2.3 Optimal Selection of Yard Trucks (UC3)

The horizontal movement of containers between stacking areas and loading/unloading areas for vessels and rail is of paramount importance for several work chains at PCT. This use case will equip yard trucks with 5G access points that collect and transmit telemetry data (CAN-Bus, container presence sensor data, GNSS) from the truck, over the 5G network to PCT's operations management platform. The aggregated telemetry data from the fleet of 5G connected yard trucks will be exploited by the algorithm that optimally assigns container jobs to yard trucks based on real-time localization data and the current load (i.e. carried containers) of each truck. The envisioned use case will have a direct impact on the environmental footprint of port operations by decreasing the travel distance, CO_2 emissions and fuel consumption of yard trucks (via selecting the closest/optimal available truck to jobs), as well as expediting port operations. The enhanced localisation services and low latency transmissions will constitute the key element blocks for realizing the objectives of the use case targeting the optimal operation scheduling of 5G-connected yard trucks.

KPI ID	A-KPI1
Measurable objectives and indicators	Extrapolation of the potential CO_2/NO_X savings based on the real traffic volume to the port terminals.
KPI	CO_2 Emissions.
Description	Reduction in the CO_2/NO_X emissions of yard vehicles (average) in daily port operations for the horizontal movement of containers between stacking areas and loading/unloading areas for vessels and rail.
Data Needed	Travel distance per vehicle, fuel consumption per vehicle.
Owner	PCT

KPI ID	A-KPI2
Measurable objectives and indicators	Reduce emissions produced by trucks delivering/picking up containers at least 15%
KPI	Fuel Consumption

Description	Reduction in the fuel consumption of yard vehicles (average) in daily port operations for the horizontal movement of containers between stacking areas and loading/unloading areas for vessels and rail
Data Needed	Travel distance per vehicle, fuel consumption per vehicle
Owner	PCT

KPI ID	A-KPI3
Measurable objectives and indicators	Reduce emissions produced by trucks delivering/picking up containers at least 15%
KPI	Truck Travel Distance
Description	Reduction of yard truck travel distance (average) in daily port operations for the horizontal movement of containers between stacking areas and loading/unloading areas for vessels and rail
Data Needed	Travel distance per vehicle in daily port operations
Owner	PCT

KPI ID	A-KPI4
Measurable objectives and indicators	Minimise percentage of yard equipment assets idling for more than one shift
KPI	Assets Idling
Description	Reduction in percent of yard trucks staying idle, i.e., not participating in port operations
Data Needed	Active/open container jobs, container presense sensor data (from on-truck sensors)
Owner	PCT

Additional KPIs for UC3 are *End-to-end Latency* (A-KPI25) and *One-way Latency* (A-KPI26) presented in detail in sub-section 4.2.8.

4.2.4 Device Management Platform Ecosystem (UC2)

This task leverages existing fleet management features of the Vodafone Innovus IoT platform. The features include real-time map visualization, event and augmented with external traffic data sources. The use of this system is to enable fleet management personnel to take actions and decisions based on current and historical analysed data.

KPI ID	A-KPI5
Measurable objectives and indicators	Reduce percentage of empty container runs by 15%
KPI	Percent of Empty Containers Runs
Description	By counting the number of non-full arrivals (20ft) at PCT
Data Needed	Location of containers, pick up/drop-off locations, real time localization
Owner	PCT, Vodafone

KPI ID	A-KPI6
Measurable objectives and indicators	Traffic redistribution in port operations based on real-time truck localization data
KPI	Mean time of container job
Description	Based on the real time ETA (estimated times of arrival) of external trucks, reassign Straddle Carriers (SCs) to either external or internal container jobs. This KPI will capture the reduction in time spent by external trucks at the port premises
Data Needed	Number of yard equipment available for external trucks, real time localization of external trucks, time spent by external truck in port premises
Owner	PCT, Vodafone

KPI ID	A-KPI7
Measurable objectives and indicators	Reduced time for a device to connect to the network in comparison to existing 3G/4G based devices
KPI	Time needed the device to open a network connection
Description	When the device wakes up from hibernation, it takes an amount of time for the modem to connect and post data; the project investigates the reduction of this time
Data Needed	Device-network connection data
Owner	Vodafone

KPI ID	A-KPI25
Measurable objectives and indicators	Reduced time for a data packet to be posted via network
KPI	End-to-end Latency
Description	Each packet generated and posted from a device takes a time to be

	submitted to the platform. This time is expected to be reduced due to the 5G low latency
Data Needed	Device-platform data
Owner	Vodafone

Additional KPIs for UC2 are *CO_2 Emissions* (A-KPI1) and *Fuel Consumption* (A-KPI2), described in sub-section 0 and *One-Way Latency* (A-KPI26) presented in sub-section 4.2.8.

4.2.5 Optimal Surveillance Cameras and Video Analytics (UC4)

Frequent incidents involving boom collisions, gantry collisions or stack collisions, along with the presence of stevedoring personnel in port areas, make the risk for serious bodily injuries considerable. This use case aims at determining human presence in restricted areas (e.g. railways, areas with increased crane operations, etc.) and thus minimizing the risk for serious bodily injuries. 5G-IoT devices will be deployed at selected risk areas, equipped with a high-resolution camera (e.g. 4K, UHD), to perform locally video analytics tasks. eMBB service of 5G technology will be exploited for consuming 4K surveillance video streams. Additionally, innovative machine learning (ML) techniques will be developed and deployed at the 5G-IoT device for human presence detection. Hence, the inference accuracy and inference time of the machine learning model is of great significance for realizing the objectives of the use case. In addition to the fact that this use case increases safety measures of the employees' workplace, it also opens up opportunities to optimize (and/or redistribute) the use of human resources in different port operations, e.g. by reducing the patrol frequency at the risk areas (currently frequent patrols are distributed to inspect risk areas), as this service is automated by the use case.

KPI ID	A-KPI8
Measurable objectives and indicators	Optimise the use of human resources in yard equipment port operations
KPI	Human resource optimization (person-hours)
Description	Computer vision assisted surveillance of high-risk areas for automatically detecting human presence. Physical staff (appointed safety/security personnel) will no longer be needed for the service at the specified area(s). High resolution video of the selected area(s) is additionally streamed at PCT backend system
Data Needed	Computer vision model inference (i.e. human presence detected), video stream of specified area(s)
Owner	PCT

KPI ID	A-KPI9
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (pioneering portable 5G-IoT device, AI/ML based video analytics) with MANO orchestration Support
KPI	Model Inference Time
Description	The time required for the machine learning model to process the input of video stream(s) and infer the presence/absence of people in the

	selected area(s)
Data Needed	Time dedicated for analysing each of the video/images of the risk area(s)
Owner	ICCS, PCT

KPI ID	A-KPI10
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (pioneering portable 5G-IoT device, AI/ML based video analytics) with MANO orchestration Support
KPI	Model Accuracy/Reliability
Description	The accuracy (ratio of success) of the developed machine learning model for detecting the presence/absence of people in specified (risk) area(s) Based on the resulting confusion matrix and the derived true/false positive/negatives relevant ratios of the classifier, precision (fraction of correctly classified instances containing humans among the entirety of instances classified as such) and recall (fraction of correctly classified instances containing humans among the entirety of instances actually containing humans) for each of the two classes (i.e., human present or not) will be calculated
Data Needed	Openly available datasets will be utilized and context-specific annotated data will be produced (annotated images/video data that will be considered as ground truth) and exploited for training the model. The model (on-board the 5G-IoT device) will process video data from specified cameras (positioned at relevant risk areas) at PCT premises to infer the presence/absence of humans
Owner	ICCS, PCT

KPI ID	A-KPI11
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (pioneering portable 5G-IoT device, AI/ML based video analytics) with MANO orchestration Support
KPI	User Experienced Data Rate
Description	The data rate that is experienced by the 5G-IoT device for delivering voluminous video streams to PCT's backend system. Due to 5G technology higher data rates can be achieved to accommodate for high resolution video streams (e.g. 4K, UHD) that will be transmitted to the control platform that monitors specific high-risk areas to minimize the risk for serious bodily injuries
Data Needed	Experienced data rate (Mbps)
Owner	ICCS, PCT

KPI ID	A-KPI12
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (pioneering portable 5G-IoT device, AI/ML based video analytics) with MANO orchestration Support.
KPI	Deployment Time.
Description	Elapsed time from the moment the deployment is started via the orchestrator until the system is ready to use.
Data Needed	Time of service instantiation request, Time that the service activated.
Owner	ICCS

Additional KPI for UC4 is *One-way Latency* (A-KPI26) presented in sub-section 4.2.8.

4.2.6 Automation for Ports: Port Control, Logistics and Remote Automation (UC5)

This use case takes advantage of 5G infrastructure at the port and advanced computer vision techniques to detect the presence (or absence) of container seals during the loading (and unloading) process of vessels. 5G-IoT devices will be deployed at quay-side cranes directly connected with ultra-high-definition cameras. eMBB service will be exploited providing a live video stream from the device to PCT monitoring platform. Advanced computer vision techniques will be developed and deployed at the 5G-IoT device for automating the service of container seal presence/absence detection, emphasizing on the computer vision model's inference accuracy and inference time. Additionally, this use case aims at expediting the vessel operations completion time and optimizing the use of human resources. Particularly, a mother vessel at Piraeus needs (on average) about 3000 stevedore moves for operations completion. Seal-presence check currently requires one person and about 30 seconds to complete. Reducing this time by e.g. 3 seconds per container, results to 9000 seconds (or 2.5 hours) reduction of vessel stay at the port and removes the need for human presence at an area with high safety risks.

KPI ID	A-KPI13
Measurable objectives and indicators	Reduce vessel operation completion times by at least 5%
KPI	Vessel Operation Completion Time
Description	The developed computer vision model will automatically detect the presence/absence of container seals at the unloading/loading phase of vessels, alleviating (or minimizing) human personnel intervention (which consumes a considerable amount of time), hence, significantly accelerating the vessel operation completion time
Data Needed	Reduction in time for vessel operation completion time after the deployment of the use case
Owner	ICCS, PCT

KPI ID	A-KPI14
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (pioneering portable 5G-IoT device, AI/ML based video analytics) with MANO orchestration Support
KPI	Model Inference Time
Description	The time required for the computer vision model to process the input of video stream(s) and infer the presence/absence of container seals
Data Needed	Time dedicated for analysing each of the video/images of containers at the loading/unloading phase of vessels
Owner	ICCS, PCT

KPI ID	A-KPI15
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (pioneering portable 5G-IoT device, AI/ML based video analytics) with MANO orchestration Support
KPI	Model Accuracy/Reliability
Description	The accuracy (ratio of success) of the developed algorithm for detecting the presence/absence of container seals Based on the resulting confusion matrix and the derived true/false positive/negatives relevant ratios of the classifier, precision (fraction of correctly classified instances containing seals among the entirety of instances classified as such) and recall (fraction of correctly classified instances containing seals among the entirety of instances actually containing seals) for each of the two classes (i.e. container seal present or not) will be calculated
Data Needed	Video feed from PCT's vessel loading/unloading operations, focusing on the seal area and on the field training of the computer vision technique hosted at the 5G-IoT device. Annotated data made available from PCT, containing positive/negative examples of sealed/unsealed containers, respectively
Owner	ICCS, PCT

KPI ID	A-KPI11
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (pioneering portable 5G-IoT device, AI/ML based video analytics) with MANO orchestration Support
KPI	User Experienced Data Rate.
Description	The data rate that is experienced by the 5G-IoT device for delivering voluminous video streams at PCT backend system. Due to 5G technology higher data rates can be achieved to accommodate for higher resolution (e.g., 4K, UHD) video streams that will be transmitted at PCT backend, monitoring the procedure for loading/unloading containers to/from vessels.
Data Needed	Experienced data rate (Mbps).
Owner	ICCS, PCT

An additional KPI for UC5 is *Human resource optimization (person hours)* (A-KPI8) and Deployment Time (A-KPI12), described in sub-section 4.2.5.

