DELIVERABLE

D2.2 – Analysis of Pilot Requirements for Big Data Use

Project Acronym	TT
Project Title	Transforming Transport
Grant Agreement number	731932
Call and topic identifier	ICT-15-2016-2017
Funding Scheme	Innovation Action (IA)
Project duration	30 Months [1 January 2017 – 30 June 2019]
Coordinator	Mr. Rodrigo Castiñeira (INDRA)
Website	www.transformingtransport.eu
Project Acronym	TT

Document fiche	
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Work Package:	WP2
Task:	T2.2
Nature:	R
Dissemination:	PU

Document History			
Version	**Date**	**Contributor(s)**	**Description**
1.0	17/04/2017	UPM	Draft document for submission to Reviewers
1.1	25/04/2017	SOF	Reviewed 1.0 document
1.2	26/04/2017	ITI	Reviewed 1.0 document
1.3	25/05/2017	UPM	Final document for submission to the EC

Keywords:	Assessment framework, KPI, Performance Targets, Pilot Requirements, Impact.
Abstract (few lines):	This deliverable reports on the work performed in WP2/T2.2 "Analysis of Pilot Requirements for Big Data Use" with respect to the process of analysis of the pilot requirements and objectives as well as to the development of the assessment framework for the whole Transforming Transport project Pilots.

ACKNOWLEDGEMENT

This document is a deliverable of Transforming Transport project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement № 731932.

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Definitions, Acronyms and Abbreviations

Acronym	Title
AM	Asset Management
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CPT	Core Performance Target
DL	Deliverable Leader
DoA	Description of Action
Dx	Deliverable (where x defines the deliverable identification number e.g. D1.1.1)
EC	Energy Consumption
EEA	European Environment Agency
EF	Economic
EQ	Environmental Quality
EU	European Union
GHG	Green House Gas
ICE	Internal Combustion Engine
KPI	Key Performance Indicator
LCV	Light Commercial Vehicle
LPG	Liquified Petroleum Gas
MSx	Project Milestone (where x defines a project milestone e.g. MS3)
Mx	Month (where x defines a project month e.g. M10)
NOx	Nitrogen Oxides
OE	Operational Efficiency
PC	Project Coordinator
PM	Particulate Matter
PPM	Partner Project Manager
PT	Priority Topic
PU	Public
R	Report
SF	Safety
TBD	To be defined
TL	Task Leader
TT	Transforming Transport
Tx	Task (where x defines the task identification number e.g. T1.1)
WPx	Work Package (where x defines the WP identification number e.g. WP1)
WPL	Work Package Leader
WPS	Work Package Structure

Executive Summary

The overall goal of the Transforming Transport project (TT) is to demonstrate in a realistic, measurable, and replicable way, the transformative effects that Big Data will have on the mobility and logistics sector. The project is designed to validate Big Data as capable of reshaping transport processes and services significantly increasing operational efficiency, improving customer experience, and fostering new business models. All of this will be achieved by demonstrating, evaluating and validating, in real operational scenarios (Pilots) belonging to different transportation domains, the capability of Big Data innovations to develop more efficient solutions.

This deliverable reports on the work performed **in WP2/T2.2 "Pilots Requirements Analysis and Lessons Learnt".** The goal of the task is to develop the framework that will perform the technical and economic evaluation of the innovations to be tested in the 13 project pilots. The deliverable covers the process of design, development and actual deployment of the **Transforming Transport Key Performance Indicator Assessment Framework,** which will be used to assess the Pilots involved in the project and their results.

Starting from the general Assessment Strategy foreseen within the project definition, as well as from the individual pilot definitions (presented in the project deliverables 4.1 to 10.1), Task 2.2 develops a definition of Priority Topics (PT), which translate Pilot objectives into clear and measurable achievements, and subsequently introduces Key Performance Indicators (KPI) to measure the degree of target achievement.

Chapter 1 summarizes the main objectives established for Task 2.2 Pilots **Requirements Analysis and Lessons Learnt** and describes the contributions of the Task to the day to day monitoring of pilots (to be implemented in T2.1), to the Market impact analysis (to be implemented in T3.1) and to the final assessment to be carried out in T2.2 on M26 and described on Deliverable 2.5 "Lessons Learnt".

In Chapter 2 the general objectives of Transforming Transport and the specific pilots are presented and analysed. The requirements for the different Pilot domains are translated into expected impact categories. Objectives are related to the different Categories for each of the pilots.

Chapter 3 presents the complete evaluation framework that will enable the assessment of the results achieved by TT Technical Innovations. The main objective of the evaluation framework is to structure the overall assessment of the project with its 13 pilot scenarios, taking into consideration the specific impacts per assessment category and the overall effects on TT's objectives. It includes the selection and definition of a number of Priority Topics (PT) so as to convert the multiple objectives into clear and measurable achievements.

In Chapter 4, the selected KPIs are specified and defined, together with their units of measurement, when possible. These will evaluate the results achieved by each pilot through its comparison with the Performance Targets to be established. The way to measure the degree of target achievement is also defined.

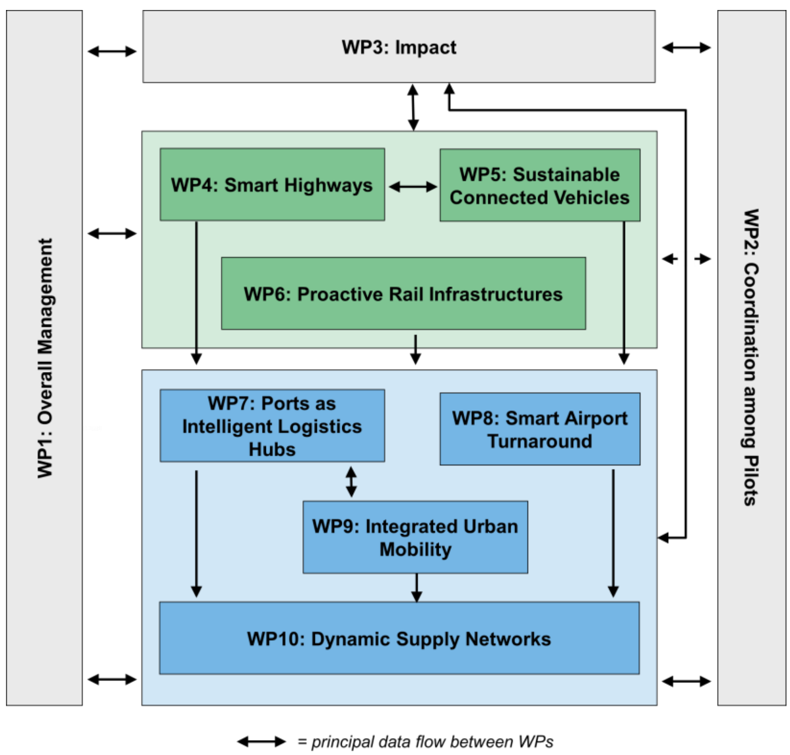
Chapter 5 describes the evaluation process to be followed, based on a four-level assessment approach: Pilot-Category level, Domain-Category Assessment, Horizontal Assessment and Strategic Assessment.

1 Introduction

The overall goal of T.T. is to demonstrate in a realistic, measurable, and replicable way the transformative effects that Big Data will have on the mobility and logistics sector. The project is designed to validate Big Data as capable of reshaping transport processes and services significantly increasing operational efficiency, improving customer experience, and fostering new business models. All of this by demonstrating, evaluating and validating, in real operational scenarios (Pilots) belonging to seven different transportation domains, the capability of Big Data innovations to develop more efficient solutions. To achieve this objective, the project is based on a consolidated methodological approach characterised by three main activities:

- Defining both global and pilot domain performance targets.
- Testing the innovations in real operation conditions.
- Evaluation and validation of the potential impact of Big Data innovations.

Figure 1 – Overall structure and relationship of Transforming Transport Workplan

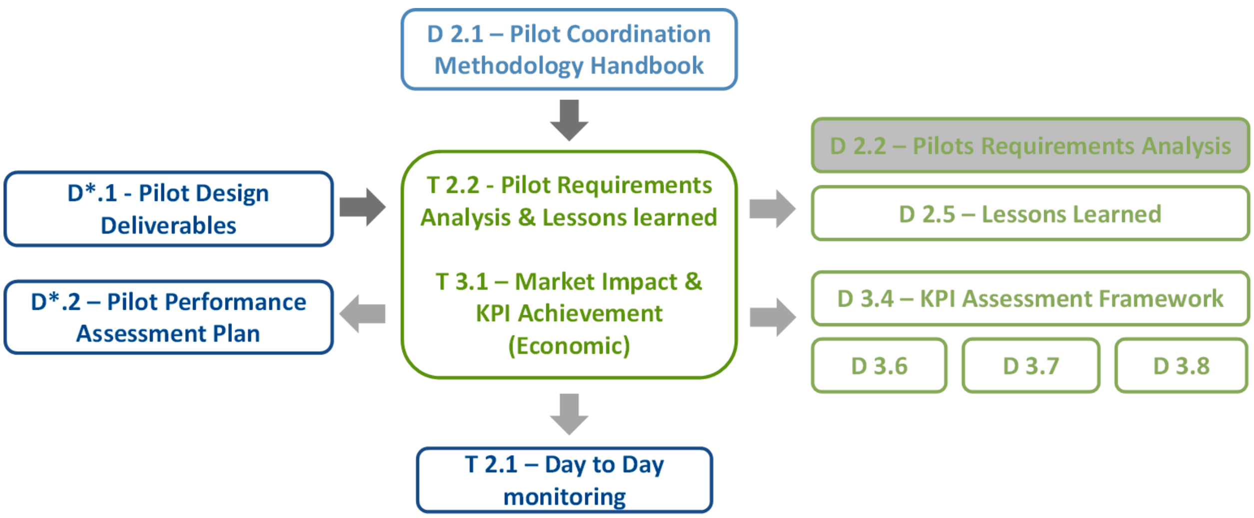


1.1 Pilot Definitions, pilot requirements and lessons learnt

The main objective of T2.2. – Pilots Requirements Analysis and Lessons Learnt is to: "assess the potential and the requirements for the pilots to effectively demonstrate the transformation potential of Big Data on Mobility and Logistics". Additional T 2.2 aims are:

- To define domain-specific KPIs and their corresponding baselines, ensuring that they remain comparable to perform a cross pilot assessment.
- To perform a thorough intra-domain and cross-pilot analysis on the use of Big Data technologies.
- To offer an analysis of applicability of TT Big Data solutions in post-project replications.

Figure 2 - Logic between the Tasks and WPs related to T 2.2



As seen in Figure 1, Task 2.2 is related to Tasks 4.1, T5.1, T6.1, T7.1, T8.1, T9.1 and T10.1, that coordinate the different Pilot Domains and the Test Scenarios (Pilots). Deliverables 4.1 to 10.1 contain the updated requirements and objectives for the seven pilot domains. In them, the Big Data technologies to be implemented are described and the expected impacts to be attained are set. Also, the specifications and definitions included in D.2.1 are considered in the development of the work.

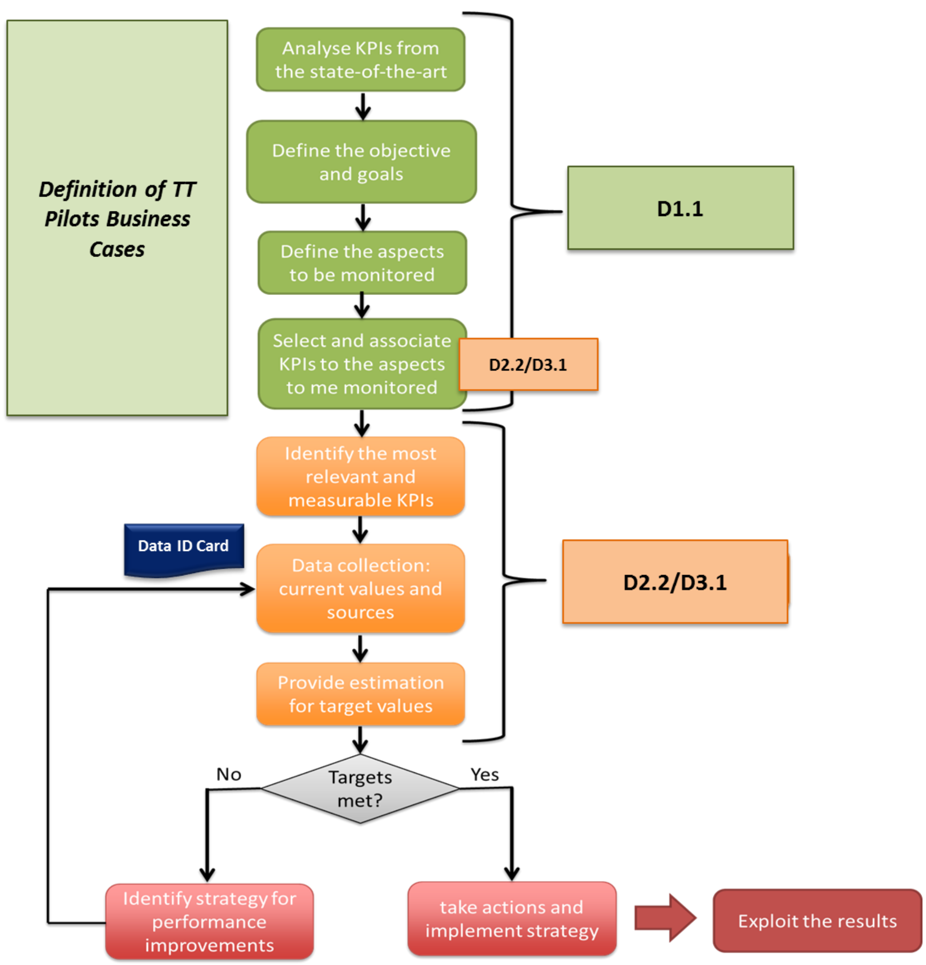
T 2.2 will deliver two reports:

- D 2.2: "Pilot Requirements Analysis"; Development of the evaluation framework including the definition of Priority Topics and KPI selection.
- D 2.5: "Lessons learnt"; execution of the final assessment and extraction of Big Data use recommendations and lessons learnt.

The main outcomes of T2.2 contained in this first Deliverable are the development of the evaluation framework to be followed as well as the specification of the selected Priority Topics that translate the Pilot objectives into measurable items, and the selection of KPIs for each of them.

The framework developed will be completed with the Market impact in Task 3.1 and included in D3.8, which will serve as a guideline for the evaluation and validation activities delivered in D3.10, D3.11 and D3.12. Also, the work carried out will be considered in D*.2 – Performance Assessment Plan (for each pilot domain) [M9] which will explain concretely how pilot-specific KPIs will be measured and assessed. Task 2.2 will also feed the development of the day to day monitoring of pilots (to be implemented in T2.1),

Figure 3 – Structure of Work for the Assessment framework development



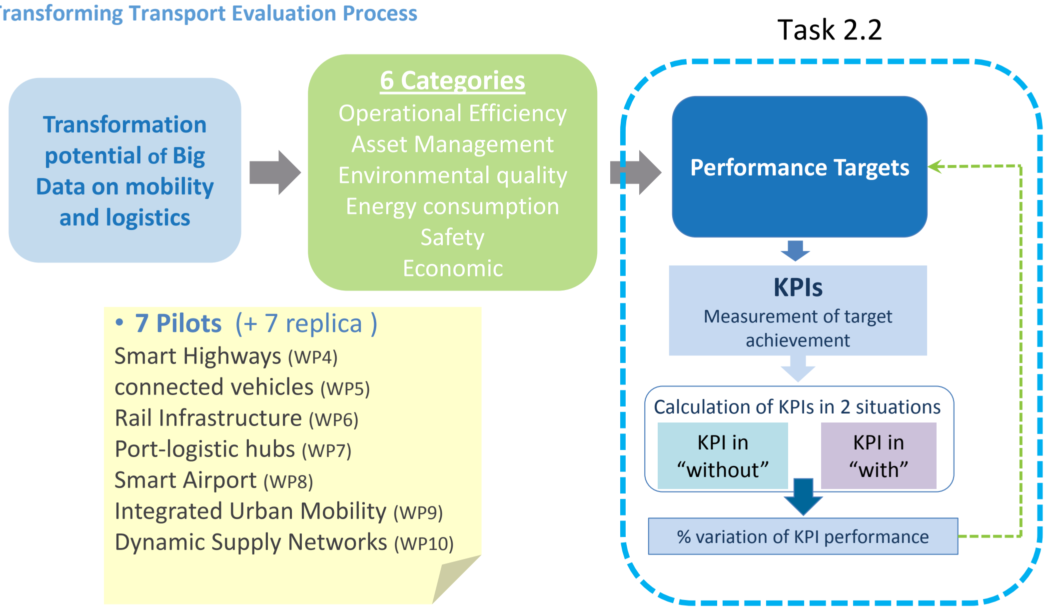
1.2 Development of evaluation framework including definition of Priority Topics and KPI selection

Pilot scenarios for the testing of Big Data technologies have already been described in tasks 4.1 to 10.1, and presented in TT deliverables D4.1 to D10.1. Taking these definitions as a starting point, the main steps developed by Task 2.2 are the following: Definition of the **structure of the evaluation framework** according to the assessment objectives of TT, Development of **Priority Topics** (PT) to translate the validation objectives into clear and measureable achievements; deriving appropriate **Key Performance Indicators** (KPIs) in order to measure the degree of PT achievement.

The selection of Categories of assessment is a key element to consider in the framework development. Categories are split beforehand in the DoW into operational categories and economic and financial categories, the first set of Categories is to be analysed by T2.2 whilst the second set is included in the effort of T3.1.

Starting from these descriptive elements, the framework can be defined. The evaluation framework will set Priority Topics capable of translating the objectives of the different pilots into clear and quantifiable levels of accomplishment. Moreover, the degree of achievement of each Priority Topic will be measured by a set of suitable KPIs that are defined within this Task (Figure 3).

Figure 4 - Transforming Transport Evaluation Process



For each qualitative objective defined in the Pilot definition deliverables D 4.1 – D 10.1, at least one quantitative Priority Topic will be defined, and appropriate KPIs will be established in order to assess the level of compliance with those targets which are previously identified for each Pilot.

The Development of the Evaluation Framework is a key outcome of Task 2.2, and consequently, the task has a significant relevance for the overall impact of the project. The work consists of identifying and defining the appropriate Priority Topics associated with each objective either general or specific to a pilot. The establishment of at least one KPI that will evaluate the performance variation achieved in every objective of the Pilot cases. Furthermore, through the definition of units and data sources, Task 2.2 sets the context which outlines the type of data that must be gathered during the tests implemented throughout the project.

Table 1 presents each Pilot's WP, code and denomination, as well as the two Pilots (initial and replication) which, when necessary, will be coded by adding 1 or 2 to the Pilot Domain Code.

Table 1 –Assessment code and denomination for TT Pilots

Pilot Domains	Code	Main pilot	Replication
WP4 Smart Highways	SH	Load balancing in Malaga	Load Balancing for Norte Litoral
WP5 Connected vehicles	CV	Sensing passenger cars	Sensing Trucks
WP6 Proactive Rail Infrastructures	RI	Predictive Rail Asset Management Pilot	Predictive High Speed Network Maintenance
WP7 Ports as Intelligent Logistic Hubs	PLH	Valencia Sea Port Pilot	Duisport Inland Port Pilot
WP8 Smart Airport Turnaround	SA	Smart Passenger Flows	Smart Passenger Flows and Turnaround
WP9 Integrated Urban Mobility	IU	Integrated Urban Mobility and Logistics in Tampere	Integrated Urban Mobility and Freight in Valladolid
WP10 Dynamic Supply Networks	SN	Shared Logistics for E-Commerce Pilot	-

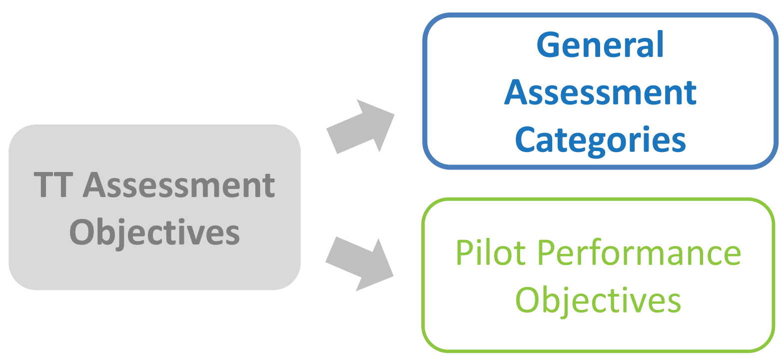
2 Assessment objectives

The overall TT objectives established in the DoW consist of:

- Demonstrating an increase of productivity in the Transport sector of at least 15%.
- Generate an Increase of market share of Big Data technology providers of up to 600% (72% on average) and/or absolute market share of up to 12% if implemented commercially within the mobility and logistics, as well as ICT sector.
- Doubling the use of Big Data technology in the mobility and logistics sector from the currently 19% to at least 38%.
- Leveraging additional target sector investments of more than 6 times the EC investment.
- Involving at least 120 organizations participating actively in Big Data demonstrations.

These are to be achieved through the validation of the different innovative Big Data solutions proposed by the 7 Pilots (plus 6 replication Pilots), which combine an improved efficiency of the transport system with an enhanced quality of service and an improvement in their business models.

Figure 5 – General Assessment Categories and Pilot Objectives



2.1 General Assessment Categories

In the project's initial phase, concrete areas of assessment were discussed with regard to the impact of the different technologies to be tested. Through the research of scientific literature, previous experience in other projects of scenario testing in the transportation sector and discussion with project partners and experts in the field a set of six general categories for the horizontal assessment have been established, namely: Operational Efficiency, Asset Management, Environmental Quality, Energy Consumption, Safety and Economic. These categories are described below:

- **Operational Efficiency Category (OE)**

Operational Efficiency is defined as the ability to deliver products and services cost effectively without sacrificing quality (. Enhancing efficiency in the transportation system is a priority topic for the EC appearing reflected as so in multiple transport related EC publications. "The future prosperity of our continent will depend on the ability of all of its regions to remain fully and competitively integrated in the world economy. Efficient transport is vital in making this happen" (White paper on transportation, EC 2011). In TT project the introduction of Big Data technologies is expected to contribute to the achievement of a more efficient provision of transport services in all the tested domains as reflected in one of the goals of the aforementioned White paper: using transport and infrastructure more efficiently through use of improved traffic management and information systems.

- **Asset Management Category (AM)**

Asset management is a systematic process of deploying, operating, maintaining, upgrading, and disposing of assets cost-effectively. Infrastructure asset management is the combination of management, financial, economic, engineering, and other practices applied to physical assets with the objective of providing the required level of service in the most cost-effective manner. It includes the management of the entire lifecycle of physical and infrastructure assets. Operation and maintenance of assets in a constrained budget environment require a prioritization scheme. Big Data technologies offer the potential to optimise the management of the usage and the maintenance of transport assets.

- **Environmental Quality Category (EQ)**

Europe's goals towards sustainability are widely acknowledged. The EU transport system is currently not sustainable, and in many respects moving away from sustainability rather than towards it. The European Environment Agency highlights in particular the sector's growing CO2 emissions that threaten the EU meeting its target under the Kyoto protocol. It also points to additional efforts that are needed to reach existing air quality targets, points to a large proportion of the population that is exposed to annoying or harmful noise levels, and highlights many more environmental impacts from transport in the EU. The Commission has been working in cooperation with the Council to prepare the ground for making European transport policy sustainable.

Air pollution has been one of Europe's main political concerns since the late 1970s. European Union policy on air quality aims to develop and implement appropriate instruments to improve air quality. The control of emissions from mobile sources, improving fuel quality and promoting and integrating environmental protection requirements into the transport and energy sector are part of these aims. In this regard the Commission establishes environmental quality standards so as to limit the concentrations of certain chemical substances that pose a significant risk to the environment or to human health. The implementation of the piloted solutions should prove useful in the achievement of a more environmentally-respectful transportation sector.

- **Energy Consumption Category (EC)**

Linked with the previous item, but with a special focus on resource efficiency for the transportation sector, the European Commission's 2012 Energy Efficiency Directive establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. Under the Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain, from production to final consumption. This objective will also be monitored in the different pilots allowing to assess the improvements in efficiency regarding energy consumption achieved by better system management derived from the use of Big Data technologies.

- **Safety Category (SF)**

Safety in transportation is another of EU's priorities for the sector. More specifically road safety, which was addressed in the last Valletta declaration (2017) as a commitment across the EU. Last year 25,500 people lost their lives on EU roads in 2016, 600 fewer than in 2015 and 6,000 fewer than in 2010. A further 135,000 people were seriously injured on the road according to Commission's estimates. (EC, 2017). The likely improvements in this regard through the processing of large amounts of data (mostly on road traffic but not exclusively) will also be a category assessed by the framework.

- **Economic Category (EF)**

An economic analysis of the impact of the implementation of Big Data solutions in diverse transport sector domains is at the core of TT project. Economic impact of the piloted technologies will be addressed, inferring their outcomes in terms of competitiveness, market impact and business improvement for operators.

It is worth mentioning that the Economic Category above is limited to the internal economic assessment of pilots. This doesn't overlap with the economic assessment of TT to be included in Task 3.1 according to the DoW, however, some items contained in this evaluation will be useful in the execution of this future task.

Through pilot analysis an initial crossing of the Categories with the potential impacts of the different transport domains has been developed. As Figure 4 shows not every transport domain is expected to generate improvements in all Categories through the planned Big Data technology implementations.

Table 2 – General Assessment Categories applicable to each TT Pilot Domain

		PILOT DOMAIN						
		SH	CV	RI	PLH	SA	IU	SN
GENERAL ASSESSMENT CATEGORY	Operational Efficiency (OE)							
	Asset Management (AM)							
	Environmental quality (EQ)							
	Energy Consumption (EC)							
	Safety (SF)							
	Economic (EF)							

Just as a reminder, the codes applied in the Figure 4 correspond to the 7 Pilot Domains to be tested within the TT project.

In order for the framework to assess the very different transport domains included in TT each of the General Assessment Categories will be concreted in a set of relevant assessment topics (Priority Topics, PT). As the assessment framework should evaluate locally and also in a transversal way across pilots, both transversal and specific Priority Topics will be defined. Transversal PTs will be common for all the Pilots for each Category, while specific PTs will be defined by each Pilot Domain to fit their specific case.

2.2 Pilot Performance Objectives

Table 2 presents the Pilots Performance Objectives list as well as the involved partners in each Pilot. This information has been subsequently updated through the pilot definition process in months 1-3 of the project, which has enabled a more thorough analysis of the performance and test requirements that should be taken into consideration during the evaluation procedure. The two pilots within each domain hold different objectives and are therefore.

The specific objectives of each Pilot are considered in the assessment framework for the local Pilot assessment. They will be measured through qualitative and quantitative evaluations designed to appraise the degree of achievement of each objective (see Section 3.5). E.g. To assess the objective of improving customer satisfaction with the service, an ad-hoc survey addressed to customers would be implemented.

Table 3 – Smart Highways Pilot Performance Objectives

Smart Higways (SH) - WP4		
Objectives	SH_O1	Understanding the mobility patterns in the corridors and the route choice criteria: - Develop a descriptive modelling of road traffic - Forecast traffic flows and the infrastructure use at short, medium and long term based on external variables (weather, calendar, etc.)
	SH_O2	Optimising highway operations by prescription: - Staff schedule optimisation - Scheduling of operations and maintenance tasks
	SH_O3	Safer roads: - Reduce the number of accidents provoked by animals by predicting, according to probability rules, the risks for this kind of accidents to happen - Prevent and react to accidents
Partners involved		.-CINTRA -INDRA -CI3

Table 4 - Connected Vehicles Pilot Performance Objectives

<table>
<tr><th colspan="3">Connected Vehicles (CV) - WP5</th></tr>
<tr><td rowspan="6">Objectives</td><td>CV_O1</td><td>Deployment of a Big Data infrastructure with descriptive and predictive analytics capabilities</td></tr>
<tr><td>CV_O2</td><td>Development of API services to carry out data injection to the Big Data infrastructure</td></tr>
<tr><td>CV_O3</td><td>Development of a generic visualization tool for data sets analysis</td></tr>
<tr><td>CV_O4</td><td>Development of a Breakdown estimator system:
- Notify information about a current car breakdown and be notified with a maintenance report
- Application of machine learning techniques to carry out predictive analysis of car breakdowns
- Visualization of breakdown report for every car
- Building up the service that will send the cars' breakdown reports to the drivers' smartphone application</td></tr>
<tr><td>CV_O6</td><td>Emissions reduction system:
- Monitoring of fuel consumption of every car to identify situations when their consumption has increased
- Monitoring of drivers' behaviours to identify non-eco-friendly ones
- Extension of SoFLEET smartphone application to allow drivers to be notified with recommendations in order to reduce emission
- Building up the service that will send the emission reports to the drivers' smartphone application
- Visualization of historical emission evolution for every car</td></tr>
<tr><td>CV_O7</td><td>Traffic jam detector system:
- Applying algorithms to carry out descriptive analysis to identify situations where a car is in a traffic jam and evaluation of the traffic congestion in real-time
- Extension of SoFLEET smartphone application to allow drivers to be notified about nearby traffic jams
- Building up the service that will send detected traffic jams to the drivers' smartphone application
- Real-time visualization of traffic jams in a map
- Heatmap visualization of historical traffic jams by hour</td></tr>
<tr><td colspan="2">Partners involved</td><td>.-ANS
-AUTOAID
-Fraunhofer
-PTV
-TOMTOM
-SOF
-JDR</td></tr>
</table>

Table 5 - Proactive Rail Infrastructures Pilot Performance Objectives

Proactive Rail Infrastructures (RI) - WP6		
Objectives	RI_O1	Verify the quality, accuracy and provenance of asset data, leading to confidence to
	RI_O2	Provide timely focused prioritised maintenance activities (predict and prevent), leading to
	RI_O3	Improved reliability and availability of track-side assets, with
	RI_O4	Higher availability of rail infrastructure for passenger and freight services; and
	RI_O5	Enhancing worker safety through minimising track-side activities
	RI_O6	Collect, process and analyse information based on Big Data techniques for the prediction of the evolution of the degradation of switches and crossings of the high speed lines throughout its useful life
	RI_O7	Collect, process and analyse information based on Big Data techniques for the prediction of the evolution of the degradation of track profiles of the high speed lines throughout its useful life
	RI_O8	Collect, process and analyse information based on Big Data techniques for the prediction of the evolution of the topographic characteristics of the slopes that are part of the railway infrastructure
Partners involved		.-ANS -INDRA -CI3 -FERROVIAL -ITINNOV -NR -THA-UK -THA TRT UK -THA-C&S

Table 6 - Ports as Intelligent Logistics Hubs Pilot Performance Objectives

Ports as Intelligent Logistics Hubs (PLH) - WP7		
Objectives	PLH_O1	Design, implement and deploy and optimisation algorithm that provides the user with the best sequence of crane movements
	PLH_O2	Apply Predictive Maintenance models to cranes' spreaders, starting with the study and deployment of a set of sensor devices to gather information regarding the spreaders of the STS cranes
	PLH_O3	Develop an advanced Cockpit for better decision-making, including a predictive decision support system that considers all the historical data available at the Valencia Port Information Systems
	PLH_O4	Terminal productivity cockpit for Duisport : - Exploit advanced data processing and predictive analytics to facilitate proactive decision making and process adaptation
Partners involved		.-Duisport -VPF -ITI -UPV - NCTV - ORB - SAG - UDE

Table 7 - Smart Airport Turnaround Pilot Performance Objectives

Smart Airport Turnaround (SA) - WP8		
Objectives	SA_O1	Operation Management Predictive Optimisation Module: - Reduce delays in departure flights caused by late passengers - Reduce the number of passenger missing connections and lost baggage - Improve the efficiency of passenger processing stations (security screening, passport control, check in desks…) - Reduce overall turnaround times
	SA_O2	Descriptive passenger behaviour system: - Obtain insight on how passenger behave along their journey, especially within the airport terminal to enable customized services/offers, increasing passenger satisfaction and non-aeronautical revenue
Partners involved		.-INDRA - AEGEAN - AIA - AG - BRTE - JEPP - Milan Airport - UDE

Table 8 - Integrated Urban Mobility Pilot Performance Objectives

Integrated Urban Mobility (IU) - WP9		
Objectives	IU_O1	Provision of tools for urban traffic management for diagnosis of traffic status and for selection of alternative solutions for mitigating the impact of roadworks and other events. Addition of new data sources for improved situational awareness, such as social media and traffic cameras.
	IU_O2	Provision of tools for drivers and travelers regarding traffic status
	IU_O3	Provision of tools to improve the access of goods delivery vehicles to parking places
	IU_O4	Generating a traffic model for particular areas in the city where freight transport has more impact
	IU_O5	Analyse different freight delivery scenarios and make decision according to the results
	IU_O6	Creation of a planning tool for delivery fleets and to inform drivers about the route plan they must follow to ensure fulfilment of (not limited to): - Minimise the time freight vehicles are inside city centre boundaries, which is related to traffic alleviation - Minimise the distance travelled by freight vehicles inside city centre boundaries, which is related to pollution reduction
Partners involved		.-CARTIF -TAMPERE -INFO -MATT -PTV -TAIPALE -VTT -TOMTOM -VALLADOLID -LINCE

Table 9 - Dynamic Supply Networks Pilot Performance Objectives

Dynamic Supply Networks (SN) - WP10		
Objectives	SN_O1	To investigate and suggest shared logistics scenarios in e-Commerce by taking into account data from various supply chain stakeholders (e.g. e-commerce retail players, 3PLs) in order to decrease cost and environmental burden and increase customer satisfaction and convenience in respect to e-commerce deliveries.
	SN_O2	To expand the shared logistics concept by incorporating replenishment aspects and conducting a synergetic inventory management strategy in order to increase service level, increase the precision of the future demand estimations and decrease the requirement of extra (non-prescheduled) vehicle routes and their respective costs
	SN_O3	To provide alternative shipping methods at the consumer in order to increase customers' satisfaction and provide lower prices
Partners involved		.-AUEB -Fraunhofer -INTRA -LOGIKA -ITML -ITAINNOVA

3 Evaluation Framework

Task 2.2 and 3.1 comprehend the establishment of the appropriate evaluation framework that will enable the overall assessment to be carried out, consisting in the appraisal and interpretation of the results accomplished by the different pilots.

The main objective of the evaluation framework is to structure the overall assessment of the project and the pilots, taking into consideration the specific impacts per assessment category and the overall effects on the level of efficiency of the pilot domain and the transport sector.

Moreover, the evaluation framework will establish the guidelines that will subsequently be used during the assessments performed in Months 9, 18 and 30, and the analysis in month 26 in order to identify synergies among Pilots, implement their economic analysis, and define the transferability guidelines for the implementation of Big Data solutions in other European sites. For this purpose, and based on the pilot objectives defined, a set of **Priority Topics** (PT) is now developed so as to convert these objectives into clear and measurable achievements. Therefore, at least one Priority Topic will be determined for each objective (see Sections 3.1 and 3.2 for more detail).

3.1 Evaluation Framework structure

Once the Objectives are set and the General Assessment Categories applicable to each Pilot have been determined and classified (Figure 4), the initial exercise within Task 2.2 consists in identifying and defining the most adequate Priority Topics associated with each Assessment Category for each Pilot, ensuring that at least one Priority Topic is related with each pilot's objectives in order to establish quantitative objectives that may be used to evaluate the results achieved by each Pilot in particular.

Besides, the definition of PTs requires an exercise of coordination at two different levels:

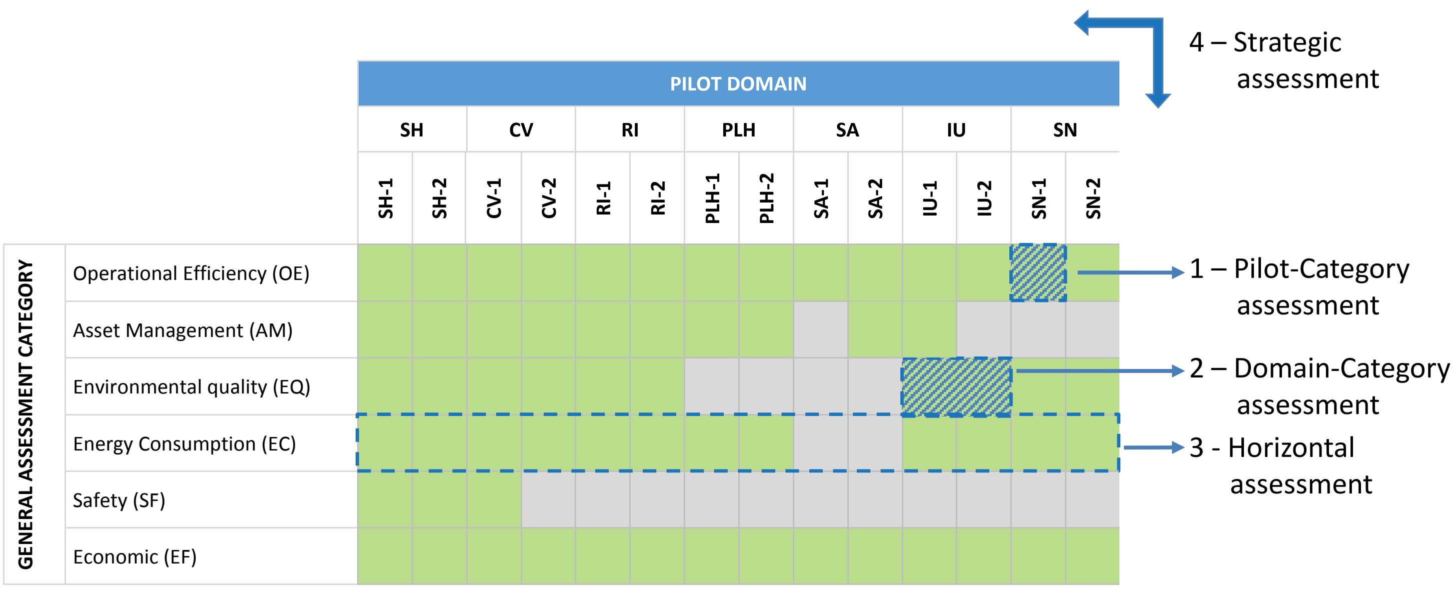
Firstly, the aim to assess at pilot domain level implies that there must be a coordination in the selection of Priority Topics among the two pilots within each domain (initial and replica). Hence, the designed framework establishes a category of PTs that is aimed to be common to both Pilots within each domain: **Specific Priority Topics**.

Secondly, the aim to compare through a horizontal assessment within each Category implies that a minimum comparability among domains must be possible. Therefore, the framework is designed to include **Transversal Priority Topics**, in all de categories except for the economic one, which are intended to establish comparability in the impacts across pilot domains and to identify the combined effects of the implementation of different Big Data solutions in diverse transport domains.

The assessment of these Priority Topics requires a quantitative comparison between the conditions in two scenarios (No-TT scenario vs TT scenario): before the implementation of Big Data technologies and once they have been introduced in the Pilot; or comparing a control scenario versus the test situation, contemporarily (the latter would be necessary when no ex ante data are available). Thus, **Key Performance Indicators** (KPIs) will be collected before and during test periods to measure the degree of achievement of each Priority Topic (see Chapter 4 for a detailed description of the KPIs).

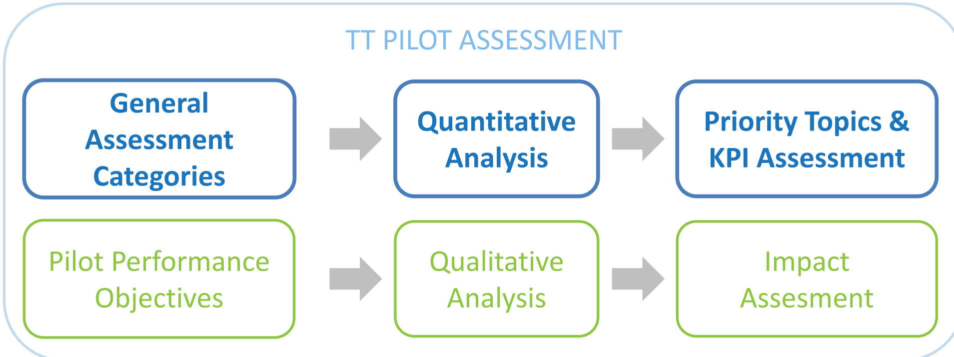
The evaluation will be performed at four levels (Figure 6):

Figure 6 – Four levels of assessment within TT



- **Pilot-Category and Objectives assessment**, based on local analysis and focusing on the expected impacts at each individual pilot in the different categories. When the Big Data technology used has effects on only a segment of the pilot's activity an upscale exercise to the whole pilot's activity will be attempted. For this assessment level a combination of the General Assessment Categories through both transversal and specific sectorial PTs and KPIs and of a qualitative assessment of the pilot objectives will be used.