4.2.7 Predictive Maintenance (UC7)

Predictive maintenance is a significant contributor to increasing operational efficiency and reducing unplanned downtime of expensive equipment by identifying and solving problems before they occur. A key concern at Athens LL is storing and managing bulky assets (such as spare/repair parts) that occupy significant space of the port, especially at PCT operating close to maximum annual capacity. This use case will equip yard trucks with 5G access points connected to truck's data sources (CAN-Bus, GNSS, and other on-truck sensors) that will be transmitted via the 5G network to PCT operations management platform. The accumulated telemetry data will be exploited by the predictive maintenance tool (based on insights from the COREALIS[2] project) to potentially predict possible breakdowns, reduce downtime for repairs and optimise stock of spare parts, increase the service life of yard vehicles and optimise operational efficiency through minimisation of breakdowns. The proposed tool will capture historical and recent status data for the assets in question, utilized by the ML algorithm and driving a per yard-vehicle data driven approach (schedule of purchases, storage of parts, proactive maintenance), by taking advantage of 5G technology that provides a flexible, reliable and predictable environment to remotely keep track of the connected assets on a real time basis.

KPI ID	A-KPI16
Measurable objectives and indicators	Reduce total cost of spare parts and tyres annually by at least 10%.
KPI	Parts in Stock.
Description	Number of items per part of yard trucks functional components. The accumulated telemetry data from sensors installed on yard trucks transmitted via the 5G network will be used by the AI/ML model that predicts possible malfunctions of functional parts of yard trucks, hence, optimizing the number of necessary parts in stock at PCT warehouse

[2] COREALIS is a H2020 project that proposes a strategic, innovative framework, supported by disruptive technologies, including IoT, data analytics, next generation traffic management and 5G, for modern ports to handle future capacity, traffic, efficiency and environmental challenges.

	for maintenance.
Data Needed	CAN-Bus, data from sensors installed on yard trucks, AI model inference, Enterprise asset system management data (EAM).
Owner	PCT

KPI ID	A-KPI17
Measurable objectives and indicators	Enhanced monitoring and predictive maintenance of port assets by collecting telemetry data from different sensors equipped on yard trucks in port Operations.
KPI	Vehicle Breakdowns.
Description	Reduce the number of yard truck breakdowns. 5G connected trucks transmit telemetry data from sensors installed on yard trucks. The transmitted data will be used by the AI/ML algorithm in order to anticipate possible malfunctions of yard truck functional components, hence providing insights and intervention indications to prevent potential breakdowns of yard vehicles.
Data Needed	CAN-Bus, data from sensors installed on yard trucks, AI model inference, Enterprise asset system management data (EAM).
Owner	PCT

KPI ID	A-KPI18
Measurable objectives and indicators	Enhanced monitoring and predictive maintenance of port assets by collecting telemetry data from different sensors equipped on yard trucks in port Operations.
KPI	Vehicles Under Maintenance.
Description	Reduce downtime for repairs. The accumulated sensor data from the fleet of 5G connected trucks will be used by the AI\ML algorithm to anticipate potential breakdown of vehicle components, and hence, pro-actively purchase/stock relevant assets/parts at PCT warehouse. This insight will minimize vehicles downtime for repairs, as relevant replacement parts will be in stock (available) at PCT premises.
Data Needed	CAN-Bus data, data from sensors installed on yard trucks, AI model inference, Enterprise asset system management data (EAM).
Owner	PCT

KPI ID	A-KPI19
Measurable objectives and indicators	Enhanced monitoring and predictive maintenance of port assets by collecting telemetry data from different sensors equipped on yard trucks in port Operations.

KPI	Vehicles Unexpected Breakdown.
Description	Reduce the number of unexpected yard truck breakdowns (Unscheduled maintenance). 5G connected trucks transmit telemetry data from on-board sensors. The transmitted data will be used by the AI/ML algorithm in order to anticipate eventual/potential breakdowns, and thus minimize events of corrective maintenance that take place after the occurrence of a breakdown.
Data Needed	CAN-Bus data, data from sensors installed on yard trucks, AI model inference, Enterprise asset system management data (EAM).
Owner	PCT

KPI ID	A-KPI20
Measurable objectives and indicators	Enhanced monitoring and predictive maintenance of port assets by collecting telemetry data from different sensors equipped on yard trucks in port Operations.
KPI	Maintenance Costs of Vehicles.
Description	Reduce maintenance costs of yard trucks. 5G connected trucks transmit telemetry data from sensors installed on yard trucks. The transmitted data will be used by the AI/ML algorithm in order to anticipate eventual breakdowns that lead to higher costs when handled with corrective maintenance or routine maintenance.
Data Needed	CAN-Bus data, data from sensors installed on yard trucks, AI model inference, Enterprise asset system management data (EAM).
Owner	PCT

An additional KPI for UC7 is *Assets Idling* (A-KPI4) described in sub-section 0.

4.2.8 Deployment and Validation of the 5G Network and Services

This subsection describes a set of KPIs related to the deployment of 5G technology at the port premises, addressing the successful operation of the envisioned use cases and their significance in port operations.

KPI ID	A-KPI21
Measurable objectives and indicators	Support the 5G next generation network architecture to deploy use case. 5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements.
KPI	Area Traffic Capacity.
Description	The total traffic throughput served per geographic area (in bps/m^2).
Data Needed	Throughput Served per Geographic Area: Site density, Bandwidth, Spectrum Efficiency.
Owner	Vodafone

KPI ID	A-KPI22
Measurable objectives and indicators	Support the 5G next generation network architecture to deploy use case. 5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements.
KPI	Bandwidth.
Description	Maximum TCP/IP uplink and downlink bandwidth measured from the end user device on 5G RAN to the reference server located in 5G core.
Data Needed	Total System Bandwidth (sys 1+ sys 2+ … + sys N).
Owner	Vodafone

KPI ID	A-KPI23
Measurable objectives and indicators	Support the 5G next generation network architecture to deploy use case. 5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements.
KPI	Connection Density.
Description	The total number of connected and/or accessible devices per unit area (per km^2).
Data Needed	Number of Active Devices in the Area Considered: Active Devices, Area.
Owner	Vodafone

KPI ID	A-KPI24
Measurable objectives and indicators	Support the 5G next generation network architecture to deploy use case. 5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements.
KPI	Reliability.
Description	The percentage (%) of the amount of sent network layer packets successfully delivered to a given system node (including the User Equipment) within the time constraint required by the targeted service, divided by the total number of sent network layer packets.
Data Needed	Packets Successfully Delivered, Total Number of Packets.
Owner	Vodafone

KPI ID	A-KPI25
Measurable objectives and indicators	Support the 5G next generation network architecture to deploy use case. 5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements.
KPI	End-to-End Latency.
Description	Measured round trip time (RTT) from the moment the IP ICMP Echo Request packet leaves the source host until the IP ICMP Echo Reply is received from the destination host.
Data Needed	Time from Source to Target Device (i.e., measured at the communication interface).
Owner	Vodafone

KPI ID	A-KPI26
Measurable objectives and indicators	Support the 5G next generation network architecture to deploy use case. 5G-based cellular communications system will be provided by the national Mobile Network Operator to meet the needs of port operations and address the use case requirements.
KPI	One-way Latency.
Description	The one-way latency is the total time that is required for a packet to be generated at the communication unit at the transmitter’s side, until it is received at the communication unit at the receiver’s side.
Data Needed	Time from Source to Target Device (i.e., measured at the communication interface).
Owner	Vodafone

4.3 Hamburg LL

With around 10 million containers, the Port of Hamburg is ranked No.3 in Europe. The disadvantage of the 70 km Elbe restricting access to the Northern Sea is compensated by the excellent rail network in the port and hinterland, of special importance for inter- and multimodal transport and logistics. Due to special situation as a city port, several terminals for container handling are spread across different parts of the city, which makes an efficient hand-over and automation within the intermodal transport chain (port internal transfers) of great importance for Hamburg's long-term competitiveness. Being part of the city's ITS Policy Strategy 2030 to optimize the transport chain, the inclusion of port transport logistics and hinterland connections was therefore crucial for the City of Hamburg policy makers (https://www.hamburg.com/business/its/11747566/strategy/).

For the ITS World Congress, which is scheduled in October 2021, Hamburg launched a test field for automated driving to optimize the access of trucks to the port terminals. The test field is available to all OEMs and mobility service providers for Car2X data exchange and other C-ITS functions. A total number of 26 traffic lights is currently available for Connected Automated Driving (CAD) test runs. The test field is located in the heart of the city close to the ferry boat terminals.

Besides ITS, the environmental pressure is another driver for innovation for the two-million city of Hamburg, ranked number two in Germany with regards to the number of citizens. Air pollution caused by trucks is crucial for the authorities in Hamburg and diesel ban was introduced together with other measures after emissions exceeded the regulations for environmental protection and clean air policy, as agreed in the Aarhus convention 1998. Adopted in German Ordinance on Air Quality Standards and Emission Ceilings, the Federal Government transposed the Aarhus EU directive into national legislation. Accordingly, the limit value for particulate matter was set at 50 $\mu g/m^3$, which may be exceeded on a maximum of 35 days a year. The average annual value for nitrogen dioxide was set at 40 $\mu g/m^3$. The EU directive obliges cities and municipalities to draw up action plans for air pollution control. These plans have formed the basis for the implementation of 48 Low Emission Zones (LEZ) with limited access for vehicles with high emissions so far. Hamburg has two restricted road segments where the annual average was exceeded, and diesel banned from entry.

In order to comply with the clean air regulations, the city wants to implement ITS solutions balancing the need for improving air quality with the economic interests of logistics service provider to deliver their goods in time and budget. Therefore, sustainable traffic management based on 5G and Connected and Automated Cooperative Mobility became a key pillar of Hamburg's 2030 ITS policy targets. The four use cases planned within 5G-LOGINNOV reflect this need for clean air projects including innovative traffic management and GLOSA-based Automated Truck Platooning.

4.3.1 Hamburg LL: Use Cases, Measurable Objectives and KPIs

UC	UC Name(s)	Measurable Objectives and Indicators	Validation/Measurable Outcomes	KPI(s)
8,9,10,11	Floating Truck & Emission Data 5G GLOSA & Automated Truck Platooning (ATP) - under 5G-LOGINNOV Green initiative Dynamic Control Loop for Environment Sensitive Traffic Management Actions	• Real-time emission data from truck sensors will be transferred to traffic controllers calculating the optimum speed for the automated truck platoon in the logistics corridor avoiding stop & go incident of the truck platoon • Facilitate the quantification of port decisions impact for mid-/long-term through Key Performance Indicators (KPIs): CO_2 emissions and air quality	5G real-time truck trip & emission data collected by LCMM, Entruck and Continental IoT devices by using 5G Precise Positioning technology. Measurement of fuel and emission reduction (CO_2/NO_X) of a truck platoon or trucks alone while driving with 5G GLOSA	• Increase average truck speed in single mode up to 5% • Reduction of average acceleration activities in single mode up to 5% • Reduction of stillstand time in single mode up to 5% • Increase average truck speed in platoon mode > 5% • Reduction of average acceleration activities in platoon mode > 5% • Reduction of stillstand time in platoon mode > 5% • Reduction of fuel consumption in single mode up to 10% • Reduction of CO_2 emission in single mode up to 10% • Reduction of fuel consumption in platoon mode up to 20% • Increase value of 'EPI - cl per ton and km' up to 10% for vehicle trips • Increase value of API 'KWh per ton and km' up to 10% for vehicle trips • Reduction of CO_2 emission in platoon mode up to 20%

UC	UC Name(s)	Measurable Objectives and Indicators	Validation/Measurable Outcomes	KPI(s)
8,9,10,11	Floating Truck & Emission Data 5G GLOSA & Automated Truck Platooning (ATP) - under 5G-LOGINNOV Green initiative Dynamic Control Loop for Environment Sensitive Traffic Management Actions	Support the 5G next generation network architecture to deploy use case	5G communication systems will be able to support dedicated bandwidths (per user) over 500MBit/s - depending on deployed network structure. LL Hamburg will use the production network of T-Mobile with 5GNR (in 3.5 GHz spectrum) to get this high capacity	Extended cellular bandwidth on urban roads by 5G net-work
8,9,10,11	Floating Truck & Emission Data 5G GLOSA & Automated Truck Platooning (ATP) - under 5G-LOGINNOV Green initiative Dynamic Control Loop for Environment Sensitive Traffic Management Actions	Support the 5G next generation network architecture to deploy use case	The product solution of Deutsche Telekom with the partner Skylark will provide a precision level on 10 cm (comparable with 3 - 10 m for uncorrected GNSS signal. This solution will be integrated in the LL Hamburg use cases to increase the precision by factor 10 and to reduce the complexity of the solution (map matching will be much simpler)	Positioning quality on urban road networks with 5G by 10 cm

UC	UC Name(s)	Measurable Objectives and Indicators	Validation/Measurable Outcomes	KPI(s)
8,9,10,11	Floating Truck & Emission Data 5G GLOSA & Automated Truck Platooning (ATP) - under 5G-LOGINNOV Green initiative Dynamic Control Loop for Environment Sensitive Traffic Management Actions	Support the 5G next generation network architecture to deploy use case	Signal latency in the 5G environment will be reduced thru Mobile Edge Computing (MEC). The signal transfer time and the stability of the transmission will be improved. The signal transfer delay (latency) can come down near to 10 ms	Average signal latency in the 5G environment will be re-duced thru Mobile Edge Computing (MEC) near to 10 ms during vehicle trips

UC	UC Name(s)	Measurable Objectives and Indicators	Validation/Measurable Outcomes	KPI(s)
8,9,10,11	Floating Truck & Emission Data 5G GLOSA & Automated Truck Platooning (ATP) - under 5G-LOGINNOV Green initiative Dynamic Control Loop for Environment Sensitive Traffic Management Actions	Support the 5G next generation network architecture to deploy use case	Mean PER in the 5G environment is an indication of 5G the network performance. The PER will be monitored on the IP layer. Reduction or PER by 10%.	Packed Error Rate (PER) in 5G NSA production network
	Qualitative Assessment	Facilitate the quantification of port decisions impact for mid-/long-term through Key Performance Indicators (KPIs): investments, stakeholder satisfaction, **accessibility**, modal split, CO_2 emissions, air quality, green energy, market share, employment; CT KPIs: truck turn time, yard inventory of containers, outbound trucks in port >1 hour, crane idle hours, (un)avoidable delay, (un)scheduled maintenance	5G-LOGINNOV 5G GLOSA & Automated Truck Platooning influencing urban road traffic by dynamic control loop for environment sensitive traffic management actions	**Port Accessibility (Qualitative Assessment)**

UC	UC Name(s)	Measurable Objectives and Indicators	Validation/Measurable Outcomes	KPI(s)
	Qualitative Assessment	Facilitate the quantification of port decisions impact for mid-/long-term through Key Performance Indicators (KPIs): investments, stakeholder satisfaction, accessibility, modal split, CO_2 emissions, air quality, green energy, market share, employment; CT KPIs: truck turn time, yard inventory of containers, **outbound trucks in port >1 hour**, crane idle hours, (un)avoidable delay, (un)scheduled maintenance	5G-LOGINNOV 5G GLOSA & Automated Truck Platooning influencing urban road traffic by dynamic control loop for environment sensitive traffic management actions	**Outbound Trucks in Port > 1 hour (Qualitative Assessment)**
	Qualitative Assessment	Time **slot allocation** of truck platoon driving connected and automated in the logistics trial corridor and the connected optimized traffic light signalling	5G-LOGINNOV 5G GLOSA & Automated Truck Platooning influencing urban road traffic by dynamic control loop for environment sensitive traffic management actions	**Slot Allocation (Qualitative Assessment)**
	Qualitative Assessment	**Reduce noise** generated by trucks delivering/picking up containers (at least 10%)	5G-LOGINNOV 5G GLOSA & Automated Truck Platooning influencing urban road traffic by dynamic control loop for environment sensitive traffic management actions	**Noise Reduction (Qualitative Assessment)**

Table 23 Hamburg LL: Use Case, Measurable Objectives and KPIs

4.3.2 LL Hamburg 5G Network and Services

The living lab Hamburg will demonstrate its 5G innovations for logistics in the Hinterland of the harbour of Hamburg by using the public 5G network operated by the Deutsche Telekom R15 with DSS. This public 5G network covers the designated test field for “connected and automated driving” (TAVF) of the city centre of Hamburg. Within this environment, the LL Hamburg will illustrate how new functionalities of 5G as MEC (Mobile Edge Computing), precise positioning as uRLLC can improve the efficiency of logistic operations, also having in mind that future 5G network functionalities as mMTC and eMBB are essential for any future mobile network application.
The LL Hamburg set-up is mainly based on the idea to use telco products as the basis for the use case demonstration. The 5G Non-Standalone network by Deutsche Telekom will be used to link mobile devices (e.g. trucks), RSU’s (e.g. traffic lights), and the related backbone infrastructure (e.g. TMS Traffic Management System from SWARCO. Figure 4 depicts this relation between the components in the LL Hamburg.

Figure 4: Hamburg Living Lab overview

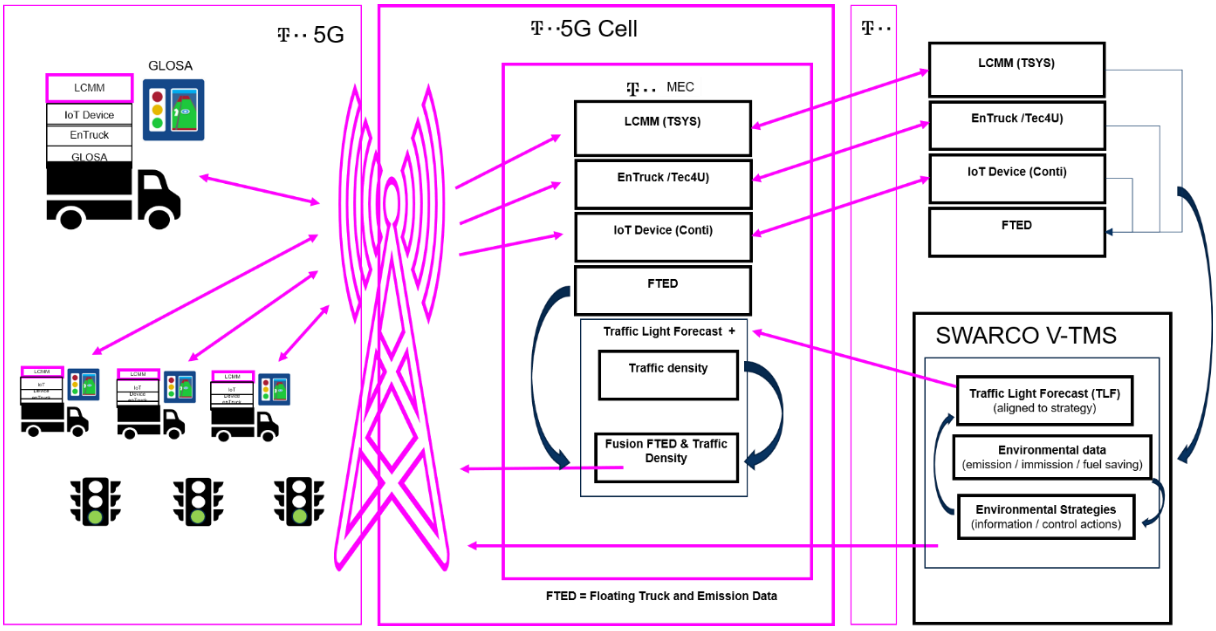

Table 24: 5G Technologies LL Hamburg

5G Service/Application	Deployed
Radio Access Network	Production network 3,6 Ghz / 2.1 Ghz
Number of cell sites	3,6 GHz more than 20 sites / 2.1 GHz over 98% full coverage in Hamburg
Frequencies used	3.6 GHz / 2.1 GHz
Frequency Bandwidth	2,1 GHz – 20 MHz / 3,6 GHz 90 MHz
Mobile Core	3GPP R15 with DSS
Virtualised infrastructure	only partly
Orchestrator	DTAG internal
MEC	MobilEdgeX as product
Precise Positioning	Skylark as product

4.3.3 Mobile Core: 3GPP R15 with DSS

From a core network evolution perspective, there are two main steps to supporting 5G New Radio (NR). The first step – a 5G Evolved Packet Core (EPC) with 5G NR Non-Standalone (NSA) operation – is to move forward from the existing EPC. This is the current situation for LL Hamburg -5G production network Deutsche Telekom AG - 3GPP R15 with DSS.

In the 5G NSA approach, the existing 4G core (EPC) is working as an anchor network mainly for signaling purposes. This EPC is combined with new extended radio functions – focused on the provisioning of additional mobile bandwidth capabilities (5G New Radio – 5GNR). T-Mobile / Deutsche Telekom is using additional frequencies from old UMTS solutions (2,1 GHz band) to offer more capacity for the clients. This function (dynamic frequency usage) is adapted from 3GPP R16.