Figure 7 – Pilot Assessment Level



- **Domain-Category assessment,** above the Pilot Assessment level an assessment based on a cross analysis for each pilot domain, crossing the impact attained at both the initial and the replica pilot for each of the assessment categories, for this assessment both transversal and specific sectorial PTs and KPIs will be used.

- **Horizontal Category assessment**, by General Assessment Category, to identify and evaluate the impact of Big Data use on the Category throughout the different Pilot domains. For instance, the Energy Consumption Category evaluates the influence of Big Data use in transport on fuel consumption or other energy related variables, for this assessment only transversal PTs and KPIs will be utilised. The economic category is the only one that will not include a transversal assessment across pilot domains.

- **Strategic assessment**, which combines the contribution of all Pilots in reaching the ***global strategic targets,*** set by the expected impact of TT. This level of evaluation will quantify the foreseen effects if the technologies tested in TT were jointly applied by also identifying and taking into consideration factors which provide synergic achievements and better results. For this assessment only global PTs and KPIs are considered.

In each case the Performance Targets are set by quantifying the expected contribution of the Big Data Technology implementation within the scope of the Priority Topics. They are calculated as the planned, and expected, percentage difference in the outcome of both test conditions, in the No-TT scenario and in the TT scenario.

Logically, the framework relies in the adequate submission of information from the pilots' side. In the event of a lack of information provision from any pilot on one or more specified KPIs the assessment of the pilot for such category of categories may lack quality or may even become unachievable.

3.2 Overview of Priority Topics

The following tables summarise both the transversal and specific Priority Topics per Pilot Domain and Category. Each pilot domain is described in a different table. Only the Categories that affect each domain are reflected.

Each PT should be quantified through the establishment of a Performance Target by the Pilot leader in order for the assessment to introduce a comparison between the expected result (target) and the actual impact of the solution in the operation or business model. This quantification of targets will be defined in the next months and delivered by the pilots on D*.2 which are due in M9 of the project.

Transversal PTs are filled in yellow on the tables while specific PTs are filled in white.

3.2.1 Smart Highways

Table 10 – Smart Highways Priority Topics per General Assessment Category

Assessment Category	Priority Topics	Performance Target 4.2 (TBD)	Performance Target 4.3 (TBD)
Operational Efficiency (OE)	Reduction of operating cost		
	Reduction of the average travel times in the roads		
	Reduction of congestion level		
	Increase number of traffic sources		
	Increase daily data collection		
	Increase data volume processed		
	Increase number of messages to users		
	Reduce the number of bottleneck locations		
	Improve traffic short-term prediction		
	Reduction of queues on toll plazas		
	Reduce the number of black spots		
Asset Management (AM)	Maintenance optimisation		
	Asset use optimisation - Increase of capacity		
	Increase length and percentage of road with data gathering systems		
	Improve toll areas performance		
	Effective forecasting of demand		
	Improve maintenance work planning		
	Reduce the distance travelled by the maintenance fleet		
	Increase highway traffic volume share		
Environmental quality (EQ)	Reduction of pollutant emissions		
	Reduction of animal runover		

Energy Consumption (EC)	Reduction of GHG emissions		
	Energy savings		
Safety (SF)	Reduction of accident rate		
	Emergency response time		
	Making driving safer		
	Increase of automatic warning or alarm messages		
Economic (EF)	Reduction of operating cost		
	CAPEX variance		
	OPEX Variance		

3.2.2 Smart Connected vehicles

Table 11 – Smart Connected Vehicles Priority Topics per General Assessment Category

Assessment Category	Priority Topics	Performance Target 5.2 (TBD)	Performance Target 5.3 (TBD)
Operational Efficiency (OE)	Reduction of operating cost		
	Time savings		
	Reduction of congestion		
	Reduction of harsh accelerations		
	Reduction of harsh decelerations		
	Increase number of traffic jam messages to users		
	Increase number of data sources used		
	Increase daily data collection		
	Reduce system latency		
	Increase data volume processed		
	Improve arrival time compliance		
Asset Management (AM)	Fleet maintenance optimisation		
	Asset use optimisation		
	Improve detection of maintenance needs		
	Predictive maintenance achievement		
Environmental quality (EQ)	Reduction of pollutant emissions		
	Noise reduction		
Energy Consumption (EC)	Reduction of GHG emissions		
	Energy savings		
	Improve driver's compliance with green driving		
Safety (SF)	Reduction of accidentality rate		
	Emergency response time		
	Making driving safer		
	Reduction of costs related to routes		
	Reduction of costs related to fuel consumption		
	Reduction of costs related to maintenance improvement		

3.2.3 Proactive Rail Infrastructures

Table 12 - Proactive Rail Infrastructures Priority Topics per General Assessment Category

Assessment Category	Priority Topics	Performance Target 6.2 (TBD)	Performance Target 6.3 (TBD)
Operational Efficiency (OE)	Reduction of operating cost		
	Reduction of average travel times		
	Improved availability		
	Improve ride comfort		
	Improve maintenance planning		
	Reduce maintenance time		
Asset Management (AM)	Maintenance optimisation		
	Asset use optimisation - Increase of capacity		
	Reduce equipment downtime		
	Increase prediction of equipment failure		
	Predictive maintenance achievement		
	Improve track operation conditions		
	Reduction of total maintenance costs		
	Reduce maintenance worker travel distance		
Environmental Quality (EQ)	Reduction of pollutant emissions		
	Fuel Savings		
Energy Consumption (EC)	Reduction of GHG emissions		
Safety (SF)	Enhancing worker safety		
Economic (EF)	Reduction of asset management		
	Reduction of maintenance cost of railway equipment		

3.2.4 Ports as Intelligent Logistic Hubs

Table 13 - Ports as Intelligent Logistic Hubs Priority Topics per General Assessment Category

Assessment Category	Priority Topics	Performance Target 7.2 (TBD)	Performance Target 7.3 (TBD)
Operational Efficiency (OE)	Reduction of operating cost		
	Time Savings		
	Time Savings at Terminal Level		
	Time Savings at Port level		
Asset Management (AM)	Maintenance optimisation		
	Asset use optimisation		
Energy Consumption (EC)	Energy Savings		
Economic (EF)	Reduce maintenance equipment costs		
	Container Handlings for gate in-out orders		

3.2.5 Smart Airport Turnaround

Table 14 - Smart Airport Turnaround Priority Topics per General Assessment Category

Assessment Category	Priority Topics	Performance Target 8.2 (TBD)	Performance Target 8.3 (TBD)
Operational Efficiency (OE)	Reduction of operating cost		
	Time savings		
	Improve the detection of Late passengers		
	Detection of missed passengers		
	Prediction of passengers		
	Passenger behaviour		
	Reduction of overall turnaround times		
	Reduction of missed connections		
	Reduce late passenger rate		
	Improve the identification of transfer passengers with late arrivals		
	Reduce passenger time at security control		
	Increase worker efficiency at security control		
	Reduce passenger time at passport control		
Asset Management (AM)	Improve efficient use of available technical and HR		
	Improvement in gate time use efficiency		
	Improve finger-pier gate use		
	Increase passenger transit through commercial spaces		
	Improve customer satisfaction with commercial spaces		
	Increase commercial space		
Environmental quality (EQ)	Noise reduction		
Economic (EF)	Improve profitability		

3.2.6 Integrated Urban Mobility

Table 15 - Integrated Urban Mobility Priority Topics per General Assessment Category

Assessment Category	Priority Topics	Performance Target 9.2 (TBD)	Performance Target 9.3 (TBD)
Operational Efficiency (OE)	Time savings in deliveries		
	Use of optimisation and reservation services		
	Route optimisation		
	Use of data sources for traffic		
	Improve customer satisfaction with service		
	Improve quantity delivered by vehicle and day		
	Reduce traffic disruptions		
	Increase use of freight delivery areas		
	Increase advance booking for car sharing		
	Increase roadwork planning		
	Increase daily data collection		
	Increase collected data quality		
	Increase data source interface availability		
	Increase future event daily data collection		
	Increase unplanned events daily data collection		
	Increase the number of events reported by the Traffic Management Centre (TMC)		
	Increase information volume sent to social media		
	Increase website visits		
	Increase number messages in variable messages signs (VMS)		
	Policy decision making		
	Reduction of congestion		
	Improve traffic flow		
	Reduce traffic disruption intensity		
	Increase data volume processed		
Asset Management (AM)	Increase length and percentage of road with data gathering systems		
	Improve occupation rates in freight delivery parking areas		
	Increase variable messages signs (VMS)		
Environmental quality (EQ)	Reduction of pollutant emissions		
	Reduction of space occupation		
Energy Consumption (EC)	Reduction of GHG emissions		
	Energy savings		
Economic (EF)	Reduction of costs related to routes		

3.2.7 Dynamic Supply Networks

Table 16 - Dynamic Supply Networks Priority Topics per General Assessment Category

Assessment Category	Priority Topics	Performance Target (TBD)
Operational Efficiency (OE)	Reduction of operating cost	
	Time savings in deliveries	
	Increase number of daily orders handled	
	Increase delivery fleet efficiency	
	Increase of punctuality	
	Improve "last-mileage" vehicle fleet efficiency	
	Improve "last-mileage" delivery efficiency	
	Improve "last-mileage" delivery efficiency	
	Increase of the use of shared logistics	
	Increase of the use of alternative shipping methods	
	Increase of drops per route	
	Increase of Load Factor	
	Decrease distance travelled	
	Decrease distance travelled per route	
	Decrease number of problematic deliveries	
	Increase forecast of problematic deliveries	
	Click and collect density	
	Click and collect coverage	
	Improve first time deliveries	
	Improve customer e.g. satisfaction with service	
	Increase number of data sources used	
	Increase daily data collection	
	Increase data source interface availability	
	Increase data volume processed	
Environmental quality (EQ)	Reduction of pollutant emissions	
Energy Consumption (EC)	Reduction of GHG emissions	
	Energy savings	
Economic (EF)	Decrease order delivery cost	
	Decrease delivery cost	
	Decrease cost of returns	

3.3 Definition of the Transversal Priority Topics

This section includes the list of Transversal Priority Topics that have been identified for each General Assessment Category, together with a thorough definition of each topic and the main goals pursued with the implementation of such evaluation. Each section begins with the name of the Assessment Category, which is quantified through its associated targets. All the PTs described in this section are wide scoped as they are meant to be shared by the different pilots in all the domains highlighted on Figure 4 for each Category.

Through the conducted work with the different pilots it was concluded that the Assessment Category of Economy is only to be assessed for each pilot and not in a transversal way, therefore it has no transversal Priority Topics.

Table 17 – Summary of Transversal Priority Topics per Assessment Category

Assessment Category	Priority Topics	Unit	SH	CV	RI	PLH	SA	IU	SN
Operational Efficiency (OE)	Reduction of operating cost	% reduction							
	Reduction of travel time	% reduction							
Asset Management (AM)	Maintenance optimisation	% reduction							
	Asset use optimisation	% increase							
Environmental Quality (EQ)	Reduction of pollutant emissions	% reduction							
	Reduction of noise levels	% reduction							
Energy Consumption (EC)	Reduction of GHG emissions	% reduction							
	Energy savings	%							
Safety (SF)	Reduction of accidentality rate	% reduction							
	Emergency response time	% reduction							

3.3.1 Operational Efficiency Category - OE

Reduction of operating cost

Operating costs are those expenses derived from the acquisition of the resources needed by an organisation to accomplish its activities. For instance, cost of goods sold, office rental and labour costs are examples of operating costs. These may be classified in two categories:

- Fixed costs: such costs remain constant regardless of the business' performance, and are not dependent on production volume. Therefore, even if a company is inactive, it must compensate its fixed costs (for example, the rent of its office building).

- Variable costs: the magnitude of these costs varies proportionally with the business' output. Hence, when a business is not operating, its variable costs are usually zero, while as the company's activity increases, its variable costs usually raise (energy consumption, cost of goods sold, telephone bill, etc.).

Operating costs does not include depreciation expense, financing costs or income taxes, nor those costs incurred during the development of new processes.

For any organisation, reducing its operating costs is an important, although challenging, task since it increases competitive advantage, improves profitability and provides a leaner cost structure in case market conditions turn difficult.

Reduction of travel time

Travel time is the time required for moving people or goods between different locations. For a business, travel time originates costs resulting from the amount of time its employees and vehicles spend travelling, and in the case of consumers, for their personal time spent during the journey, which is usually non-remunerated. In order to convert travel time savings into cost reductions, the organisation must establish a monetary value per unit time saved.

Travel time savings is often the main benefit of a transportation project. Congestion-relief initiatives are frequently validated by their potential to decrease travel time. In addition, travel time reductions may also lower vehicle maintenance and operating costs.

3.3.2 Asset Management Category - AM

Maintenance optimisation

Maintenance activities are intended to preserve as nearly, and as long as possible, the original appearance and performance of an asset by implementing planned actions which mitigate the degradation caused during its use. From an accounting perspective, maintenance is a periodic cost originated by actions that preserve an asset without extending its life, and is accounted as an expense which is not capitalised.

For transportation-related firms (either logistic service providers or infrastructure construction / maintenance companies), in which vehicles and machinery represent a significant proportion of their total assets, maintenance activities are crucial for unexpected costs prevention, and outspreads the need to purchase new equipment.

Asset use optimisation

This Priority Topic enhances the effectiveness of asset management from both an organisational and temporal standpoint. In addition, it is an important measure for business risk control. In recent years, companies have started to consider Big Data as an important source of market and business information. The development of new technologies, and the significant increase in the number of Internet users, have generated an exponential increase in data availability. Many organisations are foreseeing the potential offered by data analysis to better understand its business environment, which obviously includes improving its asset management.

3.3.3 Environmental quality Category - EQ

Reduction of pollutant emissions

In order to assess transport pollutant emissions, Transforming Transport some pilots will estimate the contents of nitrogen oxides (NOx) and particulate matter (PM) generated during their activity. In case emission factors are required, the EMEP/EEA air pollutant emission inventory guidebook – 2016[1] provides figures for all transportation modes which support the reporting of emissions data in compliance with the EU National Emission Ceilings Directive.

For road transport, in case vehicle technology is unknown, Tier 1 method may be employed using mean values. In addition, specific information for road transportation can also be obtained from the HBEFA[2] emission factor database for the different vehicle categories based on the Euro level emission standards which they comply. For railways, specific information for this transportation mode is available for locomotives using fossil fuel. As in the case of road transport, Tier 1 method may be followed by using mean values. In case electricity is the energy source, NOx emission factors related with the electric energy generation mix for the period should be utilised.

In the case of air transport, the EEA provides a spreadsheet to calculate the required emission factors.

Reduction of noise level

Noise may be defined as any unpleasant or undesired sound for someone who perceives it, although it usually depends on the sensibility level of each individual. Nevertheless, once a certain volume is reached, all affected people sense anxiety. Acoustic pollution presents several characteristics that differ from other pollutant sources: its emissions require low energy, no residues are produced, noise measurement is complex, and its effects are local. However, acoustic pollution has become a major concern in urban areas, where transport systems are a key source of noise.

Noise pollution is harmful for the environment, and for humans particularly, as it may originate psychological disturbance (stress, sleep disorders), physical troubles (difficulty to communicate, loss of audial capacity, cardiovascular disorders), social impacts (aggressive behaviour, scholar lags) and economic losses (increase in health costs, lower productivity, accidents, or even damage

[1] *http://www.eea.europa.eu/publications/emep-eea-guidebook-2016*
[2] *http://www.hbefa.net/e/index.html*

property value). In consequence, several Transforming Transport pilots will evaluate the possible use of Big Data in the reduction of noise originated by the transportation industry.

3.3.4 Energy Consumption Category - EC

Reduction of GHG Emissions

Emissions caused by transportation systems are a main contributor of global warming, which threatens to modify many natural processes in unpredictable ways. Greenhouse Gas (GHG) emissions, in particular carbon dioxide (CO_2) emissions, will be evaluated as an indicator of energy consumption, as the emission of this substance is proportional to the vehicle's energy consumption. As in the case of NOx emissions, the EMEP/EEA air pollutant emission inventory guidebook – 2016[3] provides figures for all transportation modes which support the reporting of emissions data in compliance with the EU National Emission Ceilings Directive. For passenger cars and vans, if vehicle make, model and production year is known (2010-2015 models)[4], specific emission factors may be obtained from the database provided by the European Environmental Agency (EEA), in which useful information is included in column 15, with header field "e (g/km)". The HBEFA database also contains GHG-related emission factors.

For railways, specific information for this transportation mode is available for locomotives using fossil fuel. As in the case of road transport, Tier 1 method with mean values will be used. In case electricity is the energy source, CO_2 emission factors will be based on the electric energy generation mix for the period.

For air transport, the EEA also provides a spreadsheet to calculate the corresponding emission factors.

Energy savings

This topic assesses one of the main objectives of the TT project which consists in improving the energy efficiency during the operation of the vehicles and therefore, the energy requirements of the fleet. In order to compute this PT, the potential energy savings achieved for each particular vehicle technology tested in the demo site are calculated, and overall energy savings are extrapolated to the total fleet. An improvement in the fleet's energy demand has three main advantages for the European energy outline:

[3] *http://www.eea.europa.eu/publications/emep-eea-guidebook-2016*
[4] *http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-11*

- Decrease in energy demand, and for the Public Transport Operators (PTO), less fossil fuel required by the operation, thus diminishing the overall European energy dependency, especially on conventional fuels.
- Economic savings.
- Reduction of pollutant emissions, especially in urban areas with intense transportation demands.

For vehicles consuming fossil fuels, conversion of fuel volume to energy units can be performed using the energy content of motor fuels conversion figures suggested in Table 1 of Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles[5].

Table 18 - Energy content of motor fuels conversion figures

Fuel	Energy content	
Diesel	36 MJ/litre	10 kWh/litre
Petrol	32 MJ/litre	8.89 kWh/litre
Natural Gas/Biogas	33-38 MJ/Nm^3	9.17-10.56 kWh/Nm^3
Liquefied Petroleum Gas (LPG)	24 MJ/litre	6.67 kWh/litre
Ethanol	21 MJ/litre	5.83 kWh/litre
Biodiesel	33 MJ/litre	9.17 kWh/litre
Emulsion fuel	32 MJ/litre	8.89 kWh/litre
Hydrogen	11 MJ/Nm^3	3.06 kWh/Nm^3

3.3.5 Safety Category - SF

Reduction of accidentality rate

An accident may be defined as an unforeseen event that alters the usual activities of people or organisations, especially those which cause injuries or damages to persons, animals or objects. Most ratios used to measure accidentality rates in transportation are based on the number of deaths and injured people during a certain time period (usually on an annual basis).

[5] *http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0033&from=EN*

Accidentality rates are relevant indicators to evaluate safety levels on transportation systems, since security is a priority matter when developing or modifying transport infrastructures. However, accidentality probability is affected by additional factors such as driver habits, weather conditions, vehicle age, infrastructure design and maintenance, and distance travelled. Thus, to obtain comparable figures, it is necessary to refer the accident events to additional factors, primarily the total distance travelled by the fleet. As Transforming Transport involves a wide variety of transport modes, and different physical environments, the ratios used in this project need to be customised to each type of activity.

Emergency response time

As a complement to the previous indicator, it is also important to measure, once an incident has occurred, the average response time of the emergency team. For most pilots, the indicator will assess the time interval which starts when the accident takes place, including the period required for its notification to the emergency team, and finish when both personnel and rescue vehicles are ready for departure.

3.4 Definition of the Specific Priority Topics

This section includes the list of Priority Topics that have been identified for each General Assessment Category and Pilot domain, together with a thorough definition of each target and the main goals pursued with the implementation of such evaluation. Each section begins with the name of the Pilot Domain, subdivided in the different Assessment Categories containing its associated specific targets.

3.4.1 Smart Highways

3.4.1.1 Operational Efficiency Category – OE

Reduction of congestion level

An improvement in the highway's congestion levels is expected thanks to the better operational decisions funded on the analysis of large -real time and historical- datasets. The progress in this PT will be assessed by evaluating the average commercial speed and the congestion time to total time ratio.

Increase number of traffic sources

An increase in the number of quality traffic data sources available to the operator is a desirable improvement of the pilot. The assessment topic will focus on this available quantity before and after pilot implementation.

Increase daily data collection

An increase in the amount of quality traffic data being collected by the operator is a desirable improvement in the pilot and is related to the previous and following PTs. The assessment topic will focus on this amount before and after pilot implementation.

Increase data volume processed

An increase in the volume of quality traffic data sources being processed and considered by the operator is a desirable outcome of the pilot. The assessment will focus on this volume before and after pilot implementation.

Increased number of messages to users

The increased availability of processed information should allow an improvement in the information to the highway users on relevant issues affecting their trip through variable message signs.

Reduce the number of bottleneck locations

Improvements in traffic management and in information available to the users are expected to have an impact in the number of bottleneck locations.

Improve traffic short-term prediction

Improving short-term prediction of traffic volumes is key for an adequate management of the highway. The progress in this PT will be assessed through the deviation of forecasted and real traffic.

Reduction of queues on toll plazas

Operational efficiency introduced at the toll highways operation is assessed using rate points to measure the proportion of short, medium or long waiting times during the payment process at the toll plazas.

3.4.1.2 Asset Management Category - AM

Increased length and percentage of road with data gathering systems

An increase of sensor coverage in the highway is a PT to ensure an information gathering as complete as possible on the status of the highway service.

Improve toll areas performance

Improved performance of the toll areas is a desirable asset management outcome and will be assessed through the average processing time of users.

Effective forecasting of demand

Improving demand forecast is a desirable outcome in order to improve the management of the highway. The progress in this PT will be assessed through the deviation of predicted and real demand.

Improve maintenance work planning

Wider data availability is expected to improve the planning of maintenance works in the highway. The improvement will be measured through the ratio of planned maintenance interventions on total maintenance interventions.

Reduce the distance travelled by the maintenance fleet

Optimization of maintenance fleet movements is an expected outcome to be derived from the improved maintenance planning. It will be assessed through the distance that maintenance vehicles travel in a period.

3.4.1.3 Environmental quality Category - EQ

Reduction of animal run over

A reduction of wildlife run over on the highway is a priority to be addressed as it causes environmental harm and poses a risk on user's safety.

3.4.1.4 Energy Consumption Category – EC

-No specific PTs have been defined-

3.4.1.5 Safety Category - SF

Making driving safer

Improving safety on the roads is a PT for the EC and therefore is included as a PT to be measured. Safety is expected to improve through better highway maintenance and operation.

Increase of automatic warning or alarm messages

The increased availability of processed information should allow an improvement in the information to the highway users especially under extraordinary circumstances affecting their safety. The use of the variable message signs channel for this aim is expected to improve.

3.4.1.6 Economic Category - EF

Reduction of operating cost

Predictive analysis, mobility pattern analysis and decision supports systems based on Big Data Analytics are expected to allow toll operators to reduce the costs associated to their activity. This PT will quantify this savings.

CAPEX variance

The company's Capital Expenditure (CAPEX) is evaluated to appraise its investments in capital goods. CAPEX includes those funds invested by the company to acquire or upgrade physical assets such as property, industrial buildings, vehicles, machinery or equipment.

OPEX Variance

OPEX includes those expenses incurred by the company during its normal business operations, which includes rentals, equipment, inventory costs, marketing, employee payroll, insurance and funds allocated to research and development.

3.4.2 Sustainable Connected Vehicles

3.4.2.1 Operational Efficiency Category – OE

Reduction of congestion

This PT aims to assess the improvements reached in the commercial speeds of the fleets, achieved through better route planning based on Big Data processing of traffic information.

Reduction of harsh accelerations

The improvements in traffic conditions of the chosen route as well as the increased punctuality rates through better planning shall enhance a friendlier driving. This PT aims at reflecting the reduction of harsh accelerations in the fleet's trips.

Reduction of harsh decelerations

The improvements in traffic conditions of the chosen route as well as the increased punctuality rates through better planning shall enhance a friendlier driving. This PT aims at reflecting the reduction of harsh decelerations in the fleet's trips.

Increase number of traffic jam messages to users

The increased availability of processed information should allow an improvement in the information to the drivers regarding the status of road traffic. This PT aims at quantifying the number of events reported

Increase number of data sources used

An increase in the number of quality traffic data sources available to the operator is a desirable improvement of the pilot. The assessment topic will focus on this available quantity before and after pilot implementation.

Increase daily data collection

An increase in the amount of quality traffic data being collected by the operator is a desirable improvement in the pilot and is related to the previous and following PTs. The assessment topic will focus on this amount before and after pilot implementation.

Reduce system latency

This PT aims at reflecting the improvement of the quality of communications between vehicles and data center allowing for better real time management of the fleet.

Increase data volume processed

An increase in the volume of quality traffic data sources being processed and considered by the operator is a desirable outcome of the pilot. The assessment will focus on this volume before and after pilot implementation.

Improve arrival time compliance

The processing in real time of large datasets on traffic and fleet status is expected to improve predictability. This PT aims at reflecting the improvement in the arrival time estimation rate of the fleet.

3.4.2.2 Asset Management Category - AM

Improve detection of maintenance needs

The achievement of an effective predictive maintenance of the fleet would mean a relevant competitive advantage thanks to the implementation of the Big Data technologies. This PT aims at reflecting the improvement of the early detection of maintenance needs of the fleet.

Predictive maintenance achievement

The achievement of an effective predictive maintenance of the fleet would mean a relevant competitive advantage thanks to the implementation of the Big Data technologies. This PT aims at reflecting this improvements through the monitoring of the incidence of vehicle breakdowns on the fleet.

3.4.2.3 Environmental quality Category – EQ

Noise Reduction

Noise reduction is a PT in the EU policy with specific objectives for transportation. This priority topic aims at quantifying the improvement in exposure time of population to high noise levels.

3.4.2.4 Energy Consumption Category - EC

Improve driver's compliance with green driving

This Priority Topic tries to quantify the improvement achieved when the driver operates the vehicle under energy-efficient conditions.

Based on the installation of a driver assistance device which provides information and guidance to the drivers to assist them in achieving a more “eco-friendly” driving style to decrease the vehicle’s energy consumption, and thus, its pollutant emissions. The main goal of this PT is to deliver useful and reliable information to the drivers with the intention of adapting their driving behaviour to a less energy demanding performance. The results are gathered using a questionnaire collecting the experts' opinion (drivers’ trainers) and other relevant indicators (measurement of accelerations, braking, etc.).

3.4.2.5 Safety Category – SF

Making driving safer

Improving safety on the roads is a PT for the EC and therefore is included as a PT to be measured. Safety is expected to improve through better fleet maintenance and operation.

3.4.2.6 Economic Category – EF

Reduction of costs related to routes

This PT aims at reflecting the reduction of costs for fleet operation associated to better route choice after the new ITs have been implemented. It is expected that the reduction will come from improved exploitation schemes.

Reduction of costs related to fuel consumption

This PT aims at reflecting the reduction of costs for fleet operation associated to fuel savings thanks to better route choice after the new ITs have been implemented. It is expected that the reduction will come from improved exploitation schemes.

Reduction of costs related to maintenance improvement

This PT aims at reflecting the reduction of costs for fleet operation associated to better maintenance after the new ITs have been implemented. It is expected that the reduction will come from less costly interventions as predictive maintenance is expected to reduce severe breakdowns.

3.4.3 Proactive Rail Infrastructures

3.4.3.1 Operational Efficiency Category – OE

Improved availability

This PT aims at quantifying the increase in infrastructure availability ratios linked to the reduction in maintenance works and their duration thanks to Big Data technology implementation.

Improve ride comfort

This PT aims at measuring the improvement in the accelerations felt by the users, which are a proxy of the users' comfort.

Improve maintenance planning

The achievement of an effective predictive maintenance of the tracks would mean a relevant competitive advantage thanks to the implementation of the Big Data technologies. This PT aims at reflecting the achievement of optimal maintenance planning.

Reduce maintenance time

A reduction of maintenance downtimes in the tracks is a PT for the pilot. Through preventive maintenance and data processing it is expected that a reduction on the intervention times will be achieved.

3.4.3.2 Asset Management Category – AM

Reduce equipment downtime

This PT aims at quantifying the decrease in equipment downtime ratios linked to the effective execution of predictive maintenance thanks to Big Data technology implementation.

Increase prediction of equipment failure

This PT aims at quantifying the effective prediction of failure thanks to Big Data technology implementation. The PT will be measured through the ratio of predicted failures to total failures.

Predictive maintenance achievement

An effective predictive maintenance of the tracks would mean a relevant competitive advantage thanks to the implementation of the Big Data technologies. This PT aims at reflecting this improvements through the monitoring of the ratio of preventive maintenance operations to total maintenance operations.

Improve track operation conditions

The achievement of an effective predictive maintenance of the tracks is expected to improve the minimum conditions under which the track is operating. This PT will quantify the improvement through the measurement of failures in diverse track elements.

Reduction of total maintenance costs

This PT aims at reflecting the reduction of maintenance costs associated to better operation after the new ITs have been implemented. It is expected that the reduction will come from improved exploitation schemes, and less costly interventions as predictive maintenance is expected to reduce severe breakdowns.

Reduce maintenance worker travel distance

This PT aims at quantifying the reduction on travelled distances by the maintenance thanks to better maintenance planning.

3.4.3.3 Environmental Quality Category – EQ

Fuel Savings

This PT aims at quantifying the reduction on fossil fuel consumption by the maintenance vehicles that operate during track downtimes thanks to better maintenance planning.

3.4.3.4 Energy Consumption Category – EC

-No specific PTs have been defined-

3.4.3.5 Safety Category – SF

Enhancing worker safety

Improving working safety is a priority in all transport domains. In the Railways pilot safety is expected to improve through better maintenance and planning of maintenance activities. The quantification will be addressed through the number of track-side activities performed by maintenance workers.

3.4.3.6 Economic Category – EF

Reduction of asset management cost

This PT aims at reflecting the reduction of asset management costs associated to better operation after the new ITs have been implemented. It is expected that the reduction will come from improved exploitation schemes.

Reduction of maintenance cost of railway equipment

This PT aims at reflecting the reduction of maintenance costs for railway equipment associated to better operation after the new ITs have been implemented. It is expected that the reduction will come from improved exploitation schemes, and less costly interventions as predictive maintenance is expected to reduce severe breakdowns.

3.4.4 Ports as Intelligent Logistic Hubs

3.4.4.1 Operational Efficiency Category – OE

Time Savings at Terminal Level

Big Data implementation is expected to help to achieve a better management of the terminal. This PT aims to quantify the increase in efficiency in terminal operations in terms of time savings.

Time Savings at Port level

Big Data implementation is expected to help to achieve a better management of the port. This PT aims to quantify the increase in efficiency in port operations in terms of time savings.

3.4.4.2 Asset Management Category - AM

-No specific PTs have been defined-

3.4.4.3 Energy Consumption Category - EC

-No specific PTs have been defined-

3.4.4.4 Safety Category - SF

-No specific PTs have been defined-

3.4.4.5 Economic Category - EF

Reduce maintenance equipment costs

This PT aims at reflecting the reduction of maintenance costs for port equipment associated to better operation after the new ITs have been implemented. It is expected that the reduction will come from improved exploitation schemes, and less costly interventions as predictive maintenance is expected to reduce severe breakdowns.

3.4.5 Smart Airport Turnaround

3.4.5.1 Operational Efficiency Category – OE

Improve the detection of late passengers

Big Data implementation is expected to help to achieve a better management of the passenger's airport connections to ease the achievement of connecting flights. This PT aims to quantify the increase in efficiency through detection of late passengers for their next flight.

Detection of missed passengers

Big Data implementation is expected to help to achieve a better management of the passenger's airport connections, this PT aims at quantifying the amount of passengers who have missed their connection.

Prediction of passengers

Improving demand forecast is a desirable outcome in order to improve the management of the airport. The progress in this PT will be assessed through the deviation of predicted and real demand.

Passenger behaviour

Passenger dwell time measures the traveller's flow through the Terminal building and much information may be gathered related with passenger behaviour in accordance with various individual and social features. This PT aims at monitoring the dwell time spent by passengers in the airport in order to better deal with their need of services.

Reduction of overall turnaround times

Better management of airport and airline operations through the use of data is expected to tackle and improve flight compliance with Target Off Block Time. A critical parameter for the airport's operations is the airplane's turnaround time, as low values enhance higher productivity results. The PT will be assessed through the ratio of compliant flights to total flights.

Reduction of missed connections

Big Data implementation is expected to help to achieve a better management of the passenger's airline connections, this PT aims at quantifying the reduction in the number of passengers who have missed their connection.

Reduce late passenger rate

Big Data implementation is expected to help to achieve a better management of the passenger's transit through the terminal, this PT aims at quantifying the reduction in the number of passengers who arrive late at their boarding gates.

Improve the identification of transfer passengers with late arrivals

A crucial operational parameter for airports is measured with the ratio of identified transfer passengers with late arrivals to total transfer passengers. This PT will monitor the improvements in this regard.

Reduce passenger time at security control

Queueing at security control increases inefficient passenger dwell time and surges the probability of late arrivals at the boarding gate. This PT will monitor times at Security controls in the terminal in order to quantify the improvements

Increase worker efficiency at security control

Operational efficiency at security control will also be assessed by calculating staff requisites during a certain period.

3.4.5.2 Asset Management Category – AM

Increase the turnaround ratio

Improvements in an efficient use of available technical and human resources would deliver a higher amount of aircraft daily turn-arounds, thus favouring higher productivity, more passengers, lower costs and increased profitability.

Improvement in gate time use efficiency

The monitoring of the airline operations is expected to improve the time that the gates are effectively used. This PT will quantify this improvement through the ratio of gate in use to gate not in use times.

Improve finger-pier gate use

Improving finger-pier gate use is another objective of the operation which is expected to improve though the implementation of Big Data technologies and is therefore assessed.

Increase passenger transit through commercial spaces

From a business perspective, increasing passenger transit through commercial spaces brings higher revenues to the organisation. This PT aims to quantify the improvements in this regard.

Improve customer satisfaction with commercial spaces

For airports, customer satisfaction is a crucial aspect to be monitored. Consequently, a customer service to evaluate the customer's level of satisfaction should be implemented.

Increase commercial space

The proportion of commercial space to total terminal surface provides an indication of commercial area density.

3.4.5.3 Environmental Quality Category – EQ

Noise Reduction

Reduction of acoustic emissions at the Terminal may be achieved by decreasing the number of daily announcements made over the public-address system.

3.4.5.4 Energy Consumption Category – EC

-No specific PTs have been defined-

3.4.5.5 Economic Category – EF

Improve profitability

From an economic perspective, the capacity of Big Data analysis to increase business profitability is evaluated by means of the profit margin.

3.4.6 Integrated Urban Mobility

3.4.6.1 Operational Efficiency Category – OE

Use of optimisation and reservation services

In order to assess the optimal use of parking areas, the number of vehicles using the parking spaces is evaluated.

Route optimisation

Big Data analysis should provide route planners with information that will empower their decision-taking process to modify courses and optimise the fleet’s journeys. Ideally, the distance travelled per delivery should be reduced.

Use of data sources for traffic

Traffic data sources used for the situational awareness and managing the logistic services should increase because of Big Data analysis implementation. Therefore, the integration of new data supply networks will be assessed.

Improve customer satisfaction with service

Customer satisfaction is a crucial aspect to be monitored. Consequently, a customer service to evaluate the customer's level of satisfaction should be implemented.

Improve quantity delivered by vehicle and day

Logistic activity performance will be measured by calculating the number of orders delivered by vehicle per day as well as through the average commercial speeds in the vehicles. This PT will assess the improvement in this regard.

Reduce traffic disruptions

A relevant feature of the system is its capacity to detect traffic disturbances, therefore generating improvements in traffic flow patterns. The average number of vehicles affected by traffic disruptions is also appraised.

Increase use of freight delivery areas

Increasing the use of freight delivery areas is a key objective within the project, so parking space turnover is examined during a certain period. Average parking time in the freight delivery areas is also assessed.

Increase advance booking for car sharing

Car sharing use is an increasingly priority element regarding urban mobility as it solves many issues related to vehicle ownership. This PT aims to assess the advancements made in this regard during the pilot testing.

Increase roadwork planning

Advancing information on road works is an essential element for the urban mobility network to correct planned disruptions. This PT topic will monitor the improvements in this regard using the proportion of planned roadwork to total roadwork events.

Increase in data collection and collected data quality

The collection and processing of data, as well as data source interface availability, future event daily data collection and unplanned events daily data collection are essential elements regarding the correct implementation of Big Data technologies.

Increase the number of events reported by the Traffic Management Centre (TMC)

A reasonable outcome of the innovation's implementation should result in an increase of events reported by the Traffic Management Centre (TMC).

Messages sent to social media and web page visits

In order to measure social communication volume, this PT addresses the average number of daily messages sent to social media is accounted as well as the web page visits.

Policy decision making

Policy decisions made by regulators affecting road transport logistic services is an important issue to be monitored by logistic firms. This PT will monitor the advancements in the matter.

Increase data volume processed

An increase in the volume of quality traffic data sources being processed and considered by the operator is a desirable outcome of the pilot. The assessment will focus on this volume before and after pilot implementation.

Increase length and percentage of road with data gathering systems

Complete and precise data collection requires the presence of an adequately monitored infrastructure. This PT addresses the quantification of the improvements made regarding this need.

3.4.6.2 Asset Management Category – AM

Improve occupation rates in freight delivery parking areas

The implementation of Big Data technologies is sought to improve the use of delivery parking space in the city. This PT will quantify the occupation of the space to assess the improvements achieved thanks to the technologies implemented.

Increase variable messages signs (VMS)

The increased availability of processed information should allow an improvement in the information to the highway users on relevant issues affecting their trip through variable message signs.

Reduction of pollutant emissions

In order to assess transport pollutant emissions, Transforming Transport the pilot will estimate the contents of nitrogen oxides (NOx) and particulate matter (PM) generated during their activity.

3.4.6.3 Environmental quality Category – EQ

Reduction of space occupation

The implementation of Big Data technologies is sought to reduce the need for space occupation in the city. This PT will quantify the occupation of the space to assess the improvements achieved thanks to the technologies implemented.

3.4.6.4 Energy Consumption Category – EC

-No specific PTs have been defined-

3.4.6.5 Economic Category – EF

Reduction of costs related to routes

Predictive analysis, mobility patterns and decision supports systems will allow vehicle fleets to assess the cost reduction of defined routes due to the optimisation of parameters involved in routes choices of vehicle owners such as velocity, alternative routes, congestion, etc.

3.4.7 Dynamic Supply Networks

3.4.7.1 Operational Efficiency Category – OE

Increase number of daily orders handled

This PT will aim to measure the innovation's influence on the amount of daily orders handled by the operation, which is expected to increase thanks to the operational improvements introduced.

Increase delivery fleet efficiency

Increasing the number of deliveries per vehicle, or reducing the number of vehicles that are necessary for the same amount of deliveries relies in the optimization of the routes and processes. Big Data analysis could provide logistic planners supplementary information which could improve consolidated pick-ups and deliveries per vehicle.This PT will address the quantification of this efficiency drivers regarding the fleet.

Increase of punctuality

Order delivery punctuality is a key aspect for any supplier organisation involved in logistic services. Thus, On-time monitoring is crucial for logistic firms.

Improve "last-mileage" delivery efficiency

Increase of the use of shared logistics

Big Data analysis could offer logistic planners additional information that would foster the organisation's capacity to enhance shared logistics, thus improving the deliveries that could be achieved per vehicle.

Increase of the use of alternative shipping methods

Big Data examination may also offer supplementary information that would increase the organisation's capacity to use alternative shipping methods This indicator will monitor the improvements achieved in that regard.

Increase of drops per route

In order to measure logistic operational efficiency, the number of drops per route and per unit distance will be assessed.

Increase of Load Factor

Measuring the ratio of the average load to total vehicle capacity is an essential factor for logistics providers and one main element to be considered when measuring the efficiency. Big Data analysis combined with shared approaches has a great potential in this regard. This PT will quantify the improvements achieved.