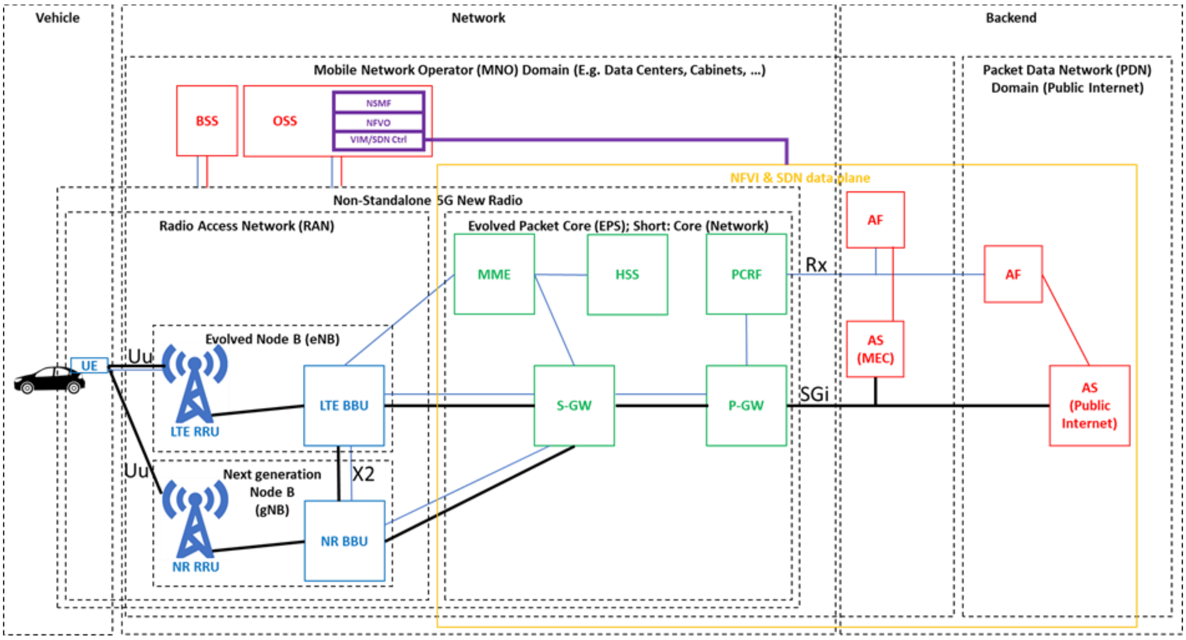

Figure 5: 5G Main Components 5G NSA Solution

The second step – 5G NR Standalone (SA) – is a complete new 5G Core (5GC) using a service-based architecture (SBA). The new architecture is fully software-based and will support network slicing. Network slicing will offer separated virtual networks for dedicated clients. But this is still the future and usable during project runtime.

4.3.4 MEC

LL Hamburg UC 10 will establish a V2X information system by combining 5G functionalities with GLOSA (Green Light Optimal Speed Advisory) to enable automated truck platooning. The optimised trajectory planning for automated vehicle manoeuvring across intersections enabled by real-time information on current and predicted traffic light signalling will require reliable connectivity and analytic capability with a low latency below 10ms. By using a MEC product by Deutsche Telekom (MobilEdgeX) between the 5G network and the connected vehicles with reducing network transfer delays to meet the specific ultra-reliable and low-latency requirements necessary to serve automated truck platoons.

The MEC will bring the analytics of the LL-Hamburg uses cases much closer to the connected vehicles by processing and combining mission-critical traffic information with manoeuvres of the vehicles and infrastructure data from the cloud. Efficient and safe driving inside a platoon requires information being shared among the platoon as synchronous as possible. The following vehicles should be on-time aware of relevant actions of the leading vehicle (imminent reduction/increasement of speed), otherwise unnecessary braking or the dissolvement of the platoon cannot be prevented.

4.3.5 Precise Positioning

The LL Hamburg will use in all four use cases 5G enabled precise positioning on lane-level.

Firstly, this requires an accuracy of the position within an error bound of lateral of 0,57m (0,10m for 95%) and longitudinal of 1,40m (0.48m for 95%) on freeways [23]. Therefore, conventional GNSS position information will not be sufficient. Secondly, the given position has to be provided in a high frequency and a low latency to be reliable in a fast-moving vehicle.

The four use cases of LL Hamburg will combine uRLLC with the precise positioning service Skylark that provides accuracy for the position of up to 0.10m.

4.3.6 Floating Truck & Emission Data (FTED)

The automatic detection and evaluation of driving manoeuvres (based on real data from individual vehicles), their resulting effect on emissions and the related influence of infrastructure are key when it comes to the demonstration and proof of the effectiveness of a dynamic traffic management. The large number of vehicles in an urban environment requires a bidirectional communication infrastructure with a high bandwidth and a low latency. Therefore, 5G is a “must” requirement to ensure a secure and reliable communication strategy.

This enables live classification of micro driving manoeuvres of the individual vehicles into characteristic cases (e.g., braking, active acceleration, constant speed) and to link them to the static infrastructure features (curve, uphill, downhill); in parallel, the dynamic traffic control system provides additional mobility data as traffic lights, lane and speed displays, which will be defined and used as specific Points of Interest (POIs).

Based on the variation and changes of the driving manoeuvres, in relation of the current valid Traffic Management System (TMS) status and the static and dynamic boundary conditions, the resulting emission behaviour is determined, assigned and evaluated. This is done by using the Low Carbon Mobility Management (LCMM) methodology that has been calibrated by Entruck analytics based on real driving and consumption profiles.

The results are stored live and in parallel with the underlying raw vehicle data on a digital map, that illustrates the effects of dynamic traffic management measures on individual vehicles in form of various driving situations and their specific manoeuvre/consumption diagram.

A further relevant component for this approach is the 5G 'Precise Positoning' technology, enabling lane-exact position of vehicles and the detailed mapping of the static infrastructure conditions (3D profile, gradient, gradient curve radii) along the route corridors. For this purpose, the corridors will be segmented into partial routes and form the basis of the digital map on which the relationships between the influencing factors (vehicle, load, driver, route as well as TMS and consumption/emissions profile) are stored for analysis and prediction.

In addition, the information bases and data, as well as results of the control strategies, will be available for the other use cases 10 and 11, where the findings from UC8/9 will be translated into promising approaches for a dynamic traffic management to meet/optimize higher-level emission and extended requirements of the participants from the port and logistics sector, as well as with the environmental and traffic management authorities in the test area.

The identified solution features:

- 5G real-time truck & emission data collected by LCMM, Entruck and Continental IoT device by using 5G Precise Positioning technology.
- Improve the LCMM standard by Entruck (e.g. tire pressure, engine, etc.).
- Characterisation of infrastructures and emissions based on real vehicle data and behaviour.
- Real-time analysis of manoeuvres and direct provision of results.
- Calibration of external services (LCMM) based on speed profiles.

4.3.7 5G GLOSA & Automated Truck Platooning (ATP)

The basis for proving and demonstrating the effectiveness of Green Light Optimal Speed Advisory (GLOSA) in interaction with Automated Truck Platooning (ATP) is, in addition to a safe and target-oriented communication strategy and environment, the automatic recognition and evaluation of the emission impact of driving manoeuvres, and the related influence of the infrastructure, TMS systems and TMS GLOSA measures. The driving manoeuvres are classified into characteristic cases (braking, accelerating, constant speed) and linked to the static infrastructure characteristics (curve, uphill, downhill); in parallel, the dynamic traffic control systems (traffic lights, lane and speed displays) are recorded/localised (and located as specific GLOSA POIs) and the specific information need/available content is queried and structured.

Based on the changes in driving manoeuvres (when TMS/GLOSA measures, the status of the traffic situation and the knowledge of other boundary conditions are known), the changes in emission behaviour are determined, assigned and evaluated, based on the driving profile change. To determine the emission behaviour, the LCMM methodology is calibrated by means of Entruck data, using real driving and consumption profiles; thanks to this approach, the effect can be recorded for individual vehicles, using the different driving situations (traffic light green phase, green wave to traffic light red phase), and evaluated using an adapted routine from UC8/9. In the fundamental diagram, this means an extreme consideration, since the manoeuvre components of acceleration and deceleration are close to zero in the ideal case, in favour of the constant driving component. The reflection on real traffic conditions will be evaluated based on field data and in a specific GLOSA simulation for the development of control strategies, applied to the potential estimation and planning of possible logistics corridors.

The fundamental building blocks for this approach are the exact (lane-level) positioning of the vehicles and the TMS systems, as well as the exact mapping of the static infrastructure conditions (3D profile, gradient, gradient curve radii), needed to predict driving resistances, traffic situation and arrival times of the platoon at the traffic control system (which influences the control time) or to transfer the necessary boundary parameters for the control strategy adaptation of the ATP in a suitable way. In this respect, the possibilities of strategies for coupling the ATP to the TMS facility must also be taken into account and secured, by means of a continuous exchange of information between vehicles and TMS facility, especially when dealing with unexpected traffic disturbances (dangerous situations).

Furthermore, the results and control strategies will be integrated into UC11, where these findings, based on the knowledge gained from UC8/9, will be translated into promising approaches for dynamic traffic management to meet/optimise higher-level emission and extended requirements of the participants from the port and logistics sector, as well as with the environmental and traffic management authorities in the test area.

4.3.8 Dynamic Control Loop for Environment Sensitive Traffic Management Actions

The SWARCO Virtual Traffic Management System (SWARCO V-TMS) is located in the SWARCO-Cloud and can be used for different application areas, e.g. to inform different road user groups about the city air quality, as well as to collect, analyse, take decisions and act managing the traffic related to the port and Hamburg City, in order to decrease the air pollution resulting from motorized traffic.

Environment Sensitive Traffic Management is a control loop involving:

- Vehicle dynamics (driving parameters) and vehicle (engine) characteristics.
- Evaluation of the vehicle dynamics and computation of emissions caused by the dynamics.
- Consideration of weather and air conditions, pollutant measurements for modelling emission of current and future time.
- Consideration of the emission and the overall traffic situation (now and future) to:
  - Select defined traffic management strategies.
  - Activate bundles of actions.
- Activating traffic management strategies, involving:
  - Changing traffic light control parameters.

- Changing speed limits or access regulations (re-routing, restriction of engine types, speed limits etc.).
    - Modifying cooperative control interaction.
    - Spreading traveller information (inform about restrictions, encourage mode shift or other mobility behaviour changes).
- Resulting impacts on vehicle dynamics/mobility behaviour/engine types running in the pollutant zone.

4.3.9 Hamburg LL KPIs

In this chapter, each KPI is described based on the template. KPIs selected by Hamburg LL are not referred to each UC but they all measure aspects of the three demonstrated UCs. All KPIs are defined in relation to the %G technical setup and the use cases described in the chapters before.

KPI ID	H-KPI1
Measurable objectives and indicators	Increase average truck speed in single vehicle mode with equipped vehicles (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Increase average truck speed in single mode up to 5%
Description	Increase the average truck speed in single mode with equipped vehicles
Data Needed	Truck/vehicle speed (LCMM, Entruck, Conti) per single vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI2
Measurable objectives and indicators	Reduction of acceleration in single mode (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Reduction of average acceleration activities in single mode up to 5%
Description	Reduction of acceleration activities in single mode with equipped vehicles
Data Needed	Acceleration (LCMM, Entruck, Conti) per single vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI3
Measurable objectives and indicators	Reduction of stillstand time in single mode (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Reduction of stillstand time in single mode up to 5%
Description	Reduction of stillstand time in single mode with equipped vehicles
Data Needed	Stillstand time (LCMM, Entruck, Conti) per single vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI4
Measurable objectives and indicators	Increase average truck speed in platoon vehicle mode with equipped vehicles (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Increase average truck speed in platoon mode > 5%
Description	Increase the average truck speed in platoon mode with equipped vehicles
Data Needed	Truck/vehicle speed (LCMM, Entruck, Conti) per platoon vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI5
Measurable objectives and indicators	Reduction of acceleration in platoon mode (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Reduction of average acceleration activities in platoon mode > 5%
Description	Reduction of acceleration activities in platoon mode with equipped vehicles
Data Needed	Acceleration (LCMM, Entruck, Conti) per platoon vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI6
Measurable objectives and indicators	Reduction of stillstand time in platoon mode (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Reduction of stillstand time in platoon mode > 5%
Description	Reduction of stillstand time in platoon mode with equipped vehicles
Data Needed	Stillstand time (LCMM, Entruck, Conti) per platoon vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI7
Measurable objectives and indicators	Reduction of fuel consumption in single mode (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Reduction of fuel consumption in single mode up to 10%
Description	Reduction of fuel consumption in single mode with equipped vehicles
Data Needed	Fuel consumption (LCMM, Entruck, Conti) per single vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI8
Measurable objectives and indicators	Reduction of CO_2 emissions in single mode (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Reduction of CO_2 emission in single mode up to 10%
Description	Reduction of CO_2 emission in single mode with equipped vehicles
Data Needed	CO_2 emission (LCMM, Entruck, Conti) per single vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI9
Measurable objectives and indicators	Reduction of fuel consumption in platoon mode (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Reduction of fuel consumption in single mode up to 20%
Description	Reduction of fuel consumption in single mode with equipped vehicles
Data Needed	Fuel consumption (LCMM, Entruck, Conti) per single vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI10
Measurable objectives and indicators	Reduction of CO_2 emissions in platoon mode (vehicles for LL Hamburg will be equipped with devices for Entruck, Conti IoT and LCMM)
KPI	Reduction of CO_2 emission in platoon mode up to 20%
Description	Reduction of CO_2 emission in single mode with equipped vehicles
Data Needed	CO_2 emission (LCMM, Entruck, Conti) per single vehicle trip
Owner	LCMM T-Systems, Entruck TEC4U, Conti IoT Continental

KPI ID	H-KPI11
Measurable objectives and indicators	Optimize Energy Performance Index 'EPI - cl per ton and km' (vehicles for LL Hamburg will be equipped with devices for LCMM)
KPI	Increase value of 'EPI - cl per ton and km' up to 10% for vehicle trips
Description	Optimize energy performance index 'EPI - cl per ton and km'
Data Needed	LCMM data per vehicle trips
Owner	LCMM T-Systems

KPI ID	H-KPI12
Measurable objectives and indicators	Optimize Acceleration Performance Index 'API - KWh per ton and km' (vehicles for LL Hamburg will be equipped with devices for LCMM)
KPI	Increase value of API 'KWh per ton and km' up to 10% for vehicle trips
Description	Optimize acceleration performance index 'API - KWh per ton and km'
Data Needed	LCMM data per vehicle trips
Owner	LCMM T-Systems

KPI ID	H-KPI13
Measurable objectives and indicators	5G bandwidth on urban roads
KPI	Extended cellular bandwidth on urban roads by 5G network
Description	5G communication systems will be able to support dedicated bandwidths (per user) over 500MBit/s - depending on deployed network structure. LL Hamburg will use the production network of T-Mobile with 5GNR (in 3.5 GHz spectrum) to get this high capacity
Data Needed	5G bandwidth values during vehicle trips
Owner	Deutsche Telekom

KPI ID	H-KPI14
Measurable objectives and indicators	Positioning quality on urban road networks with 5G
KPI	Positioning quality on urban road networks with 5G by 10 cm
Description	The product solution of Deutsche Telekom with the partner Skylark will provide a precision level on 10 cm (comparable with 3 - 10 m for uncorrected GNSS signal. This solution will be integrated in the LL Hamburg use cases to increase the precision by factor 10 and to reduce the complexity of the solution (map matching will be much simpler)
Data Needed	5G positioning data during vehicle trips
Owner	Deutsche Telekom

KPI ID	H-KPI15
Measurable objectives and indicators	Signal latency in the 5G environment using Mobile Edge Computing
KPI	Average signal latency in the 5G environment will be reduced thru Mobile Edge Computing (MEC) to 10 ms during vehicle trips

Description	Signal latency in the 5G environment will be reduced thru Mobile Edge Computing (MEC). The signal transfer time and the stability of the transmission will be improved. The signal transfer delay (latency) can come down near to 10 ms
Data Needed	Quality data of cellular 5G using MEC during vehicle trips
Owner	Deutsche Telekom

KPI ID	H-KPI16
Measurable objectives and indicators	Packed Error Rate (PER) in 5G NSA production network
KPI	Average rate of packed errors during 5G data transmission from vehicle to backend. The KPI will be measured while performing the different use cases. Reduction of PER by 10%.
Description	Mean PER in the 5G environment is an indication of 5G the network performance. The PER will be monitored on the IP layer.
Data Needed	Transmission data and packed error data during vehicle trips
Owner	Deutsche Telekom

4.4 Koper LL

The Port of Koper is located in the Northern part of the Adriatic Sea. In 2018, the container throughput was 988.499 TEUs[3]. With the extension of Pier I, the port's annual capacity will rise to 1.3M TEUs. The core business of the port comprises the transhipment and warehousing of a variety of goods and a range of complementary services, providing customers with comprehensive logistics support. Transhipment and warehousing are carried out at 12 specialised port terminals. The terminals are organised according to the goods/cargo they receive. Each terminal has its own characteristics, depending on its specific work process, technological procedures and technology. The Koper Living Lab is directly linked to the Port of Koper and its logistic services, which is operated by Luka Koper Company.

4.4.1 LL Koper 5G Network and Services

The Koper Living Lab targets the implementation of novel 5G technologies (MANO-based services and network orchestration, Industrial IoT, AI/ML-based video analytics, drone-based security monitoring, etc.) and cutting-edge prototypes tailored to be operated in the port environment. This represents not only operational but also development challenges, particularly with regards to possible immaturity of some of its 5G components and consequently a possibility to disrupt/affect the established operations of the port. To overcome deployment and operational challenges of the current 5G technologies in the port environment, the implementation of the Living Lab infrastructure is planned as a controlled and independently operating subsystem, and the interconnection points with the operational infrastructure (e.g. integration of 5G mobile network with the operational port network) will be carried out using proven and verified equipment. 5G capabilities and services under test (e.g.

[3] https://ec.europa.eu/inea/sites/inea/files/cefpub/12_-_panel_2-5_richter.pdf

eMBB, mMTC, MEC, the use of drones) represent an add-on to the existing port infrastructure and complement the overall service portfolio, not substituting any of its vital parts.

5G technology will be provided by ININ and Telekom Slovenije as part of commercial mobile infrastructure and integrated into the 5G-LOGINNOV Koper Living Lab to support identified use-cases. 5G network in Koper LL will be based on the 5G NR NSA architecture deployed over the commercial mobile infrastructure and 5G NR SA deployed over the private 5G infrastructure. The NR NSA radio access network will consist of two base station sites. Evaluating the current 4G LTE coverage is a key factor for ensuring the correct anchoring in the midterm phase in which the control plane needs to be driven by LTE Infrastructure.

5G NR in SA mode will be deployed as part of a private 5G system which will be prepared in a compact form and will enable simple reallocation of the gNb site inside the Koper LL. Optimal location will be chosen based on the needs and operational requirements of the planned use cases.

The General E2E architecture of the Koper Living Lab is shown in Figure 6. In order to assist all of the planned use cases, we will set up two 5G networks in the Port of Koper, namely the private 5G SA network and the 5G NSA commercial network. During the project, an incremental upgrade of the commercial 5G NSA network with the 5G SA option 2 is planned, but only if commercial equipment will be available on time.

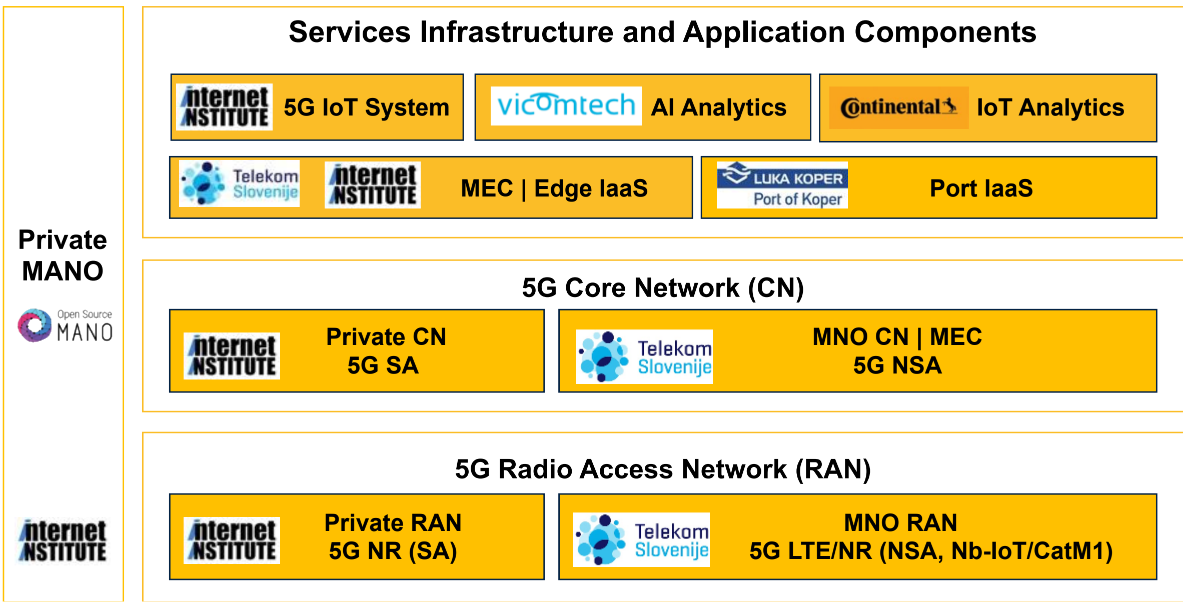

Figure 6: High level network scheme fot Koper Living Lab

The IaaS requirements will be covered by placing dedicated physical servers at the data centre at the Koper LL location that will serve as a private IaaS (Infrastructure-as-a-Service) in terms of NFV-based terminology. Regarding the radio network, it is one of the design goals of the LL Koper to provide both flavours of 5G connectivity: Non-Standalone (NSA) and standalone (SA). The first variant (NSA) will be deployed by Telekom Slovenije using their production core network and dedicated 5G base stations at the LL Koper location. The SA variant will be deployed as a completely private 5G network using the aforementioned IaaS infrastructure at LL Koper and placing the base station at a strategically chosen location within the living lab. Two mobile networks will operate independently and will allow testing various use case scenarios on SA/NSA 5G topologies. To support strict port security requirements, commercial Mobile Network Operator (MNO) infrastructure will be extended with Multi-access Edge Computing (MEC) capabilities that will assure smart routing of the port-related network services and applications traffic directly to the operations support systems of the Koper LL. In addition to commercial MNO services, the private 5G SA mobile network with dedicated cloud infrastructure will be built and tailored to the needs of port operation and targeted UCs.

5G network within Koper Living Lab will be designed to support the deployment of the innovative advanced use cases involving several cutting-edge 5G features and technologies and new devices (e.g. slicing, eMBB, uRLLC, mMTC, MEC, 5G-NR, etc.). The deployment of the 5G mobile network in the Port of Koper will rely on the availability of commercial 5G products, especially those related to the support of eMBB and mMTC features.