Decrease distance travelled

Big Data analysis should provide route planners with information that will empower their decision-taking process to modify courses and optimise the fleet's journeys. Ideally, the distance travelled per delivery should be reduced.

Decrease distance travelled per route

Big Data analysis should provide route planners with information that will empower their decision-taking process to modify courses and optimise the fleet's journeys. Ideally, the distance travelled per route should be reduced.

Decrease number of problematic deliveries

Tis PT addresses the efficacy of the logistic process in the sense that it can be improved by reducing the number of problematic procedures, which also increases customer satisfaction.

Increase forecast of problematic deliveries

Operational efficiency may be enhanced by augmenting the organisation's capacity to predict problematic deliveries and decrease its impact on distribution ineffectiveness.

Click and collect density

The number of click and collect points density will be monitored to evaluate customer pick-up point availability and convenience.

Click and collect coverage
The proportion of orders served in click and collect points will be assessed to measure the utilisation of such delivery procedure.

Improve first time deliveries
The ratio of first time deliveries is an important topic in logistic services because, not only provides increased customer satisfaction, but additionally reduces logistic costs, as return trips are avoided.

Improve customer satisfaction with service
For any logistic service provider, customer satisfaction is a key aspect to be monitored. Consequently, a customer service to evaluate the customer's level of satisfaction will be carried-out.

Increase number of data sources used, data collection
Data sources used for the situational awareness and managing the logistic services should increase because of Big Data analysis implementation. Therefore, the integration of new data supply networks will be assessed.

Increase data volume processed
An increase in the volume of quality deliveries data being processed and considered by the operator is a desirable outcome of the pilot. The assessment will focus on this volume before and after pilot implementation.

3.4.7.2 Environmental quality Category – EQ

-No specific PTs have been defined-

3.4.7.3 Economic Category – EF

Decrease order delivery and returns cost
The implementation of Big Data analysis in the shared logistics sector is sought to introduce efficiencies that will lead to a cost reduction for individual orders, for deliveries and also for the cost of returns. This PT will monitor each of the costs to quantify these advantages.

3.5 Pilot Objectives Qualitative Assessment.

The following table reflects TT Pilot's Performance Objectives. These objectives were defined by the pilots on D*.1 and are reflected on chapter 2.2. As it is specified in the description of the Assessment Framework, the different objectives will be evaluated through a qualitative appraisal of the different impacts.

Table 19 – Pilot Performance Objectives Qualitative Assessment (TBD)

SMART HIGHWAYS		
	Objective	Qualitative assessment
SH_O1	Understanding the mobility patterns in the corridors and the route choice criteria: - Develop a descriptive modelling of road traffic - Forecast traffic flows and the infrastructure use at short, medium and long term based on external variables (weather, calendar, etc.)	
SH_O2	Optimising highway operations by prescription: - Staff schedule optimisation - Scheduling of operations and maintenance tasks	
SH_O3	Safer roads: - Reduce the number of accidents provoked by animals by predicting, according to probability rules, the risks for this kind of accidents to happen - Prevent and react to accidents	

CONNECTED VEHICLES		
	Objective	Qualitative assessment
CV_O1	Deployment of a Big Data infrastructure with descriptive and predictive analytics capabilities	
CV_O2	Development of API services to carry out data injection to the Big Data infrastructure	
CV_O3	Development of a generic visualization tool for data sets analysis	
CV_O4	Development of a Breakdown estimator system: - Notify information about a current car breakdown and be notified with a maintenance report - Application of machine learning techniques to carry out predictive analysis of car breakdowns - Visualization of breakdown report for every car - Building up the service that will send the cars' breakdown reports to the drivers' smartphone application	
CV_O5	Emissions reduction system: - Monitoring of fuel consumption of every car to identify situations when their	

	consumption has increased - Monitoring of drivers' behaviours to identify non-eco-friendly ones - Extension of SoFLEET smartphone application to allow drivers to be notified with recommendations in order to reduce emission - Building up the service that will send the emission reports to the drivers' smartphone application - Visualization of historical emission evolution for every car	
CV_O6	Traffic jam detector system: - Applying algorithms to carry out descriptive analysis to identify situations where a car is in a traffic jam and evaluation of the traffic congestion in real-time - Extension of SoFLEET smartphone application to allow drivers to be notified about nearby traffic jams - Building up the service that will send detected traffic jams to the drivers' smartphone application - Real-time visualization of traffic jams in a map - Heatmap visualization of historical traffic jams by hour	
CV_O7	Deployment of a Big Data infrastructure with descriptive and predictive analytics capabilities	

PROACTIVE RAIL INFRASTRUCTURES		
Objective		Qualitative assessment
RI_O1	Verify the quality, accuracy and provenance of asset data, leading to confidence to	
RI_O2	Provide timely focused prioritised maintenance activities (predict and prevent), leading to	
RI_O3	Improved reliability and availability of track-side assets, with	
RI_O4	Higher availability of rail infrastructure for passenger and freight services; and	
RI_O5	Enhancing worker safety through minimising track-side activities	
RI_O6	Collect, process and analyse information based on Big Data techniques for the prediction of the evolution of the degradation of switches and crossings of the high speed lines throughout its useful life	
RI_O7	Collect, process and analyse information based on Big Data techniques for the prediction of the evolution of the degradation of track profiles of the high speed lines throughout its useful life	
RI_O8	Collect, process and analyse information based on Big Data techniques for the prediction of the evolution of the topographic characteristics of the slopes that are part of the railway infrastructure	

PORTS AS INTELLIGENT LOGISTIC HUBS		
Objective		Qualitative assessment
PLH_O1	Design, implement and deploy and optimisation algorithm that provides the user with the best sequence of crane movements	
PLH_O2	Apply Predictive Maintenance models to cranes' spreaders, starting with the study and deployment of a set of sensor devices to gather information regarding the spreaders of the STS cranes	
PLH_O3	Develop an advanced Cockpit for better decision-making, including a predictive decision support system that considers all the historical data available at the Valencia Port Information Systems	
PLH_O4	Terminal productivity cockpit for Duisport : - Exploit advanced data processing and predictive analytics to facilitate proactive decision making and process adaptation	

SMART AIRPORT TURNAROUND		
Objective		Qualitative assessment
SA_O1	Operation Management Predictive Optimisation Module: - Reduce delays in departure flights caused by late passengers - Reduce the number of passenger missing connections and lost baggage - Improve the efficiency of passenger processing stations (security screening, passport control, check in desks…) - Reduce overall turnaround times	
SA_O2	Descriptive passenger behaviour system: - Obtain insight on how passenger behave along their journey, especially within the airport terminal to enable customized services/offers, increasing passenger satisfaction and non-aeronautical revenue	

INTEGRATED URBAN MOBILITY		
	Objective	Qualitative assessment
IU_O1	Provision of tools for urban traffic management for diagnosis of traffic status and for selection of alternative solutions for mitigating the impact of roadworks and other events. Addition of new data sources for improved situational awareness, such as social media and traffic cameras. This objective corresponds to requirement	
IU_O2	Provision of tools for drivers and travelers regarding traffic status	
IU_O3	Provision of tools to improve the access of goods delivery vehicles to parking places	
IU_O4	Generating a traffic model for particular areas in the city where freight transport has more impact	
IU_O5	Option to analyse different freight delivery scenarios and make best decision according to the results	
IU_O6	Creation of a planning tool for delivery fleets and to inform drivers about the route plan they must follow to ensure fulfilment of (not limited to): - Minimise the time freight vehicles are inside city centre boundaries, which is related to traffic alleviation - Minimise the distance travelled by freight vehicles inside city centre boundaries, which is related to pollution reduction	

DYNAMIC SUPPLY NETWORKS		
	Objective	Qualitative assessment
SN_O1	To investigate and suggest shared logistics scenarios in e-Commerce by taking into account data from various supply chain stakeholders (e.g. e-commerce retail players, 3PLs) in order to decrease cost and environmental burden and increase customer satisfaction and convenience in respect to e-commerce deliveries.	
SN_O2	To expand the shared logistics concept by incorporating replenishment aspects and conducting a synergetic inventory management strategy in order to increase service level, increase the precision of the future demand estimations and decrease the requirement of extra (non-prescheduled) vehicle routes and their respective costs	
SN_O3	To provide alternative shipping methods at the consumer in order to increase customers' satisfaction and provide lower prices	

4 KPIs for the General Assessment

As previously mentioned, Key Performance Indicators (KPIs) are needed in order to measure the degree of target achievement. Thus, for each Priority Topic (PT) identified, at least one KPI will be defined to measure to which extent the target has been reached.

Performance measurement is a fundamental principle of management. The measurement of performance is important because it identifies current performance gaps between actual and expected/desired performance, and provides an indication of the progress towards closing the gaps. Carefully selected KPIs precisely identify those areas which require actions to improve performance (Weber & Thomas, 2005). A set of well-defined KPIs will identify those transport systems which perform outstandingly during their operation. The KPIs provide a means of comparing performance and identifying best practice for the different transport systems across the demo cases (Randall et al, 2007). Therefore, using comprehensive and objective KPIs will enable the comparison between the different Pilots being implemented.

Within the TT project, KPIs are used to measure the performance of different categories related with the transport systems among them and versus *status quo*. They are considered relevant for measuring the degree of achievement of the Performance Targets in each Pilot. The challenge in the definition of the KPIs is to select the appropriate indices that will provide a sufficient understanding of overall performance (Henning et al, 2011). The KPIs should also be practical in terms of data availability and understandable to the audience. According to Doran (1981), KPIs should be SMART, which means Specific, Measurable, Achievable, Realistic and Timely.

The final aim of the selected KPIs is to ensure that, by defining an appropriate amount of such indicators, the objectives of the project are duly covered (from operational efficiency, to energy management, economic affordability and sustainability, and public awareness). With these suppositions under consideration, the KPIs for this research work have been selected in accordance with the preceding composition of Pilot Objectives and Priority Topics.

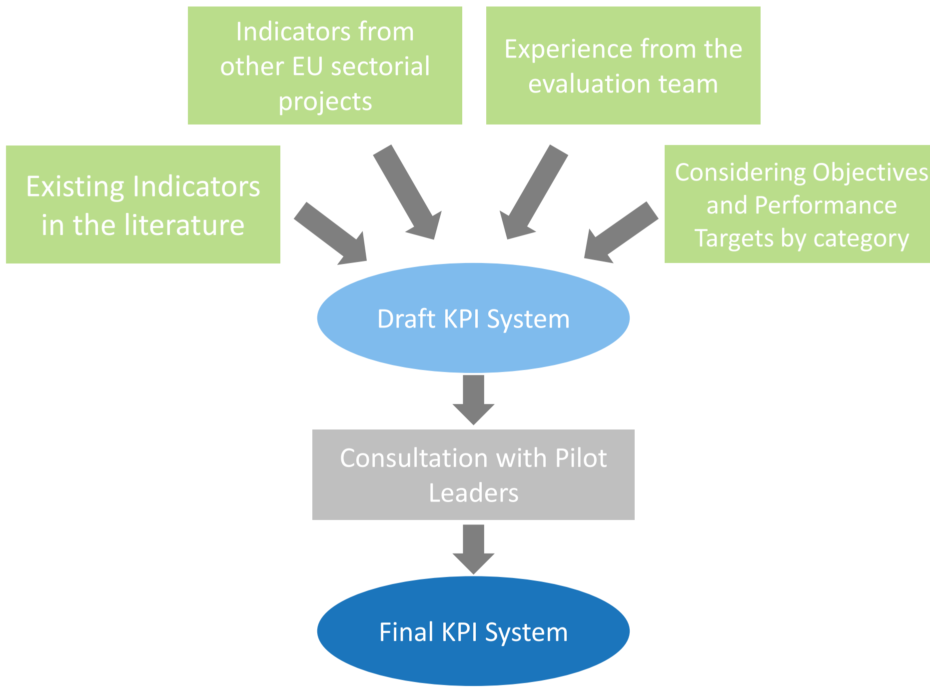
The identification of the KPIs has been an accurate and demanding task in which all pilot leaders have been involved, together with the evaluation team. The process can be summarised in two steps:

I. The evaluation team proposed an initial **draft list of Priority Topics and KPIs**, which were coherent with the predetermined assessment Categories and pilot objectives, considering the existing KPIs in literature, and with a special focus on the expected impacts generated by the introduction of Big Data technologies, the local situation and testing environment of each Pilot, while also taking into account the experience of the evaluation team and the results of other sectorial EU projects.

II. Demo leaders performed an **internal assessment** to evaluate the suitability of the KPIs proposed for each TI and finalised the local selection.

The KPI development process is shown in Figure 8. The diagram illustrates how the KPI system is established through a combination of means and sources of information.

Figure 8 - KPI development process



(Based on Randall et al, 2007)

KPIs will be calculated in two scenarios[6] in order to obtain the degree of variation among the different circumstances.

Some of the KPIs are quantitative (e.g. average commercial speed), while others can be qualitative (e.g. drivers' perception of safety). These qualitative KPIs rely on assessments, ratings or rankings derived from different surveys (to passengers, drivers and/or operators), or even through experts' opinions. To this end, common questionnaires will be designed to ensure the comparability of results between pilots.

[6] *No-TT and TT scenarios: before the implementation of the Big Data technologies and once it has been introduced in the Pilot; or comparing a control scenario versus the test situation, contemporarily (the latter needed when no ex-ante data are available).*

This section presents the PT and KPIs that every single Pilot has selected for its measurement within the global evaluation.

4.1 Selection of KPIs

For each Assessment Category, its KPIs are selected and classified in two categories: transversal or specific. Transversal KPIs are chosen to provide qualitative and quantitative results which may be useful in comparing the activities performed by the diverse WP pilots. Specific KPIs are defined to deliver traversed information concerning the performance of those pilots performing similar business activities.

In this section, a summary of transversal and specific KPIs is presented for each of the pilots. For a more detailed description on each KPI please refer to ANNEX I: KPI tables.

4.1.1 KPIs for Smart Highways (WP4)

These pilots' objectives are to improve traffic flows (mitigate congestion, accident reduction…) along the corridor, together with a more efficient management of the present infrastructure, while enhancing user satisfaction and interaction with the network.

Consequently, indicators for this innovation are based on measurements of traffic flow and its distribution, safety and maintenance improvements, increases in customer satisfaction levels and user loyalty, together with a more efficient cost structure. Table 20 shows the set of KPIs selected for Smart Highways. KPIs marked with an "X" are those which have been selected by the pilot, and a shaded KPI designates its categorisation as transversal indicator.

Table 20 - Summary of KPIs for the Pilot

WP4	Smart Highways			
Operational Efficiency (OE)				
Ref.	Key Performance Indicator (KPI)	Units	P 4.2	P 4.3
SH-OE-1	Operating cost	€/vehicle-km €/tonne-km	X	X
SH-OE-2	Time savings to users	Minutes/vehicle-km Minutes/passenger-km	X	X
SH-OE-3	Traffic congestion time to total time	%	X	
SH-OE-4	Average commercial speed	km/h	X	X
SH-OE-5	Number of traffic sources (#) used by operator (before and after)	Dimensionless (#)	X	X

SH-OE-6	Average data volume collected daily (Gb) (before and after)	Gb/day	X	X
SH-OE-7	Average ratio of data processed vs collected	%	X	X
SH-OE-8	Number of messages to users (before and after)	Messages (#)/day	X	X
SH-OE-9	Black spots per 100 km	Black spots (#)/100 km		X
SH-OE-10	Bottleneck locations per 100 km	Bottleneck loc. (#)/100 km	X	
SH-OE-11	Average traffic short-term prediction as of real traffic	%	X	X
Asset Management (AM)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 4.2**	**P 4.3**
SH-AM-1	Number of maintenance interventions	Interventions (#)/(year x x 100,000 vehicle-km)	X	X
SH-AM-2	Average duration of maintenance interventions	Minutes	X	X
SH-AM-3	Traffic volume (AADT and average vehicle hourly flow)	AADT (vehicles/day) vehicle-km/hour	X	X
SH-AM-4	Length and percentage of road with data gathering systems	km %	X	X
SH-AM-5	Waiting time at queues in toll areas	Hours/10,000 vehicles Queue (h)/Total hours (%)	X	
SH-AM-6	Differences between real and forecasted traffic	%	X	X
SH-AM-7	Ratio of planned maintenance work to total maintenance interventions	%	X	X
SH-AM-8	Distance travelled by the maintenance fleet per year	km/(year x km of highway)	X	X
Environmental Quality (EQ)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 4.2**	**P 4.3**
SH-EQ-1	NOx emissions	g NOx/km	X	X
SH-EQ-2	Animal runover	Runovers/10,000 veh.-km	X	X
Energy Consumption (EC)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 4.2**	**P 4.3**
SH-EC-1	GHG emissions	g CO_2/km	X	X
SH-EC-2	Vehicle energy consumption per 100 km	kWh/100 km	X	X
	Safety (SF)			
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 4.2**	**P 4.3**
SH-SF-1	Accidentality rate	Accidents (#)/(10,000 veh.-km)	X	X
SH-SF-2	Reduction of response time	Minutes	X	X
SH-SF-3	Drivers' perception of safer driving (Automated digital score)	Survey – Score: (1-5)	X	
SH-SF-4	Messages to platform by automated systems	Messages (#)/100 km	X	X

Economic (EF)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 4.2**	**P 4.3**
SH-EF-1	Average cost of network maintenance per lane kilometre of road network	€/km	X	X
SH-EF-2	Variance metric based on Capital expenditure	Currency (€)	X	X
SH-EF-3	Variance metric based on Operational expenditure	Currency (€)	X	X

4.1.2 KPIs for Sustainable Connected Vehicles (WP5)

These pilot's innovations focus on the application of Big Data real-time processing can provide safety and sustainability to road transport. Pilots will assess:

- High added value services driven by large-scale analyses for predictive maintenance, traffic accidents identification, and enhancing green-driving for emission reductions.
- Optimise vehicle fleet management by continuous monitoring and the use of data-gathering systems and decision support methodologies.
- Increase fleet efficiency optimising route journeys based on predictive demand and historical analysis of local mobility patterns.

Therefore, the set of indicators developed for these technologies emphasise features related with route optimisation based on traffic data sources, operating safety and maintenance improvements, green-driving promotion and a more efficient cost structure. The selected KPIs for Sustainable Connected Vehicles are listed in Table 21.

Table 21 - Summary of KPIs for the Sustainable Connected Vehicles Pilot

WP5	**Sustainable Connected Vehicles**			
Operational Efficiency (OE)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 5.2**	**P 5.3**
CV-OE-1	Operating cost	€/vehicle-km	X	X
CV-OE-2	Time savings to users	Minutes/vehicle-km	X	X
CV-OE-3	Average commercial speed in peak hour	km/h	X	
CV-OE-4	Average commercial speed in off-peak hour	km/h	X	
CV-OE-5	Number of harsh accelerations per vehicle-km (≥3 m/s^2)	Harsh accelerations (#) / / Vehicle-km	X	
CV-OE-6	Number of harsh decelerations/vehicle-km (≤-4 m/s^2)	Harsh decelerations (#) / / Vehicle-km	X	

CV-OE-7	Number of daily traffic jam messages to users (before and after)	Messages (#)/day	X	
Asset Management (AM)				
Ref.	Key Performance Indicator (KPI)	Units	P 5.2	P 5.3
CV-AM-1	Average idle time	%	X	X
CV-AM-2	Number of Diagnostic Trouble Codes (DTC) per vehicle and 10,000 km	DTCs (#)/10,000 veh.-km	X	
CV-AM-3	Vehicle breakdowns per vehicle and 10,000 km	Breakdowns (#)/10,000 vehicle-km	X	
Environmental Quality (EQ)				
Ref.	Key Performance Indicator (KPI)	Units	P 5.2	P 5.3
CV-EQ-1	NOx emissions	g NOx/km	X	X
CV-EQ-2	PM emissions	g PM/km	X	X
CV-EQ-3	Number of driver notifications to reduce emissions / 100 vehicle-km	Notif. (#)/100 vehicle-km	X	
Energy Consumption (EC)				
Ref.	Key Performance Indicator (KPI)	Units	P 5.2	P 5.3
CV-EC-1	GHG emissions	g CO_2/km	X	X
CV-EC-2	Vehicle energy consumption per 100 km	kWh/100 km	X	X
CV-EC-2	Time proportion driven in Eco-friendly conditions	%	X	
	Safety (SF)			
Ref.	Key Performance Indicator (KPI)	Units	P 5.2	P 5.3
CV-SF-1	Drivers' perception of safer driving	Survey – Score: (1-5)	X	
Economic (EF)				
Ref.	Key Performance Indicator (KPI)	Units	P 5.2	P 5.3
CV-EF-1	Reduction of fuel costs	Currency (€)/vehicle-km	X	
CV-EF-2	Reduction of maintenance costs	Currency (€)/vehicle-km	X	

4.1.3 KPIs for Proactive Rail Infrastructures (WP6)

These pilots' objectives focus on developing new methodologies to optimise rail infrastructure maintenance to enhance:

- Rail worker safety by minimising trackside time.
- Overall railroad passenger safety by applying predictive failure detection techniques.
- Service reliability by minimising downtime and service incidences.
- Cost efficiency, thus prioritising on asset preventative maintenance.
- Service reliability by minimising disruptions.