4.4.2 Koper LL: Use Case, Measurable Objectives and KPIS

UC	UC Name(s)	Measurable Objectives and Indicators	Validation/Measurable Outcomes	KPI(s)
1	Management and Network Orchestration platform (MANO)	Enhancing 5G IoT backend system elements with new NFV functionalities and MANO orchestration support - Remote network monitoring (OSM-CNF/rMON) IoT platform	Deployment and validation of the 5G IoT backend system components in LL Koper to support operation of the UC1	• Components Onboarding and Configuration (Backend) • Deployment Time (Backend) • Time to Scale (Backend) • Service Availability (Backend) • Components Onboarding and Configuration (Agent) • Deployment Time (Agent)
1,5	Management and Network Orchestration platform (MANO)	Dedicated private mobile system that will be built as standalone and self-operated 5G network and services platform infrastructure - VNF network (OSM-VNF) Private 5G network	Deployment and validation of the 5G network and services in LL Koper to support operation of the UC1, UC5 and UC6	• Components Onboarding and Configuration (Backend) • Deployment Time (Backend) • Time to Scale (Backend) • Service Availability (Backend) • Slice Reconfiguration (Backend)
1,5	Management and Network Orchestration platform (MANO)	Private 5G-based mobile services provided by the national MNO (Mobile Network Operator), tailored to the needs of port operation, will be provisioned and operated over the public MNO infrastructure	Deployment and validation of the 5G network and services in LL Koper to support operation of the UC1, UC5 and UC6	• Area Traffic Capacity • Availability • Bandwidth • Connection Density • Coverage Area Probability • End-to-End Latency • Reliability
5,6	Automation for Ports: Port Control, Logistics and Remote Automation	Enhancing functionalities of the 5G IoT GW to support 5G Non-Standalone and Standalone capabilities (NSA/SA), MANO	Deployment and validation of 5G IoT platform in the LL Koper to support operation of the UC5 and UC6	**Qualitative assessment**

UC	UC Name(s)	Measurable Objectives and Indicators	Validation/Measurable Outcomes	KPI(s)
		orchestration and capturing of vertical and horizontal network and services KPIs, with support of E2E 5G monitoring capabilities		
5,6	Automation for Ports: Port Control, Logistics and Remote Automation	Proprietary computer vision SDK, multiplatform, to rapid prototyping in a large variety of sectors, including Advanced Driver Assistance System (ADAS), security, inspection and HMI	Development and deployment of the SDK in LL Koper to support operation of the UC5 and UC6	**Qualitative assessment**
5,6	Automation for Ports: Port Control, Logistics and Remote Automation	Annotation model to describe content of image sequences, in the form of: spatiotemporal entities, called Elements. Thus, VCD contains lists of Elements being: Objects, Events, Actions, Context or Relations, etc.	Development and deployment of the annotated model in LL Koper to support operation of the UC5 and UC6	• Model Accuracy/Reliability • Model Inference Time
5	Automation for Ports: Port Control, Logistics and Remote Automation	Enhancing equipment monitoring through the collection of telemetry data from vehicles involved in port operations	Development and deployment of IoT devices on vehicles in LL Koper, to support UC5	**Qualitative assessment**
5,6	Mission Critical Communications in Ports	Enhancing functionalities of the 5G IoT GW to support 5G Non-Standalone and Standalone capabilities (NSA/SA), MANO orchestration and capturing of vertical and horizontal network and services KPIs, with support of E2E 5G monitoring capabilities	Deployment and validation of 5G IoT platform in the LL Koper to support operation of the UC5 and UC6	**Qualitative assessment**
6	Mission Critical Communications in Ports	Novel surveillance technologies and mechanisms (drone-based, wearable cameras, AI/ML based video analytics)	Development and deployment of the mission critical and security related uses case (UC6) in LL Koper	• Model Accuracy/Reliability • Model Inference Time • Model Accuracy/Reliability • Model Inference Time

Table 25 Koper LL: Use Case, Measurable Objectives and KPIs

4.4.3 Management and Network Orchestration platform (MANO)

The baseline 5G network and cloud infrastructure will be designed and deployed on the premises of the Koper LL. To support strict port security requirements, commercial Mobile Network Operator (MNO) infrastructure will be extended with Multi-access Edge Computing (MEC) capabilities that will assure smart routing of the port-related network services and applications traffic directly to the operations support systems of the Koper LL. In addition to commercial MNO services, the private 5G mobile network with dedicated cloud infrastructure will be built and tailored to the needs of port operation and targeted UCs.

KPI ID	K-KPI1
Measurable objectives and indicators	Enhancing 5G IoT backend system elements with new NFV functionalities and MANO orchestration support - Remote network monitoring (OSM-CNF/rMON) IoT platform
KPI	Components Onboarding and Configuration (Backend)
Description	Elapsed time from the beginning of component configuration and onboarding process via the orchestrator until the components are ready to deploy
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI2
Measurable objectives and indicators	Enhancing 5G IoT backend system elements with new NFV functionalities and MANO orchestration support - Remote network monitoring (OSM-CNF/rMON) IoT platform
KPI	Deployment Time (Backend)
Description	Elapsed time from the moment the deployment is started via the orchestrator until the system is ready to use
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI3
Measurable objectives and indicators	Enhancing 5G IoT backend system elements with new NFV functionalities and MANO orchestration support - Remote network monitoring (OSM-CNF/rMON) IoT platform
KPI	Time to Scale (Backend)
Description	Elapsed time from the moment the scaling request is triggered until the component is scaled and ready to use
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI4
Measurable objectives and indicators	Enhancing 5G IoT backend system elements with new NFV functionalities and MANO orchestration support - Remote network monitoring (OSM-CNF/rMON) IoT platform
KPI	Service Availability (Backend)
Description	Percentage of successful connection tests (RTT)/ service tests (WEB) to the reference service endpoint over a period of time
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI5
Measurable objectives and indicators	Enhancing 5G IoT backend system elements with new NFV functionalities and MANO orchestration support - Remote network monitoring (OSM-CNF/rMON) IoT platform
KPI	Components Onboarding and Configuration (Agent)
Description	Elapsed time from the beginning of component configuration and onboarding process via the orchestrator until the components are ready to deploy
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI6
Measurable objectives and indicators	Enhancing 5G IoT backend system elements with new NFV functionalities and MANO orchestration support - Remote network monitoring (OSM-CNF/rMON) IoT platform
KPI	Deployment Time (Agent)
Description	Elapsed time from the moment the deployment is started via the orchestrator until the system is ready to use
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI7
Measurable objectives and indicators	Dedicated private mobile system that will be built as standalone and self-operated 5G network and services platform infrastructure - VNF network (OSM-VNF) Private 5G network
KPI	Components Onboarding and Configuration (Backend)

Description	Elapsed time from the beginning of component configuration and onboarding process via the orchestrator until the components are ready to deploy
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI8
Measurable objectives and indicators	Dedicated private mobile system that will be built as standalone and self-operated 5G network and services platform infrastructure - VNF network (OSM-VNF) Private 5G network
KPI	Deployment Time (Backend)
Description	Elapsed time from the moment the deployment is started via the orchestrator until the system is ready to use
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI9
Measurable objectives and indicators	Dedicated private mobile system that will be built as standalone and self-operated 5G network and services platform infrastructure - VNF network (OSM-VNF) Private 5G network.
KPI	Time to Scale (Backend)
Description	Elapsed time from the moment the scaling request is triggered until the component is scaled and ready to use.
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI10
Measurable objectives and indicators	Dedicated private mobile system that will be built as standalone and self-operated 5G network and services platform infrastructure - VNF network (OSM-VNF) Private 5G network
KPI	Service Availability (Backend)
Description	Percentage of successful connection tests (RTT)/ service tests (WEB) to the reference service endpoint over a period of time
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI11
Measurable objectives and indicators	Dedicated private mobile system that will be built as standalone and self-operated 5G network and services platform infrastructure - VNF network (OSM-VNF) Private 5G network
KPI	Slice Reconfiguration (Backend)
Description	Elapsed time from the moment the slice reconfiguration is requested until the slice is reconfigured and ready to use
Data Needed	No calculation needed
Owner	Internet Institute

KPI ID	K-KPI12
Measurable objectives and indicators	Private 5G-based mobile services provided by the national MNO (Mobile Network Operator), tailored to the needs of port operation, will be provisioned and operated over the public MNO infrastructure
KPI	Area Traffic Capacity
Description	The total traffic throughput served per geographic area (in bps/m^2)
Data Needed	Throughput Served per Geographic Area: Site density, Bandwidth, Spectrum Efficiency
Owner	Telekom Slovenije

KPI ID	K-KPI13
Measurable objectives and indicators	Private 5G-based mobile services provided by the national MNO (Mobile Network Operator), tailored to the needs of port operation, will be provisioned and operated over the public MNO infrastructure
KPI	Availability
Description	Percentage of successful connection tests (RTT)/ service tests (WEB) to the reference service endpoint over a period of time
Data Needed	Time Delivering, Total Time of Observation
Owner	Telekom Slovenije, Internet Institute

KPI ID	K-KPI14
Measurable objectives and indicators	Private 5G-based mobile services provided by the national MNO (Mobile Network Operator), tailored to the needs of port operation, will be provisioned and operated over the public MNO infrastructure
KPI	Bandwidth
Description	Maximum TCP/IP uplink and downlink bandwidth measured from the

	end user device on 5G RAN to the reference server located in 5G core
Data Needed	Total System Bandwidth (sys 1+ sys 2+ … + sys N)
Owner	Telekom Slovenije, Internet Institute

KPI ID	**K-KPI15**
Measurable objectives and indicators	Private 5G-based mobile services provided by the national MNO (Mobile Network Operator), tailored to the needs of port operation, will be provisioned and operated over the public MNO infrastructure
KPI	Connection Density
Description	The total number of connected and/or accessible devices per unit area (per km^2)
Data Needed	Number of Active Devices in the Area Considered: Active Devices, Area
Owner	Telekom Slovenije

KPI ID	**K-KPI16**
Measurable objectives and indicators	Private 5G-based mobile services provided by the national MNO (Mobile Network Operator), tailored to the needs of port operation, will be provisioned and operated over the public MNO infrastructure
KPI	Coverage Area Probability
Description	The percentage (%) of the area under consideration, in which a service is provided by the mobile radio network to the end user in a quality (i.e. data rate, latency, packet loss rate) that is sufficient for the intended application
Data Needed	Coverage Area Probability: Area Covered by Mobile Radio Network, Area Case Study
Owner	Telekom Slovenije

KPI ID	**K-KPI17**
Measurable objectives and indicators	Private 5G-based mobile services provided by the national MNO (Mobile Network Operator), tailored to the needs of port operation, will be provisioned and operated over the public MNO infrastructure
KPI	End-to-End Latency
Description	Measured round trip time (RTT) from the moment the IP ICMP Echo Request packet leaves the source host until the IP ICMP Echo Reply is received from the destination host
Data Needed	Time from Source to Target Device (i.e., measured at the communication interface)

Owner	Telekom Slovenije, Internet Institute

KPI ID	K-KPI18
Measurable objectives and indicators	Private 5G-based mobile services provided by the national MNO (Mobile Network Operator), tailored to the needs of port operation, will be provisioned and operated over the public MNO infrastructure
KPI	Reliability
Description	The percentage (%) of the amount of sent network layer packets successfully delivered to a given system node (incl. the UE) within the time constraint required by the targeted service, divided by the total number of sent network layer packets
Data Needed	Packets Successfully Delivered, Total Number of Packets
Owner	Telekom Slovenije

4.4.4 Automation for Ports: Port Control, Logistics and Remote Automation

Operating port machinery (STS crane) will be equipped with industrial cameras for capturing and transfer of Ultra-High Definition (UHD) streams to the cloud-based video analytics system for identification of container markers and detection of structural damage of containers using advanced AI/ML based video processing techniques. Each targeted STC crane will have up to five cameras installed, so 5 different angled images will be received from each container. In addition, the transfer of remotely collected information will be enabled and made available to other port operations systems. Telemetry data will be collected from some of the vehicles (e.g. terminal tractors). This information will be collected from the vehicle CAN-Bus, using the IoT Device, and transmitted via the 5G network, to the port operation support system. Typical data to be collected include vehicle position, battery level, fuel level and consumption, oil level and tire pressure.

A real-time video surveillance will be implemented using body-worn cameras carried by security personnel to support their regular and mission critical operations and to provide additional personnel security. Portable video surveillance cameras with night vision capabilities will be used to monitor specific port area (e.g. railway entrance) for the specific security services, and automated and coordinated drone-based surveillance will be implemented for extended ad-hoc video surveillance support. To complement video-based security operations an automated detection of objects, vehicles and personnel movement in a specific port area will be targeted using ML and AI based video analytics.

KPI ID	K-KPI19
Measurable objectives and indicators	Vision based model to describe content of image sequences
KPI	Model accuracy/reliability
Description	Ratio of success of the computer vision model for detection of damages in containers. This ratio will consider false positives, false negatives and true positives, using for this evaluation a set of annotated images that will be considered as the ground truth. The use of 5G will allow the transmitted images to have a higher quality, which will be reflected in a greater precision of the detection model,

	comparing with the previous schema
Data needed	To evaluate the accuracy of the model, several metrics will be calculated: • Recall is the number of correctly identified positive results divided by the number of all samples that should have been identified as positive • Precision is also known as positive predictive value, and recall is also known as sensitivity in diagnostic binary classification • The F-score is the harmonic mean of the precision and recall
Data owner	Vicomtech, Luka Koper

KPI ID	K-KPI20
Measurable objectives and indicators	Vision based model to describe content of image sequences
KPI	Model Inference Time
Description	Time to analyse each image. Using 5G will allow higher band width, so the transmitted images will not need so high compression rates, which will lead into easier compression / decompression algorithms and lower global inference times for each image
Data needed	Time dedicated for analysing each of the images of the containers
Data owner	Vicomtech, Luka Koper

As part of use case 5, the Continental 5G IoT device will be used to collect information from the vehicle CAN bus, as well as from the internal GNSS sensor, and transmit this information to the Continental backend via 5G mobile system. This information will be used as the basis for several KPIs:

KPI ID	K-KPI25
Measurable objectives and indicators	Enhancing equipment monitoring through the collection of telemetry data from vehicles involved in port operations
KPI	Time Trucks Parked in the Area
Description	Measure the amount of time spent by tracked vehicles in fully stopped mode (engine off), to determine overall efficiency of use of vehicles
Data needed	Time with engine stopped
Data owner	Continental, Luka Koper

KPI ID	K-KPI26
Measurable objectives and indicators	Enhancing equipment monitoring through the collection of telemetry data from vehicles involved in port operations
KPI	Truck Speed
Description	Measure the average vehicle speed during vehicle operation
Data needed	Average vehicle speed, in km/h
Data owner	Continental, Luka Koper

KPI ID	K-KPI27
Measurable objectives and indicators	Enhancing equipment monitoring through the collection of telemetry data from vehicles involved in port operations
KPI	Truck Acceleration

Description	Measure the vehicle acceleration, based on the information collected from the CAN bus, as well as the GNSS module inside the IoT device. This information can serve as input in improving driving style (with positive impact on fuel consumption), as well as in determining dangerous driving behaviour
Data needed	Instantaneous vehicle acceleration, in m/s^2
Data owner	Continental, Luka Koper

KPI ID	K-KPI28
Measurable objectives and indicators	Enhancing equipment monitoring through the collection of telemetry data from vehicles involved in port operations
KPI	Truck Stand Still Time
Description	Measure the amount of time spent by tracked vehicles in idle mode (engine on, vehicle speed is 0 m/s) , to determine overall efficiency of use of vehicles
Data needed	Time in idle mode
Data owner	Continental, Luka Koper

KPI ID	K-KPI29
Measurable objectives and indicators	Enhancing equipment monitoring through the collection of telemetry data from vehicles involved in port operations
KPI	Fuel Consumption
Description	Measure the instantaneous and average fuel consumption, based on information collected from vehicle CAN bus
Data needed	Instantaneous fuel consumption
Data owner	Continental, Luka Koper

4.4.5 Mission Critical Communications in Port

Private security operations management and support, featuring services to enable security operations, including personnel/team status monitoring, positioning and triage operations support with dedicated mobile applications will be evaluated.

KPI ID	K-KPI21
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (drone-based, wearable cameras, AI/ML based video analytics)
KPI	Model accuracy/reliability
Description	Ratio of success of the computer vision model for detection of people/vehicles not authorised in risk areas. This ratio will consider false positives, false negatives and true positives, using for this evaluation a set of annotated images that will be considered as the ground truth. The use of 5G will allow the transmitted images to have a higher quality, which will be reflected in a greater precision of the detection model, comparing with the previous schema
Data needed	To evaluate the accuracy of the model, several metrics will be calculated: • Recall is the number of correctly identified positive results divided by the number of all samples that should have been identified as positive • Precision is also known as positive predictive value, and recall is also known as sensitivity in diagnostic binary classification

	• The F-score is the harmonic mean of the precision and recall
Data owner	Vicomtech, Luka Koper

KPI ID	K-KPI22
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (drone-based, wearable cameras, AI/ML based video analytics)
KPI	Model Inference Time
Description	Time to analyse each image. Using 5G will allow higher band width, so the transmitted images will not need so high compression rates, which will lead into easier compression / decompression algorithms and lower global inference times for each image
Data needed	Time dedicated for analysing each of the images of the risk area
Data owner	Vicomtech, Luka Koper
KPI ID	**K-KPI23**
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (drone-based, wearable cameras, AI/ML based video analytics)
KPI	Model accuracy/reliability
Description	Accuracy of the vehicle counting and vehicle model detection
Data needed	To evaluate the accuracy of the model, several metrics will be calculated: • Recall is the number of correctly identified positive results divided by the number of all samples that should have been identified as positive • Precision is also known as positive predictive value, and recall is also known as sensitivity in diagnostic binary classification • The F-score is the harmonic mean of the precision and recall
Data owner	Vicomtech, Luka Koper

KPI ID	K-KPI24
Measurable objectives and indicators	Novel surveillance technologies and mechanisms (drone-based, wearable cameras, AI/ML based video analytics)
KPI	Model Inference Time
Description	Time to analyse each image. Using 5G will allow higher band width, so the transmitted images will not need so high compression rates, which will lead into easier compression / decompression algorithms and lower global inference times for each image
Data needed	Time dedicated for analysing each of the images captured of the vehicles
Data owner	Vicomtech, Luka Koper

5 REQUIREMENTS FOR THE DATA COLLECTION TOOLS

5.1 Overview of the data collection in 5G-LOGINNOV

The project's Data Management Plan (deliverable D6.4) outlines three phases regarding the data management, as illustrated on Figure 3, shaping the data collection process.

During the technical developments phase, different types of data are generated including raw data from the sensors or processed data from the various Living Labs platforms. The data are stored locally for the purposes of use cases operation and validation during the trials. Then, a sub-set of these data is enriched with metadata and sent to the central data server for evaluation purposes: impact assessment of the 5G-LOGINNOV platform and use cases on port operations (task T3.5) and on the society, economy and environment (task T3.6). Finally, some data will be collected from the central data server and published according to the Open Research Data Pilot (ORDP).

The data collection process relies on the data collection tools deployed at the Living Labs premises and a central data server. This chapter will introduce the interactions between the different components of the data collection tools and will provide initial requirements on the data and the tools for a safe data collection supporting the evaluation process. It is important to note that a thorough requirement analysis followed by the development of the data collection tools, will be done in task T2.2.

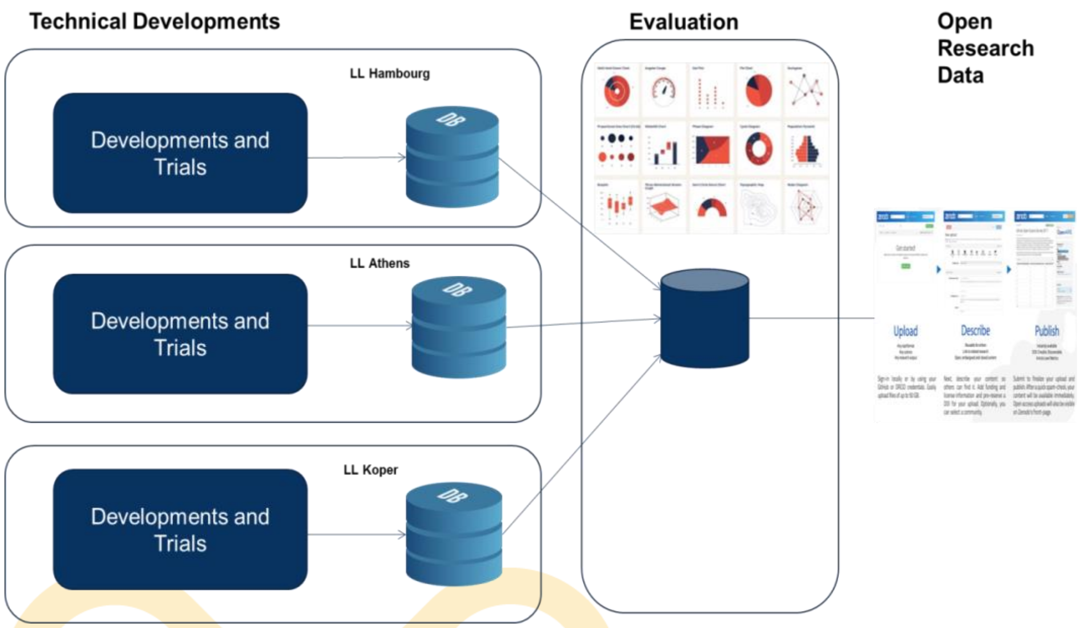

Figure 7: Overview of the data collections in 5G-LOGINNOV

5.2 Data collection in the Living Labs

Each LL can have its own preference regarding the data collection tools to be deployed. However, they serve the same purposes, which are:

- Collection of data from the sensors, devices, vehicles, boats, etc. in the ports. These entities are the data acquisition units (Figure 8).
- Data processing by the data acquisition units according to the Living Labs specifications to derive several kinds of proprietary or open data.
- Data storage in local databases.