Monitoring the results achieved by the technologies requires evaluating those aspects related with infrastructure availability, trackside activity characteristics and enhanced safety conditions, while simultaneously obtaining maintenance cost reductions. The list of indicators selected for these innovations is shown in Table 22.

Table 22 - Summary of KPIs for the Proactive Rail Infrastructures Pilot

WP6	Proactive Rail Infrastructures			
Operational Efficiency (OE)				
Ref.	Key Performance Indicator (KPI)	Units	P 6.2	P 6.3
RI-OE-1	Operating cost	€/km	X	X
RI-OE-2	Time savings to users	Minutes	X	
RI-OE-3	Availability (time % with infrastructure in operating conditions)	%		X
RI-OE-4	Average train vertical upwards acceleration (car body)	m/s^2		X
RI-OE-5	Average train vertical downwards acceleration (car body)	m/s^2		X
RI-OE-6	Maximum train lateral acceleration (car body).	m/s^2		X
RI-OE-7	Ratio of maintenance time on holidays to total maintenance time	%		X
RI-OE-8	Average maintenance time per intervention	Man-hours		X
Asset Management (AM)				
Ref.	Key Performance Indicator (KPI)	Units	P 6.2	P 6.3
RI-AM-1	Number of interventions	Interv. (#)/(year x 100 km)	X	X
RI-AM-2	Average duration of interventions	Minutes	X	X
RI-AM-3	Train circulations	Trains (#)/day	X	X
RI-AM-4	Vehicle / equipment downtime (%)	%		X
RI-AM-5	Ratio of predicted failures to total breakdowns	%		X
RI-AM-6	Ratio of preventive maintenance interventions to total maintenance interventions (preventive + corrective)	%		X
RI-AM-7	Failures in switch and crossing elements	Failures (#)/(100 km x yr.)		X
RI-AM-8	Failures in track profile elements	Failures (#)/(100 km x yr.)		X
RI-AM-9	Failures in slopes close to tracks	Failures (#)/(100 km x yr.)		X
RI-AM-10	Poor quality track identified per 100 km and year	km/(100 km x year)		X
RI-AM-11	Ratios of maintenance costs per worker and maintenance costs to total costs	€/(worker x year) %		X
RI-AM-12	Maintenance worker travel distance	km/(worker x year)		X

Environmental Quality (EQ)				
Ref.	Key Performance Indicator (KPI)	Units	P 6.2	P 6.3
RI-EQ-1	NOx emissions	g NOx/km	X	X
Energy Consumption (EC)				
Ref.	Key Performance Indicator (KPI)	Units	P 6.2	P 6.3
RI-EC-1	GHG emissions	g CO_2/km	X	X
RI-EC-2	Fossil fuel energy consumption	Litres/day		X
Safety (SF)				
Ref.	Key Performance Indicator (KPI)	Units	P 6.2	P 6.3
RI-SF-1	Number of track-side activities	Activ. (#)/(mth. x 100 km)		X
Economic (EF)				
Ref.	Key Performance Indicator (KPI)	Units	P 6.2	P 6.3
RI-EF-1	Total asset turnover ratio	%	X	X
RI-EF-2	Maintenance cost of railway equipment	€/(100 km x day)	X	X

4.1.4 KPIs for Ports as Intelligent Logistic Hubs (WP7)

These pilots apply Big Data technologies to improve port operations by designing new cockpits, using predictive maintenance techniques and optimising port operation activities. The KPIs developed for this application assess time and cost savings, and measure the system's capacity to enhance equipment reliability. These indicators are enumerated in Table 23.

Table 23 - Summary of KPIs for the Ports as Intelligent Logistic Hubs Pilot

WP7	Ports as Intelligent Logistic Hubs			
Operational Efficiency (OE)				
Ref.	Key Performance Indicator (KPI)	Units	P 7.2	P 7.3
PLH-OE-1	Operating cost	€/(tonne x year)		X
PLH-OE-2	Average time per operation	Minutes/tonne		X
PLH-OE-3	Average Truck Turnaround Time in Terminal per week	Minutes/truck	X	X
PLH-OE-4	Average time per transaction (container order)	Minutes/transaction	X	X
PLH-OE-5	Average Truck Turnaround Time from a port in-gate to a terminal gate per year	Minutes/truck	X	X
PLH-OE-6	Average Truck Turnaround Time from a terminal gate to a port out-gate per year	Minutes/truck	X	X

Asset Management (AM)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 7.2**	**P 7.3**
PLH-AM-1	Average downtime per equipment item X	Hours		X
PLH-AM-2	Average breakdowns per equipment item X	Dimensionless		X
PLH-AM-3	Asset use optimisation	%		X
PLH-AM-4	Average downtime per monitored terminal equipment	%	X	X
PLH-AM-5	Average breakdowns per monitored terminal equipment	Breakdowns (#) / / (equip. x 10,000 hours)	X	X
PLH-AM-6	Mean container handlings between failure (MMBF) per monitored terminal equipment	Containers (#) (Dimensionless)	X	X
Energy Consumption (EC)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 7.2**	**P 7.3**
PLH-EC-1	Average energy consumption by monitored terminal equipment per container handling	kWh/container	X	X
Economic (EF)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 7.2**	**P 7.3**
PLH-EF-1	Operational cost per container	€/container	X	X
PLH-EF-1	Average per monitored terminal equipment maintenance costs	€/equipment	X	X

4.1.5 KPIs for Smart Airport Turnaround (WP8)

The application of Big Data to airport management can deliver substantial advances to facilitate the operation's administration and improve its profitability and competitiveness. The main objectives of innovations proposed by the pilots are:

- Optimising the airport's operation with increased stakeholder satisfaction.
- Reducing the number of connecting passengers losing their flight.
- Lessening customer complaints.
- Enhancing passenger experience by offering personalised services.

Consequently, the related KPIs aim to measure reductions in the magnitude of delays, missed connections, passenger complaints, and customer satisfaction. Table 24 illustrates the list of KPIs selected to assess the Smart Airport innovations.

Table 24 - Summary of KPIs for the Smart Airport Turnaround Pilot

WP8	Smart Airport Turnaround			
Operational Efficiency (OE)				
Ref.	Key Performance Indicator (KPI)	Units	P 8.2	P 8.3
SA-OE-1	Operating cost	€/(passenger x year)	X	X
SA-OE-2	Terminal operating cost	€/(passenger x year)	X	
SA-OE-3	Flight delays	Minutes/flight Minutes/passenger Delay/Total duration (%)	X	X
SA-OE-4	Time at gate for the latest passenger	Minutes	X	
SA-OE-5	Late connected passengers	%	X	
SA-OE-6	Economy checked passengers without boarding	%	X	
SA-OE-7	Business checked passengers without boarding	%	X	
SA-OE-8	Checked passengers without boarding	%	X	
SA-OE-9	Economy passengers expected per time interval	%	X	
SA-OE-10	Business passengers expected per time interval	%	X	
SA-OE-11	Total passengers expected per time interval	%	X	
SA-OE-12	Dwell time for Economy passengers	Minutes/passenger	X	
SA-OE-13	Dwell time for Business passengers	Minutes/passenger	X	
SA-OE-14	Dwell time for passengers	Minutes/passenger	X	
SA-OE-15	Average aircraft turnaround time	Minutes/aircraft		X
SA-OE-16	Number of flights complying TOBT (Target Off Block Time) to total departures.	%	X	X
SA-OE-17	Missed connections per 100 passengers	%	X	X
SA-OE-18	Ratio of identified transfer passengers with late arrivals to total transfer passengers	%		X
SA-OE-19	Ratio of delays caused by late transfer passengers to total delays	%		X
SA-OE-20	Number of passengers arriving late to boarding to total passengers	%	X	
SA-OE-21	Average passenger time at security control	Minutes/passenger		X
SA-OE-22	Ratio of worker time to passenger volume at security control	Man-hours/10,000 pass.		X
SA-OE-23	Average passenger time for passport control	Minutes/passenger		X
SA-OE-24	Average time required by passenger from Terminal entry to boarding gate	Minutes/passenger	X	
SA-OE-25	Passenger Satisfaction Index	CSI: Dimensionless (1-5)		X

SA-OE-26	Complaints per 100 passengers	%		X
SA-OE-27	Number of data sources used (before and after)	Dimensionless (#)		X
SA-OE-28	Average data volume collected daily (Gb) (before and after)	Gb/day		X
SA-OE-29	Ratio of time with data source interface accessibility	%		X
SA-OE-30	Average ratio of data processed vs collected	%		X
Asset Management (AM)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 8.2**	**P 8.3**
SA-AM-1	Number of turn-arounds per day	Turn-arounds (#)/day		X
SA-AM-2	Number of in-time turn-arounds to total t-a	%		X
SA-AM-3	Gate time use efficiency	%		X
SA-AM-4	Ratio of aircrafts using finger-pier gate as of total aircrafts	%		X
SA-AM-5	Passenger transit through commercial spaces	Passengers/day		X
SA-AM-6	Passenger Satisfaction Index	CSI: Dimensionless (1-5)		X
SA-AM-7	Ratio of commercial space to total terminal surface	%		X
Environmental Quality (EQ)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 8.2**	**P 8.3**
SA-EQ-1	Number of daily announcements made over the public address-system	Announcements (#)/day		X
Economic (EF)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 8.2**	**P 8.3**
SA-EF-1	Profit margin	%		X

4.1.6 KPIs for Integrated Urban Mobility (WP9)

These pilots assess potential of Big Data in supporting urban traffic managers to recognise disturbances, alleviating the impact of roadworks and exceptional situations. Furthermore, Big Data provides drivers with current traffic information and assists them in optimising route selection and available parking space.

Thus, indicators to evaluate these technologies will evaluate aspects concerning disruption prediction, optimal route design, parking space management and system-driver communication enhancements. The selected KPIs for Integrated Urban Mobility are described in Table 25.

Table 25 - Summary of KPIs for the Integrated Urban Mobility Pilot

WP9	Integrated Urban Mobility			
	Operational Efficiency (OE)			
Ref.	Key Performance Indicator (KPI)	Units	P 9.2	P 9.3
IU-OE-1	Time used by freight vehicles in the city centre for driving and parking	h/(vehicle x day)	X	X
IU-OE-2	Average delivery time	Minutes/delivery	X	X
IU-OE-3	Number of vehicles which have used the parking spaces	Dimensionless (#)	X	X
IU-OE-4	Average number of km/delivery	km/(delivery x day)	X	X
IU-OE-5	Traffic data sources used for managing services	Dimensionless: Data sources (#)	X	X
IU-OE-6	Customer satisfaction with service	CSI: Score 1-5	X	X
IU-OE-7	Orders delivered by vehicle per day	Orders (#)/(vehicle x day)	X	X
IU-OE-8	Average commercial speed	km/h		X
IU-OE-9	Traffic flow	Vehicle-km/h		X
IU-OE-10	Number of traffic disruptions detected per hour	Disruptions (#)/hour	X	X
IU-OE-11	Average number of vehicles affected by traffic disruptions	Dimensionless: Vehicles (#)/Disruption (#)		X
IU-OE-12	Number of daily vehicles using freight delivery areas	Vehicle/(100 places x day)	X	X
IU-OE-13	Average parking time in freight delivery areas	Minutes	X	X
IU-OE-14	Ratio of advance booking for freight delivery areas	%	X	
IU-OE-15	Ratio of advance bookings for car sharing and average time in advance	% Minutes	X	
IU-OE-16	Ratio of planned roadwork to total roadwork events	%	X	
IU-OE-17	Average data volume collected daily (Gb) (before and after)	Gb/day	X	X
IU-OE-18	Average daily collected events/observations per data set (before and after)	Events (#)/day	X	
IU-OE-19	Data quality of observations per data set (ratio of outliers)	%	X	X
IU-OE-20	Ratio of time with data source interface accessibility (per data source)	%	X	
IU-OE-21	Average daily future events assessed	Events (#)/day	X	
IU-OE-22	Average daily unplanned events assessed	Events (#)/day	X	
IU-OE-23	Average ratio of data processed vs collected	%		X

IU-OE-24	Average daily number of events reported by the Traffic Management Centre (TMC)	Events (#)/day	X	
IU-OE-25	Average number of daily messages sent to social media	Messages (#)/day	X	
IU-OE-26	Average number of social media followers receiving information	Dimensionless: Followers (#)	X	
IU-OE-27	Average daily number of website visitors	Visits/day (#)	X	
IU-OE-28	Average daily messages displayed in variable messages signs (VMS)	Messages (#)/day	X	
IU-OE-29	Number of regulations proposed by the city council related to load and unload car places	Dimensionless (#)	X	X
Asset Management (AM)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 9.2**	**P 9.3**
IU-AM-1	Length and percentage of road with data gathering systems	km %	X	
IU-AM-2	CCTV camera installations	Cameras (#)/intersect. (#) Cameras (#)/10 km	X	
IU-AM-3	Total number of existing freight delivery places	Dimensionless (#)	X	X
IU-AM-4	Number of variable messages signs (VMS) per 100 km	VMS (#)/100 km	X	
Environmental Quality (EQ)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 9.2**	**P 9.3**
IU-EQ-1	NOx emissions	g NOx/km	X	X
IU-EQ-2	Occupied surface while delivering	m^2	X	X
IU-EQ-3	Occupied surface by cargo	m^2	X	X
Energy Consumption (EC)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 9.2**	**P 9.3**
IU-EC-1	GHG emissions	g CO_2/km	X	X
IU-EC-2	Energy consumption per 100 km	kWh/100 km	X	X
Economic (EF)				
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 9.2**	**P 9.3**
IU-EF-1	Ratio of cost performance of defined routes through data monitoring	€/km	X	X

4.1.7 KPIs for Dynamic Supply Networks (WP10)

This pilot's goal is to develop guidelines regarding the potential use of Big Data in e-commerce logistics and deliver a roadmap to define how Big Data solutions can be managed and implemented. As main objectives, the project pretends to:

- Use Big Data techniques to quantify the impact of shared logistics in e-commerce deliveries to reduce costs, energy consumption and emissions.
- Enhance shared logistics at the reverse logistics supply chain.
- Evaluate alternative shipping methods.

Hence, the set of indicators proposed for these innovations intend to measure those features related with route optimisation and traffic flow management, energy and time efficiency improvements in the delivery process, potential benefits provided by novel logistic methodologies, and overall operational cost reductions for the organisation. The list of indicators selected for these innovations is shown in Table 26.

Table 26 - Summary of KPIs for the Dynamic Supply Networks Pilot

WP10	Dynamic Supply Networks		
Operational Efficiency (OE)			
Ref.	Key Performance Indicator (KPI)	Units	P 10.2
SN-OE-1	Operating cost	€	X
SN-OE-2	Average delivery time	Minutes	X
SN-OE-3	Number of daily orders handled	Orders (#)/day	X
SN-OE-4	Number of daily deliveries per vehicle	Deliveries (#)/(veh. x day)	X
SN-OE-5	On time deliveries to customers	%	X
SN-OE-6	Average number of vehicles in the delivery fleet	Dimensionless: Vehicles (#)	X
SN-OE-7	Average number of daily consolidated pick-ups and deliveries per vehicle	Deliveries (#)/(veh. x day)	X
SN-OE-8	Ratio of consolidated pick-ups and deliveries to total deliveries	%	X
SN-OE-9	Orders using shared logistics	Deliveries (#)/(veh. x day)	X
SN-OE-10	Orders using alternative shipping methods	%	X
SN-OE-11	Drops per route	Drops (#)/km	X
SN-OE-12	Load factor	%	X
SN-OE-13	Daily distance travelled per delivery	km/(delivery x day)	X
SN-OE-14	Average distance travelled per route	km/route	X
SN-OE-15	Ratio of problematic deliveries	%	X
SN-OE-16	Ratio of forecasted problematic deliveries to actual problematic deliveries	%	X
SN-OE-17	Number of click and collect points per area	Click and coll. pts. (#)/km^2	X
SN-OE-18	Orders served by click and collect	%	X
SN-OE-19	First time delivery ratio	%	X
SN-OE-20	Customer satisfaction with service	CSI: Score (1-5)	X
SN-OE-21	Number of data sources used (before and after)	Dimensionless: Sources (#)	X

SN-OE-22	Average data volume collected daily (Gb) (before and after)	Gb/day	X
SN-OE-23	Ratio of time with data source interface accessibility	%	X
SN-OE-24	Ratio of data processed vs collected	%	X
Environmental Quality (EQ)			
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 10.2**
SN-EQ-1	NOx emissions	g NOx/km	X
SN-EQ-2	PM emissions	g PM/km	X
Energy Consumption (EC)			
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 10.2**
SN-EC-1	GHG emissions	g CO_2/km	X
SN-EC-2	Energy consumption per 100 km	Litres/100 km	X
Economic (EF)			
Ref.	**Key Performance Indicator (KPI)**	**Units**	**P 10.2**
SN-EF-1	Order delivery cost	Cost (€)/order (#)	X
SN-EF-2	Delivery cost	Cost (€)/delivery (#)	X
SN-EF-3	Cost of returns	Cost (€)/return (#)	X

4.2 KPI performance according to scenarios

The assessment of the results provided by any investment in a transportation system is based on its validation and comparison in different scenarios. Within this methodology, the benefits are evaluated by means of the variation between the "No-TT", control or ex-ante, scenario (situation without the implementation of the Big Data Technology) and the "TT" scenario (according to the data collected when the corresponding innovations are being implemented).

Consequently, it is necessary to define and utilize KPIs with the purpose of gathering quantitative and qualitative information concerning the level of achievement of the General Assessment Categories and the Performance Targets defined for the topics within them, and consequently attain a more thorough understanding of the conditions related with the results, which may be used for scenario comparison, and ultimately for the Global Evaluation analysis. Therefore, all KPIs related to each Pilot scenario require its measurement prior to and once the Big Data technology has been implemented, within the TT time span. These KPI results, and its variation between both scenarios, provide the necessary basis to evaluate the degree of achievement of those targets previously established.

The variation of KPIs between scenarios will be calculated as the relative difference, following the formula (1):

(1)

$$KPI_{Var} = \left(\frac{KPI_2 - KPI_1}{KPI_1}\right) x100$$

With KPI_1 reporting the performance in the No-TT scenario (before or control) and KPI_2 the performance during the TT scenario.

For each of the selected KPIs, its related definition, unit of measurement and source for the data provision have been preliminarily established to avoid misunderstandings during data provision process. Therefore, in accordance with the aforementioned requisites, the previous section included the list of KPIs to be addressed, per Pilot, Category and Priority Topic.

4.3 Performance Target achievement

As a continuation of the evaluation process, once the innovations have been implemented and the tests are completed, the contribution of Big Data in each pilot case is assessed by comparing the results for the KPI variations with the expected/planned outcomes expressed by its related Performance Target.

The comparison will be performed following the process explained below:

Table 27 – Assessment of Performance Target achievement

KPI variation (%)	Values of the Performance Targets (%)	Level of achievement of the PT
$KPI_{Var(code)}$	PT_{code}	• If $KPI_{Var(code)} \geq PT_{code}$, then the target is achieved → **full achievement** • If $0\% < KPI_{Var(code)} < PT_{code}$, then the target is almost achieved → **achievement** • If $KPI_{Var(code)} < 0\%$, then the target has not been achieved → **incomplete achievement**

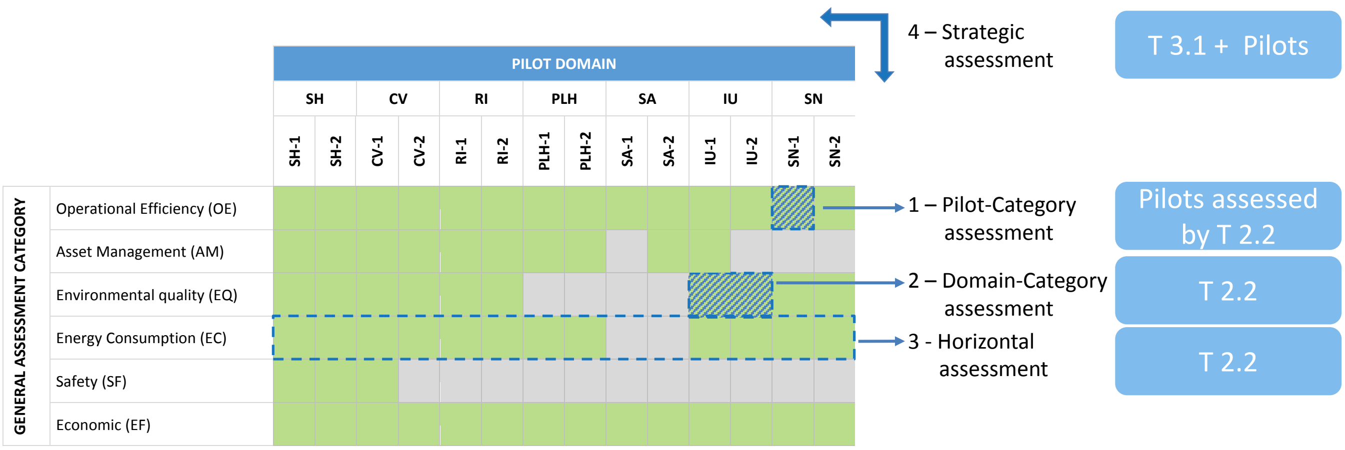
*code refer to the numbering of KPI or PT.

This process of comparing the KPI variation with the performance targets will be implemented during the Four-level assessment (see Chapter 5).

5 Performing the four-level assessment

Within this chapter, the evaluation process to be followed is described, based on the four-level assessment approach introduced in Chapter 3.

Figure 9 – Four level assessment performance by partners



5.1 Pilot-Category and Pilot-objectives assessment

The first level of the assessment approach is the evaluation of each individual Pilot. The assessment will be based on local analysis and focusing on the expected impacts of Big Data technology implementation on the pilot. A combination of assessment of the

For each individual case, the KPIs should be measured in the two scenarios (No-TT and TT). The variation of one specific KPI_i between both scenarios (in percentage) is then calculated according to the calculation indicated in equation 1. For each KPI_i, we will obtain **ΔKPI_i**, where i refers to the numbering of each KPI.

Thus, the level of achievement of the established Performance Targets for the different Priority Topics will be determined, following the procedure explained in sections 4.2 and 4.3. The level of achievement provides an indication as to the degree of fulfilment of the Pilot's Targets. Subsequently, for each Pilot and each Assessment Category, a **weighted aggregation** composed by all the KPI variations of the KPIs measured in the Category will be reported. At this time, it will be feasible to provide an answer to the question: Has the individual Pilot fulfilled the targets specified within the Categories which are relevant for him?

In addition, a qualitative analysis of the level of fulfilment of the specific objectives set for the Pilot will be conducted. At this time, it will be feasible to provide an answer to the question: Has the individual Pilot fulfilled its Objectives?

5.2 Domain-Category assessment

The second level of the assessment approach is the Domain-Category assessment, that is, the evaluation of the effects of Big Data technologies in the two pilots within one transport domain and for each of the Assessment Categories. The intention is to extract well-founded conclusions and to investigate the existence of differences among the two Pilots in each Pilot Domain.

This level of assessment will try to identify where the differences lie and how synergies and complementarities may take place. For this reason, it will be necessary to collect similar specific KPI values in both Pilots. Furthermore, additional information concerning the test conditions for both Pilots should be gathered and analysed so as to evaluate any test condition variation which could influence the comparative appraisal procedure. This assessment will only be possible if this kind of information from the Pilots is available.

5.3 Horizontal assessment *(by Category)*

The third level of the evaluation process is the horizontal assessment, that is, by Assessment Category (except for Economy), in order to evaluate which aspects of the Transport Sector are improved through the use of Big Data. So, for each of the six Assessment Categories, the transversal KPIs related to an individual topic will be analysed and their results will be compared.

For instance, the Energy Consumption Category will evaluate the influence of Big Data use in transport on fuel consumption or other energy related variables, for this assessment only transversal KPIs will be used.

Consequently, under each Assessment Category, the results obtained in the Domain level assessment (Level 2) will be aggregated, obtaining one **aggregated value of KPI variation per Assessment Category**: $f(AKPI_{Var})_j$, where j corresponds to each priority topic.

Therefore, it will be possible to assess which Categories have the best overall fulfilment in their objectives for the transport sector (the highest value of $f(AKPI_{Var})_j$. Test conditions and infrastructure peculiarities should also be considered.

5.4 Strategic assessment

The last level of the assesment approach is the Strategic Assessment which combines the contribution of all Pilots to reach the ***global targets*** set by the expected impact. It will allow to quantify the impacts of all pilots combined together also considering which influential factors contribute to achieve more synergies and better results.

Taking TT's objectives as a departure point a set of Objective Functions (OF), linked to a sub-set of CORE PTs to be used for appraisal of strategies or for optimisation, will be developed and described on D 3.8.

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ANNEX I – KPI TABLES

1. KPIs for Smart Highways (WP4)

These pilots' objectives are to improve traffic flows (mitigate congestion, accident reduction…) along the corridor, together with a more efficient management of the present infrastructure, while enhancing user satisfaction and interaction with the network.

Consequently, indicators for this innovation are based on measurements of traffic flow and its distribution, safety and maintenance improvements, increases in customer satisfaction levels and user loyalty, together with a more efficient cost structure.

1.1. Transversal KPIs for Smart Highways

Operational Efficiency (OE)

KPI SH-OE-1	Operating cost per user and unit distance.
KPI definition:	Average operating cost per vehicle-km or tonne-km using the highway during a specific period of time.
Calculation:	Average operating cost per vehicle-km = Total operating cost (€) / / (average trip length per vehicle (km) x number of users). Average operating cost per tonne-km = = Total operating cost / $\sum_{i=1}^{n}$ (average trip length$_i$ (km) x x number of vehicles$_i$ x average vehicle weight$_i$ (tonnes)). Where i represents each of the n types of vehicles travelling the highway during the considered time period (two-wheel vehicles, passenger cars, sport utility vehicles (SUV), commercial vehicles, buses, small lorries or heavy lorries).
Data requirements:	Total operating cost in the specified period (€). Average trip length per user or vehicle class for the specified period (km). Number of users or vehicles per class during the specified period (#). Average unladen weight per vehicle class (tonne). Average load per vehicle class (tonne). Average weight per vehicle class (tonne) = Average unladen weight per vehicle class (tonne) + Average load per vehicle class (tonne).
Units:	€/vehicle-km €/tonne-km

KPI SH-OE-2	Time savings to users.
KPI definition:	Time savings are calculated as the difference between the average travel time spent by users (vehicle or passengers) divided by the average trip length per vehicle before and after the innovation is implemented. Calculations are to be applied to traffic on both ways.
Calculation:	Average vehicle travel time (min) = Total travel time (all vehicles) (min) / / (Average trip length (km) x number of vehicles). Average passenger travel (min) = Average vehicle travel time (min) / / Average number of passengers per vehicle (#).
Data requirements:	Total travel time (min). Average trip length (km). Number of vehicles (#). Average vehicle occupation (# passengers/vehicle).
Units:	Minutes/vehicle-km Minutes /passenger-km

Asset Management (AM)

KPI SH-AM-1	Number of maintenance interventions.
KPI definition:	In order to assess maintenance optimisation, the number of maintenance interventions will be monitored.
Calculation:	Maintenance intervention ratio = Maintenance interventions in period / / (year x 100,000 vehicle-km).
Data requirements:	Number of maintenance interventions during the period (#). Vehicles-km travelled in the period (vehicle-km).
Units:	# interventions/(year x 100,000 vehicle-km)

KPI SH-AM-2	Average duration of maintenance interventions.
KPI definition:	To evaluate maintenance optimisation, the average time duration of maintenance processes will be supervised.
Calculation:	Average maintenance time duration per intervention (min) = = Total maintenance time (min) / Maintenance interventions (#).
Data requirements:	Total time dedicated to maintenance operations during the period (min). Number of maintenance interventions in the period (#).
Units:	Minutes

KPI SH-AM-3	Traffic volume (AADT and average vehicle hourly flow).
KPI definition:	The evolution of traffic volume is monitored to assess asset use optimisation.
Calculation:	AADT (Annual Average Daily Traffic): Average daily traffic on the highway during a period, counted for traffic circulating both ways at a particular location, and expressed in vehicles per day. AADT (Total number of vehicles / 365 / day). Average vehicle hourly flow (vehicle-km/hour) = AADT x x average daily distance per vehicle (km/day).
Data requirements:	Traffic volume in the period (# vehicles both ways). Average distance travelled per vehicle in 1 hour (km) = = Average speed (km/h) x 1 h.
	AADT (vehicles/day) vehicle-km/hour

Environmental Quality (EQ)

KPI SH-EQ-1	NOx emissions.
KPI definition:	The average emissions of NOx per km will be assessed to identify the reduction in pollutant emissions achieved by the innovation during a predetermined period.
Calculation:	NOx emissions (g/km) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ ($W_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g NOx/kg fuel)) Where i represents each of the m vehicle classes (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), j its type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g NOx/kg fuel).
Units:	g NOx/km

Energy Consumption (EC)

KPI SH-EC-1	GHG emissions.
KPI definition:	CO_2 emissions per km will be evaluated, as these are proportional to the vehicle's energy consumption.
Calculation:	$CO_2 \text{ emissions (g/km)} = \sum_{i=1}^{m} \sum_{j=1}^{n} (W_{i,j} \text{ x Fuel consumption}_{i,j} \text{ (l/km) x}$ $\text{x fuel density}_{i,j} \text{ (kg/l) x Emission factor}_{i,j} \text{ (g } CO_2\text{/kg fuel))}.$ Where i represents each of the m vehicle classes (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), and j its type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g CO_2/kg fuel).
Units:	g CO_2/km

KPI SH-EC-2	Vehicle energy consumption per 100 km.
KPI definition:	In order to assess the reduction of energy consumption, the average amount of energy consumed referred to distance will be monitored.
Calculation:	$\text{Energy consumption (kWh/100 km)} = \sum_{i=1}^{m} \sum_{j=1}^{n} (W_{i,j} \text{ x 100 x}$ $\text{x Fuel consumption}_{i,j} \text{ (l/km) x Fuel energy content}_{i,j} \text{ (kWh/l)}.$ Where i represents each class of vehicle and j its type of fuel (gasoline, diesel, ethanol, biodiesel, biogas LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel energy content for each type of fuel (kWh/l).
Units:	kWh/100 km

Safety (SF)

KPI SH-SF-1	Accidentality rate.
KPI definition:	The evolution in highway safety is monitored by measuring the accidentality rate.
Calculation:	Accidentality rate in the period = Number of accidents (#) / / (10,000 vehicle-km).
Data requirements:	Accidentality in the period (# of accidents). Number of vehicles in the period (#). Average length of trip per vehicle during the period (km).
Units:	Accidents (#)/(10,000 vehicle-km)

1.2. Specific KPIs for Smart Highways

Operational Efficiency (OE)

KPI SH-OE-3	Traffic congestion time to total time.
KPI definition:	The expected improvement in highway congestion level is appraised by evaluating the proportion of traffic congestion time to total time.
Calculation:	Traffic congestion time to total time (%) = = Total traffic congestion time (h) x 100 / Total travelling time (h).
Data requirements:	Total traffic congestion time (h). Total travelling time (h).
Units:	%

KPI SH-OE-4	Average commercial speed.
KPI definition:	An additional indicator in highway congestion level is evaluated by measuring the average commercial speed.
Calculation:	Average commercial speed (km/h) = Distance travelled by users (km) / / Total travelling time (h).
Data requirements:	Total distance travelled by all users (km). Total travelling time (h).
Units:	km/h

KPI SH-OE-5	Number of traffic data sources used (before and after).
KPI definition:	Since the use of Big Data involves the processing of significant volumes of data gathered from numerous sources, this KPI, together with the following indicators will measure overall IT related parameters. In this case, the number of data sources used is monitored.
Calculation:	Number of traffic data sources used (before) (#). Number of traffic data sources used (after) (#).
Data requirements:	Number of traffic data sources used (before) (#). Number of traffic data sources used (after) (#).
Units:	Data sources (#) (Dimensionless)

KPI SH-OE-6	Average data volume collected daily (Gb) (before and after).
KPI definition:	The information volume compiled daily from the various sources is appraised.
Calculation:	Information volume collected daily (before) (Gb/day). Information volume collected daily (after) (Gb/day).
Data requirements:	Information volume collected daily (before) (Gb/day). Information volume collected daily (after) (Gb/day).
Units:	Gb/day

KPI SH-OE-7	Ratio of data processed vs. collected.
KPI definition:	As complementary evaluation, the proportion of data processed as of total collected is also supervised during a predetermined period.
Calculation:	Ratio of data processed vs collected (%) = = Total data processed (Tb) x 100 / Total data collected (Tb).
Data requirements:	Total data processed during the period (Tb). Total data collected during the period (Tb).
Units:	%

KPI SH-OE-8	Number of messages to users (before and after).
KPI definition:	The number of average daily messages to users (before and after) will be measured during a predetermined period to assess communications sent to customers.
Calculation:	Average number of daily messages to users (messages (#)/day) = = Total number of messages to users (after) / Days (#).
Data requirements:	Number of messages to users (before). Number of messages to users (after). Days in the period (#).
Units:	Messages (#)/day

KPI SH-OE-9	Blackspot locations per 100 km
KPI definition:	Safety and maintenance costs may be reduced by recognising the existence of blackspots in the infrastructure, and adopting corrective actions.
Calculation:	Blackspot locations (#/100 km) = = Total blackspot locations (#) x100 / Infrastructure length (km).
Data requirements:	Total blackspot locations (#). Infrastructure length (km).
Units:	Blackspot locations (#)/100 km

KPI SH-OE-10	Bottleneck locations per 100 km
KPI definition:	Operational efficiency at the toll highways is assessed by identifying the presence of bottleneck spots in the infrastructure.
Calculation:	Bottleneck locations (#/100 km) = = Total bottleneck locations x 100 (#) / Infrastructure length (km).
Data requirements:	Total bottleneck locations (#). Infrastructure length (km).
Units:	Bottleneck locations (#)/100 km

KPI SH-OE-11	Average traffic short-term prediction as of real traffic
KPI definition:	In order to enhance short-term infrastructure efficiency planning, traffic prediction algorithms will be implemented. Consequently, the correlation between predicted and real traffic flows will be appraised.
Calculation:	Average traffic short-term prediction as of real traffic (%) = = Traffic prediction (vehicles/h) x 100 / Real traffic (vehicles/h).
Data requirements:	Hourly short-term traffic prediction (vehicles/h). Real short-term traffic (vehicles/h).
Units:	%

Asset Management (AM)

KPI SH-AM-4	Length and percentage of road with data gathering systems
KPI definition:	The presence of relevant information sources is measured with the following indicators.
Calculation:	Length of road with data gathering systems (km). Percentage of road with data gathering systems (%) = = Road length with data gathering systems (km) x 100 / Road length (km).
Data requirements:	Length of road with data gathering systems (km). Total road length (km).
Units:	km %

KPI SH-AM-5	Waiting time at queues in toll plazas.
KPI definition:	The average waiting time at queues in toll plazas is measured to evaluate an expected improvement in asset management.
Calculation:	Average waiting time = Number of queue hours / 10,000 vehicles. Proportion of hours in queue (%) = Time spent by vehicles in queue (h) x x 100 / Total travelling time for a predetermined period (h) (i.e, 1 year).
Data requirements:	Number of queue hours spent by 10,000 vehicles (h). Total hours spent by vehicles in queues during certain time interval (h/year). Total travelling time spent by the vehicles (h/year).
Units:	Hours/10,000 vehicles Hours queue/total hours (%)

KPI SH-AM-6	Differences between real and forecasted traffic.
KPI definition:	Efficient infrastructure management and organisation is enhanced using mid-term demand prediction tools.
Calculation:	Average traffic prediction as of real traffic (%) = = Traffic prediction (vehicles/h) x 100 / Real traffic (vehicles/h).
Data requirements:	Mid-term traffic prediction (vehicles/h). Real traffic (vehicles/h).
Units:	%

KPI SH-AM-7	Ratio of planned maintenance work to total maintenance interventions.
KPI definition:	To assess maintenance prediction and coordination, the ratio of planned maintenance work to total maintenance interventions is monitored.
Calculation:	Planned maintenance work to total maintenance interventions (%) = = Planned maintenance work (#) x 100 / Total interventions (#).
Data requirements:	Planned maintenance work (#). Total maintenance interventions (#).
Units:	%

KPI SH-AM-8	Distance travelled by the maintenance fleet per year.
KPI definition:	The innovation's predictive capacity is expected to detect system failures prematurely and improve the organisation of the maintenance staff.
Calculation:	Distance travelled by maintenance fleet (km/(year x km of highway)) = = Total distance travelled by the maintenance fleet per year (km/year) / / Infrastructure length (km).
Data requirements:	Total distance travelled by the maintenance fleet per year (km/year). Infrastructure length (km).
Units:	km/(year x km of highway)

Environmental Quality (EQ)

KPI SH-EQ-2	Animal runover.
KPI definition:	Environmental actions will also be implemented so as to reduce animal runover. Animal paths will be protected by barriers and crossroad points built.
Calculation:	Ratio of animal runover (Number of animals / 10,000 vehicle-km) = Animal runover events in the period / traffic flow (vehicle-km).
Data requirements:	Traffic volume (highway) (vehicles). Traffic volume (surroundings) (vehicles).
Units:	Number of animals/10,000 vehicle-km

Safety (SF)

KPI SH-SF-2	Emergency response time.
KPI definition:	The response time in case of emergencies is monitored to determine the capacity to decrease the reaction period when a safety alert is detected.
Calculation:	Average emergency response time (min) = Total reaction time required by all emergency situations (min) / Total number of emergency cases.
Data requirements:	Total reaction time required by all emergency situations (min). Total number of emergency cases (#).
Units:	Minutes

KPI SH-SF-3	Drivers' perception of safer driving (Automated digital score).
KPI definition:	Safety will also be evaluated from the user's perspective. An automated digital survey will be implemented to receive drivers' input.
Calculation:	Drivers' perception of safer driving (automated digital score) (1-5).
Data requirements:	Automated digital score results for a certain period.
Units:	Score: 1-5

KPI SH-SF-4	Messages to platform by automated systems.
KPI definition:	In order to assess the safety-related communications sent to users, the number of messages to platform by automated systems is monitored during a predetermined period of time.
Calculation:	Ratio of number of messages to platform (messages (#)/100 km) = = number of messages to platform (#) / 100 km of infrastructure length.
Data requirements:	Number of messages to platform (messages (#). Infrastructure length (km).
Units:	Messages (#)/100 km

Economic (EF)

KPI SH-EF-1	Average cost of network maintenance per lane kilometre of road network.
KPI definition:	In order to assess the performance in the total operation cost allocated to maintenance per kilometre of lane of road network during a certain period.
Calculation:	Average cost of network maintenance per kilometre (€/(km x year) = Total annual cost of network maintenance (€/year) / road length (km).
Data requirements:	Total cost of road maintenance during a predetermined period (€/year). Total length of road lanes being maintained (km).
Units:	€/km

KPI SH-EF-2	Variance metric based on Capital Expenditure (CAPEX).
KPI definition:	The company's Capital Expenditure (CAPEX) is evaluated to appraise its investments in capital goods. CAPEX includes those funds invested by the company to acquire or upgrade physical assets such as property, industrial buildings, vehicles, machinery or equipment.
Calculation:	CAPEX during a specific period (€).
Data requirements:	Capital Expenditure for a certain period (€)
Units:	Currency: (€)

KPI SH-EF-3	Variance metric based on Operational Expenditure (OPEX).
KPI definition:	The company's Operational Expenditure (OPEX) is also assessed to evaluate its operational expense. OPEX includes those expenses incurred by the company during its normal business operations, which includes rentals, equipment, inventory costs, marketing, employee payroll, insurance and funds allocated to research and development.
Calculation:	OPEX during a specific period (€).
Data requirements:	Operational Expenditure for a certain period (€)
Units:	Currency (€)

2. KPIs for Sustainable Connected Vehicles (WP5)

These pilot's innovations focus on the application of Big Data real-time processing can provide safety and sustainability to road transport. Pilots will assess:

- High added value services driven by large-scale analyses for predictive maintenance, traffic accidents identification, and enhancing green-driving for emission reductions.
- Optimise vehicle fleet management by continuous monitoring and the use of data-gathering systems and decision support methodologies.
- Increase fleet efficiency optimising route journeys based on predictive demand and historical analysis of local mobility patterns.