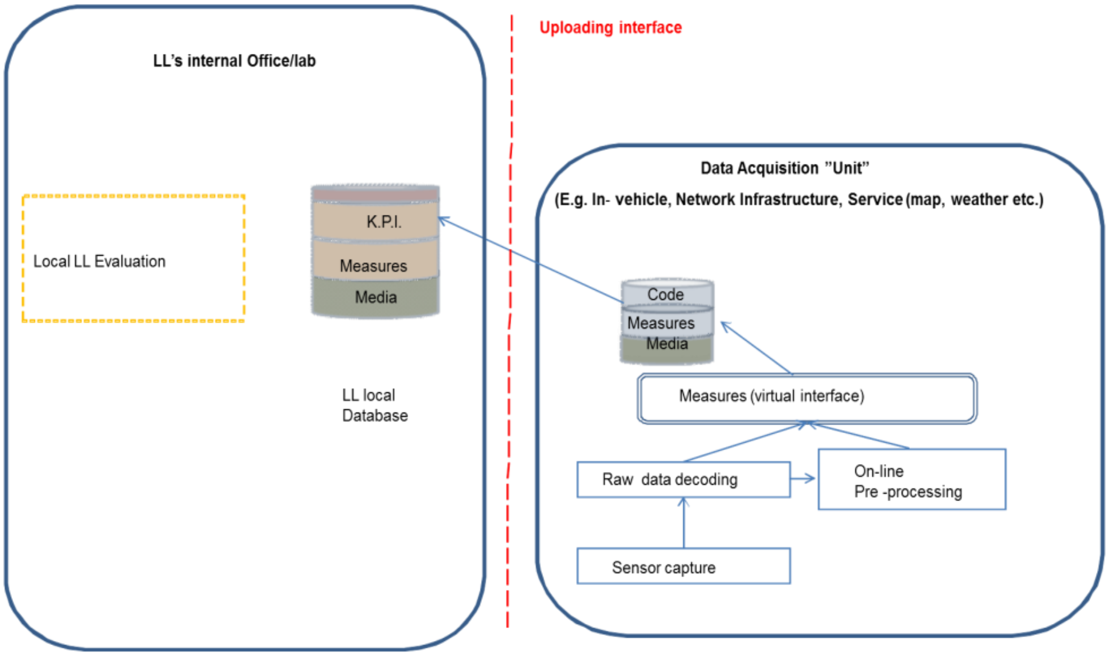

Figure 8 Functional view of the data collection tools at the Living Labs

According to the 5G-LOGINNOV evaluation methodology, some evaluation processes can be done at the Living Labs level; therefore, a Living Lab can send to the central data server metadata-enriched data and/or KPIs which are the results of the local evaluation.

5.3 The central data server

The central server receives data enriched with metadata from the three Living Labs. The metadata will be devised for 5G-LOGINNOV based on DataCite and other metadata models relevant to port operations. The central server performs a quality check on the data received from each Living Lab. The quality check procedures will be defined and implemented in task T2.2. If the data pass the quality check process, they are stored in a central database.

To sum up, the central data server consists of:

- A quality check component that also offers interfaces to the Living Labs. It is also capable of aggregation and filtering operations if necessary.
- A central database for the data storage.
- A user interface used for the evaluation and the management of the central server. The user interface offers functionalities such as search, advanced computation of the KPIs and elaborated visualisation of the data and the results of the evaluation.

Figure 9 illustrates the various components of the 5G-LOGINNOV central server.

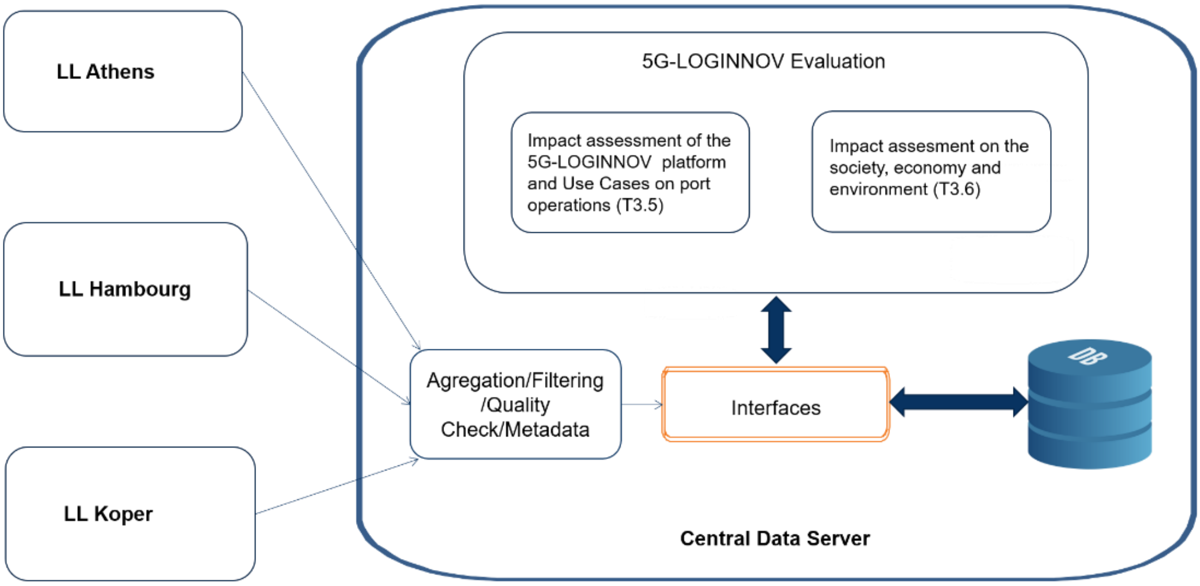

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Figure 9 Functional view of the data Collection in the Central Server

5.4 Common Requirements on the data collection tools

Based on the evaluation methodology and the data collection process described earlier, this chapter introduces the common requirements on the data collection tools regarding evaluation. It is important to note that additional requirements from task T1.5 and some specific requirements from the Living Labs tools will be considered during the development phase in task T2.2.

The requirements are described in Table 26. They are prioritised using the MoSCoW method (Must, Should, Could, Won't).

Requirement Category	Requirement ID	Description
Data Quality	D-Q-0	Each measurement done at a Living Lab must be described using features (or characteristics) which names and description are aligned with other Living Labs. When the feature is not common to other Living Labs, a detailed description must be given
	D-Q-1	Each characteristic must be described with its units
	D-Q-2	Each measurement must be enriched with metadata using the metadata model devised for 5G-LOGINNOV
Data Processing	D-P-0	Specific feature extraction must be ensured at each Living Lab (e.g. video pre-processing requiring GPU capabilities done at the Living Lab)
KPI Computation	K-C-0	All the KPIs must be defined in terms of mathematical functions or more elaborated models
	K-C-1	All inputs and expected outputs for each KPI must be defined mathematically in terms of the characteristics and their types and units

	K-C-2	The result of each KPI computation must be reproducible. When reproducibility is not attainable, all the computation parameters must be given in terms of CPU, RAM, configuration used to compute the KPIs
Hypothesis testing	H-T-0	All the hypothesis used for the evaluation in tasks T3.5 and T3.6 must be defined to guarantee the reproducibility of the evaluation
5G-LOGINNOV evaluation results	E-R-0	The results of the evaluation must be provided using well-defined characteristics.
	E-R-1	The evaluation results must be enriched with metadata as described using the metadata model defined for 5G-LOGINNOV
	E-R-2	The evaluation results must be stored in the central data server

Table 26 Common requirements for the data collection tool

6 CONCLUSION

This document presented the evaluation methodology that will be implemented in the context of 5G-LOGINNOV. The proposed approach consists of a qualitative and quantitative analysis to evaluate the impact of the use cases based on different areas or criteria.

The first step of the evaluation methodology consists of setting up an Action Plan that has to be agreed by all the project participants. This Action Plan specifies the actions needed to develop the evaluation procedure and the responsibilities of the partners. The quantitative analysis consists of the identification of the KPIs that, based on the data collected during the demonstrations, will measure the impact of the use cases. The KPIs are associated to a set of Macro and Micro-Criteria that represent the areas of impact. Furthermore, the KPIs are associated to the measurable objectives and indicators identified in the context of the 5G-LOGINNOV project. When it was not possible to associate a quantitative KPI to the measurable objectives, a new Micro-Criteria was identified to be assessed in the quali-quantitative framework of the Multi Criteria Analysis.

Furthermore, in this document, the results of the evaluation of the Critical Success Factors for the optimization of port operations have been presented. After having identified a set of Critical Success Factors based on the existing literature, the list was integrated by the 5G-LOGINNOV participants. It turned out that employees more involved in operational activities of the port considered the synchronization of sea-land's operations the most important factor for the success of the port, while employees with a more technological background or with more than 11 years of experience considered more important than the development of joint-projects on R&D, green issues, safety and security, inland infrastructures. Finally, young employees (less than 11 years) considered instead the green innovations in processes and facilities as the most important aspects for the optimization of port operations.

Similarly, the evaluation of the impact of the use cases has been performed by considering a set of Micro-Criteria. Based on the opinion of the respondents, a Multi Criteria Analysis has been carried out to rank UCs. It was found that UC8 and UC11 are considered to have the highest impact from the point of view of the environment, while UC5 and UC6 were considered the most important in terms of technological, operational and societal point of view. According to the proposed methodology, a new evaluation of the impact of the UCs will be performed during the demonstrations, by identifying new Micro-Criteria and based on a new survey.

Finally, the deliverable has presented the requirements for the data collection tool.

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ANNEX 1: SURVEY ON THE IMPACT OF THE USE CASES

Survey Question #	Question	Answers Allowed
40 [UC1.1], 42 [UC2.1], 44 [UC3.1], 46 [UC4.1], 48 [UC5.1], 50 [UC6.1], 52 [UC7.1], 54 [UC8/9.1], 56 [UC10.1], 58 [UC10.1]	Do you agree or disagree that by achieving the following objective (i.e. Micro-Criteria, see Table 4) the use case implemented within your LL will be considered successful?	Strongly Disagree, Disagree, Somehow Agree, Agree, Strongly Agree
41 [UC1.2], 43 [UC2.2], 45 [UC3.2], 47 [UC4.2], 49 [UC5.2], 51 [UC6.2], 53 [UC7.2], 55 [UC8/9.2], 57 [UC10.2], 59 [UC11.2]	Please rank from the most to the least important objective (i.e. Micro-Criteria, see Table 3) achieved by the use case implementation	Rank from 1st to 12th
35 [S8.1]	Please identify the level of your agreement on each Critical Success Factor (see Annex 2 for a complete list) according to the port optimization success	Strongly Disagree, Disagree, Somehow Agree, Agree, Strongly Agree
36 [S8.1.1]	Please list other Critical Success Factors that you recommend as important	Name of the missing Critical Success Factor
3 [S1.3]	Total work experience	Less than 3 years, 3 to 5 years, 6 to 10 years, 11 to 20 years, 21 to 30 years, Over 30 years
6 [S1.5]	At which level of the logistics chain does the company operate?	Sender, Receiver, 1 PL, 2 PL, 3 PL, Warehouse management, Technology provider, IT and Telco service providers, Other

ANNEX 2: APPENDIX TO CHAPTER 3 - QUALITATIVE ANALYSIS

ID	Critical Success Factor
1	Agile and coherent institutional chain
2	Bargaining power of customers and users
3	Cooperation/federation among logistics operators, aiming to create a true digital port ecosystem
4	Creation of a trustable regulatory/organizational framework for sharing data yet protecting own business
5	Degree of competition for attracting customers and investors
6	Development of joint-projects on R&D, green issues, safety and security, inland infrastructures
7	Encourage digital innovation and collaboration throughout the port
8	Green innovations in processes and facilities
9	Influence of port multinationals on long-term port development and strategic decisions
10	Joint marketing and communication activities
11	Lobbying activity towards governmental institutions
12	Market openness and selection of competitive private investors
13	Presence of dedicated terminals ensuring a stable cargo base
14	Preservation of port image and reputation
15	Proactive hinterland strategies by Port Authorities governance framework and managerialization of the Port Authority
16	Proactiveness and scope of Port Authority strategies
17	Real-time and large-scale data processing
18	Relations between local and international stakeholders and intensity of conflicts
19	Respect of international green regulations
20	Smooth city-port relationship and social stability and consensus
21	Sustainable port planning
22	Synchronization of sea-land operations
23	Tailored landside infrastructures and inland connections/dry ports