Therefore, the set of indicators developed for these technologies emphasise features related with route optimisation based on traffic data sources, operating safety and maintenance improvements, green-driving promotion and a more efficient cost structure.

2.1. Transversal KPIs for Sustainable Connected Vehicles

Operational Efficiency (OE)

KPI CV-OE-1	Operating cost per vehicle and unit distance.
KPI definition:	Average operating cost per vehicle-km (car or lorry) or tonne-km during a specific period of time.
Calculation:	Average operating cost per vehicle-km$_i$ = Total operating cost$_i$ (€) / / (average trip length per vehicle$_i$ (km) x number of vehicles$_i$). Average operating cost per tonne-km = Total operating cost$_i$ (€) / (avg. trip length$_i$ (km) x number of vehicles$_i$ x x average vehicle weight$_i$ (tonne). Where i represents the total car fleet in the case of Pilot 5.2 and the lorry fleet for Pilot 5.3.
Data requirements:	Total operating cost for each of the pilot fleets in the specified period (€). Average length of trip per fleet type for the specified period (km). Number of vehicles per fleet type during the specified period (#). Average unladen weight per vehicle type (tonne). Average load per vehicle type (tonne). Average weight per vehicle type (tonne) = Average unladen weight per vehicle type (tonne) + Average load per vehicle type (tonne).
Units:	€/vehicle-km €/tonne-km

KPI CV-OE-2	Travel time.
KPI definition:	The average travel time spent per vehicle and unit distance is calculated to assess the savings in travel time achieved with the implementation of the technological innovation.
Calculation:	Average vehicle travel time during the period$_i$ (Min/vehicle-km) = = Total travel time required by all vehicles$_i$ (min) / / (Average trip length$_i$ (km) x number of vehicles$_i$). Where i represents the total car fleet in the case of Pilot 5.2 and the lorry fleet for Pilot 5.3.
Data requirements:	Total travel time (min). Average trip length (km). Number of vehicles (#).
Units:	Minutes/vehicle-km

Asset Management (AM)

KPI CV-AM-1	Average idle time.
KPI definition:	Route optimisation is foreseen to reduce the fleet's average idle time, thus achieving energy cost savings and reducing unnecessary emissions. Thus, the vehicle's proportion of time in idle conditions is measured.
Calculation:	Average idle time (%) = Total fleet idle time (h) x 100 / / Total fleet operating time (h).
Data requirements:	Total fleet idle time (h). Total fleet operating time (h).
Units:	%

Environmental Quality (EQ)

KPI CV-EQ-1	NOx emissions.
KPI definition:	Pollutant emissions of NOx per unit distance will be evaluated for both car and lorry pilots to identify the reduction in pollutant emissions achieved by the innovation during a predetermined period.
Calculation:	NOx emissions (g/km) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ (W$_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g NOx/kg fuel)). Where i represents each of the vehicle classes for either the car fleet in the case of Pilot 5.2 and the lorry fleet for Pilot 5.3, j the type of fuel (gasoline, diesel, LPG or CNG), and W$_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed for each vehicle class contained in i.
Data requirements:	Fuel consumption per type of fuel for each pilot's fleet (litres). Distance travelled by those vehicles using the same type of fuel in each pilot's fleet (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g NOx/kg fuel).
Units:	g NOx/km

KPI CV-EQ-2	PM emissions.
KPI definition:	Similarly, particle (PM) emissions per km will be evaluated to recognise improvements in the reduction of these pollutant emissions.
Calculation:	PM emissions (g/km) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ (W$_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g PM/kg fuel)). Where *i* represents each of the vehicle classes (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), and *j* its type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g PM/kg fuel).
Units:	g PM/km

Energy Consumption (EC)

KPI CV-EC-1	GHG emissions.
KPI definition:	Average CO_2 emissions per unit distance will be monitored for both pilot fleets, as these releases are proportional to the vehicle's energy consumption.
Calculation:	CO_2 emissions (g/km) = $\sum_{i=1}^{m}\sum_{j=1}^{n}$ ($W_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g CO_2/kg fuel)). Where i represents each of the vehicle classes for either the car fleet in the case of Pilot 5.2 and the lorry fleet for Pilot 5.3, j the type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed for each vehicle class contained in i.
Data requirements:	Fuel consumption per type of fuel for each pilot's fleet (litres). Distance travelled by those vehicles using the same type of fuel in each pilot's fleet (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g CO_2/kg fuel).
Units:	g CO_2/km

KPI CV-EC-2	Vehicle energy consumption per 100 km.
KPI definition:	In order to assess the reduction of energy consumption, the amount of energy consumed per distance will be measured.
Calculation:	Energy consumption (kWh/100 km) = $\sum_{i=1}^{m}\sum_{j=1}^{n}$ ($W_{i,j}$ x 100 x x Fuel consumption$_{i,j}$ (l/km) x Fuel energy content$_{i,j}$ (kWh/l). Where i represents each of the vehicle classes for either the car fleet in the case of Pilot 5.2 and the lorry fleet for Pilot 5.3, j the type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed for each vehicle class contained in i.
Data requirements:	Fuel consumption per type of fuel for each pilot's fleet (litres). Distance travelled by those vehicles using the same type of fuel in each pilot's fleet (km). Fuel energy content for each type of fuel (kWh/l).
Units:	kWh/100 km

2.2. Specific KPIs for Sustainable Connected Vehicles

Operational Efficiency (OE)

KPI CV-OE-3	Average commercial speed in peak hour.
KPI definition:	Route optimisation based on traffic conditions may contribute to improve the vehicle's efficiencies during peak hour conditions.
Calculation:	Average commercial speed (peak hour) (km/h) = = Total distance covered in peak hours (km) / Total travel time (p h) (h).
Data requirements:	Total distance covered in peak hours (km). Total travel time in peak hours (h).
Units:	Km/h

KPI CV-OE-4	Average commercial speed in off-peak hour.
KPI definition:	Furthermore, route optimisation based on traffic conditions can also enhance the vehicle's efficiencies in off-peak hour circumstances.
Calculation:	Average commercial speed (off-peak hour) (km/h) = = Total distance in off-peak hours (km) / Total travel time (o-p h) (h).
Data requirements:	Total distance covered in off-peak hours (km). Total travel time in off-peak hours (h).
Units:	Km/h

KPI CV-OE-5	Number of harsh accelerations per vehicle-km (≥3 m/s^2).
KPI definition:	Efficient driving conditions and increased travel comfort are monitored measuring the number of harsh accelerations accounted during the journey.
Calculation:	Ratio of harsh accelerations per vehicle-km ((#)/Vehicle-km) = = Total number of harsh accelerations (#) / Total Vehicle-km.
Data requirements:	Total number of harsh accelerations (≥3 m/s^2) during the period (#). Total vehicle-km covered by the fleet during the period.
Units:	Harsh accelerations (#)/Vehicle-km

KPI CV-OE-6	Number of harsh decelerations per vehicle-km (≤-4 m/s^2).
KPI definition:	For similar reasons, harsh decelerations are also calculated.
Calculation:	Ratio of harsh decelerations per vehicle-km ((#)/Vehicle-km) = = Total number of harsh decelerations (#) / Total Vehicle-km.
Data requirements:	Total number of harsh decelerations (≤-4 m/s^2) during the period (#). Total vehicle-km covered by the fleet during the period.
Units:	Harsh decelerations (#)/Vehicle-km

KPI CV-OE-7	Number of daily traffic jam messages to users (before and after).
KPI definition:	Traffic information transmitted to users is assessed by accounting for the number of traffic jam messages to users, both before and after the innovations are implemented.
Calculation:	Number of daily traffic jam messages to users (#) (before) / Days (#). Number of daily traffic jam messages to users (#) (after) / Days (#).
Data requirements:	Number of daily traffic jam messages to users (#) (before). Number of daily traffic jam messages to users (#) (after). Number of days (#).
Units:	Messages (#)/day

Asset Management (AM)

KPI CV-AM-2	Number of Diagnostic Trouble Codes (DTC) per vehicle and 10,000 km.
KPI definition:	Prevention of vehicle failures is evaluated by measuring the number of Diagnostic Trouble Codes (DTC) per vehicle and 10,000 km.
Calculation:	Number of Diagnostic Trouble Codes (DTC) per vehicle and 10,000 km = = Total number of DTC x 10,000 / (Total distance (km) x Vehicle (#)).
Data requirements:	Total number of DTCs (#). Total distance covered by the fleet (km). Average number of vehicles in the fleet.
Units:	DTCs (#)/10,000 vehicle-km

KPI CV-AM-3	Vehicle breakdowns per vehicle and 10,000 km.
KPI definition:	As supplementary information related with the previous indicator, vehicle breakdowns are additionally monitored.
Calculation:	Number of breakdowns per vehicle and 10,000 km = = Total vehicle breakdowns x 10,000 / (Total distance (km) x Vehicle (#)).
Data requirements:	Total number of breakdowns (#). Total distance covered by the fleet (km). Average number of vehicles in the fleet (#).
Units:	Vehicle breakdowns (#)/10,000 vehicle-km

Environmental Quality (EQ)

KPI CV-EQ-3	Number of driver notifications to reduce emissions per 100 vehicle-km.
KPI definition:	Eco-friendly driving conditions are fostered by sending warning messages to drivers.
Calculation:	Number of driver notifications per vehicle and 100 km = = Total driver notifications (#) x 100 / (Total distance (km) x Vehicles (#)).
Data requirements:	Total driver notifications (#). Total distance covered by the fleet (km). Average number of vehicles in the fleet (#).
Units:	Emission notifications (#) / 100 vehicle-km

Energy Consumption (EC)

KPI CV-EC-3	Time proportion driven in Eco-friendly conditions
KPI definition:	Green driving reduces fuel consumption and decreases pollutant emissions. Thus, the time proportion driven in Eco-friendly circumstances.
Calculation:	Time proportion driven in Eco-friendly conditions (%) = = Time driven in Eco-friendly conditions (h) x 100 / Total travel time (h).
Data requirements:	Time driven in Eco-friendly conditions (h). Total travel time (h).
Units:	%

Safety (SF)

KPI CV-SF-1	Drivers' perception of safer driving
KPI definition:	Safety will also be evaluated from the user's perspective. survey will be carried out to obtain drivers' opinions.
Calculation:	Drivers' perception of safer driving (survey) (score: 1-5).
Data requirements:	Survey score results for a certain period (before and after).
Units:	Score: 1-5

Economic (EF)

KPI CV-EF-1	Reduction of fuel costs.
KPI definition:	Fuel savings result in fuel cost savings and reduced emissions. Energy costs are calculated by means of this indicator.
Calculation:	Average fuel cost ((€)/vehicle-km) = Total fuel costs (€) / / (Total distance (km) x Vehicles (#)).
Data requirements:	Total fuel costs (€). Total distance covered by the fleet (km). Average number of vehicles in the fleet (#).
Units:	Currency (€)/vehicle-km

KPI CV-EF-2	Reduction of maintenance costs.
KPI definition:	Similarly, maintenance costs are also monitored.
Calculation:	Average maintenance cost ((€)/vehicle-km) = Maintenance costs (€) / / (Total distance (km) x Vehicles (#)).
Data requirements:	Total maintenance costs (€). Total distance covered by the fleet (km). Average number of vehicles in the fleet (#).
Units:	Currency (€)/vehicle-km

3. KPIs for Proactive Rail Infrastructures (WP6)

These pilots' objectives focus on developing new methodologies to optimise rail infrastructure maintenance to enhance:

- Rail worker safety by minimising trackside time.
- Overall railroad passenger safety by applying predictive failure detection techniques.
- Service reliability by minimising downtime and service incidences.
- Cost efficiency, thus prioritising on asset preventative maintenance.
- Service reliability by minimising disruptions.

Monitoring the results achieved by the technologies requires evaluating those aspects related with infrastructure availability, trackside activity characteristics and enhanced safety conditions, while simultaneously obtaining maintenance cost reductions.

3.1 Transversal KPIs for Proactive Rail Infrastructures

Operational Efficiency (OE)

KPI RI-OE-1	**Operating cost.**
KPI definition:	Average operating cost per kilometre of infrastructure during a specific period of time.
Calculation:	Average operating cost per km = Total operating cost (€) / / Length of infrastructure (km).
Data requirements:	Total operating cost in the specified period (€). Average length of the railway infrastructure during the period (km).
Units:	€/km

KPI RI-OE-2	Time savings to users.
KPI definition:	Time savings are calculated as the potential to reduce the average delay time per passenger. The KPI measures average delay, while achievement will be assessed by evaluating its variation.
Calculation:	Average delay time per passenger (minutes) = $\sum_{i=1}^{d}$ (n_i x t_i (min)) / / Total number of passengers (#). Where i represents each of the d delay events, and t its duration. For each delay, the number of affected passengers is n.
Data requirements:	Number of delays (#). Average time per delay (minutes). Number of passengers affected per delay (#). Total number of passengers during the period (#).
Units:	Minutes

Asset Management (AM)

KPI RI-AM-1	Number of interventions.
KPI definition:	To assess management optimisation, the number of maintenance interventions is studied during a certain period.
Calculation:	Number of interventions for the period / (year x 100 km).
Data requirements:	Number of interventions during the period (#). Length of the railway infrastructure (km).
Units:	# interventions/(year x 100 km)

KPI IR-AM-2	Average duration of interventions.
KPI definition:	To evaluate asset use optimisation, the average time duration of the intervention processes will be overseen.
Calculation:	Average time duration per intervention (min) = Total time dedicated to interventions (min) / Number of interventions (#).
Data requirements:	Total time dedicated to interventions during the period (min). Number of interventions during the period (#).
Units:	Minutes

KPI RI-AM-3	Train circulations.
KPI definition:	The evolution of train traffic volume is monitored to assess asset use optimisation. Traffic is measured both ways.
Calculation:	Average number of daily trains = Total train traffic (#) / Days (#).
Data requirements:	Daily train traffic (#). Number of days (#).
Units:	Trains (#)/day

Environmental Quality (EQ)

KPI RI-EQ-1	NOx emissions.
KPI definition:	The average emissions of NOx per km will be assessed to identify the reduction in pollutant emissions achieved by the innovation during a predetermined period. The activities impact requires the measurement and aggregation of both fossil fuels and electric energy consumption.
Calculation:	Fossil fuel – road vehicles (if applicable): NOx emissions (g/km) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ ($W_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g NOx/kg fuel)). Where i represents each of the m vehicle classes used in the operations (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), j its type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed in road transport. Fossil fuel – trains: NOx emissions (g/km) = $\sum_{k=1}^{q}$ (W_k x Fuel consumption$_i$ (l/km) x x fuel density (kg/l) x Emission factor$_k$ (g NOx/kg fuel)). In which k represents the set of q locomotives used in the activities. Emission factors for such vehicles are published by the EEA. Electric energy: NOx emissions = Electric energy consumed (kWh) x NOx emissions factor for electric energy (kg NOx/kWh) / distance (km). The emissions factor for electric energy to be used will correspond to the associated value for the electricity generation mix during the involved period of time.

	Consequently, the NOx emissions for the complete operation is obtained calculating the weighted average of all emission sources.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g NOx/kg fuel). Consumption of electric energy during the period (kWh). Emissions factor for local electricity generation mix (g NOx/kWh).
Units:	g NOx/km

Energy Consumption (EC)

KPI RI-EC-1	GHG emissions.
KPI definition:	CO_2 emissions will be measured during a predetermined period. Since these pilots' operations include vehicles consuming fossil fuels and electricity, and machinery utilising electric energy, total GHG emissions will be computed independently for both energy sources.
Calculation:	Fossil fuel – road vehicles (if applicable): CO_2 emissions (g/km) = $\sum_{i=1}^{m}\sum_{j=1}^{n}$ ($W_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g CO_2/kg fuel)). Where i represents each of the m vehicle classes used in the operations (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), j its type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed by road vehicles. Fossil fuel – trains: CO_2 emissions (g/km) = $\sum_{k=1}^{q}$ (W_k x Fuel consumption$_i$ (l/km) x x fuel density (kg/l) x Emission factor$_k$ (g CO_2/kg fuel)). In which k represents the set of q locomotives used during the activities. Emission factors for such vehicles are available at the EEA webpage. Electric energy: CO_2 emissions = Electric energy consumed (kWh) x CO_2 emissions factor for Electric energy (kg CO_2/kWh) / distance (km).

	The emissions factor for electric energy to be used is the rate for the electricity generation mix during the involved period of time. Thus, CO_2 emissions for the complete operation are calculated in accordance with the weighted average of all emission sources.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g CO_2/kg fuel). Consumption of electric energy during the period (kWh). Emissions factor for local electricity generation mix (g CO_2/kWh).
Units:	g CO_2/km

3.2 Specific KPIs for Proactive Rail Infrastructures

Operational Efficiency (OE)

KPI RI-OE-3	Availability (time % with infrastructure in operating conditions).
KPI definition:	This indicator measures the percentage of time during which the infrastructure is in operating conditions.
Calculation:	Availability (%) = Time in operating conditions (h) x 100 / Total time (h).
Data requirements:	Time in operating conditions (h). Total time (h).
Units:	%

KPI RI-OE-4	Average train vertical upwards acceleration (car body).
KPI definition:	Efficient operating conditions and increased travel comfort are monitored measuring the average vertical upwards acceleration accounted in the car body during the journeys.
Calculation:	Average vertical upwards acceleration in the car body (m/s^2).
Data requirements:	Vertical upwards acceleration function in the car body vs. time (m/s^2). Total time (h).
Units:	m/s^2

KPI RI-OE-5	Average train vertical downwards acceleration (car body).

KPI definition:	Similarly, average vertical downwards acceleration in the car body during the journeys is measured.
Calculation:	Average vertical downwards acceleration in the car body (m/s^2).
Data requirements:	Vertical downwards acceleration function in the car body vs. time (m/s^2). Total time (h).
Units:	m/s^2

KPI RI-OE-6	**Maximum train lateral acceleration (car body).**
KPI definition:	Lateral accelerations in the car body are also assessed by monitoring its maximum value.
Calculation:	Maximum lateral acceleration in the car body (m/s^2).
Data requirements:	Lateral acceleration function in the car body versus time (m/s^2).
Units:	m/s^2

KPI RI-OE-6	**Maximum train lateral acceleration (car body).**
KPI definition:	Lateral accelerations in the car body are also assessed by monitoring its maximum value.
Calculation:	Maximum lateral acceleration in the car body (m/s^2).
Data requirements:	Lateral acceleration function in the car body versus time (m/s^2).
Units:	m/s^2

KPI RI-OE-7	**Ratio of maintenance time on holidays to total maintenance time.**
KPI definition:	Improvement in maintenance planning is evaluated calculating the ratio of maintenance hours in holidays to total maintenance hours, since high traffic volumes are expected during holidays, and staff costs are also more expensive.
Calculation:	Ratio of maintenance time on holidays to total maintenance time (%) = = Maintenance time on holidays (h) x 100 / Total maintenance time (h).
Data requirements:	Maintenance time on holidays (h). Total maintenance time (h).
Units:	%

KPI RI-OE-8	**Average maintenance time per intervention.**

KPI definition:	In addition, the average maintenance time per intervention is measured to verify manpower requirement reductions.
Calculation:	Average maintenance time per intervention (Man-hours) = $= \sum_{i=1}^{n}$ (Workers$_i$ x Time duration of intervention$_i$) / Interventions (#). Where i represents each of the n maintenance interventions performed during the period.
Data requirements:	Number of workers required in each intervention (#). Time duration of each intervention (h).
Units:	Man-hours

Asset Management (AM)

KPI RI-AM-4	Vehicle / equipment downtime.
KPI definition:	The use of Big Data for equipment maintenance management is expected to reduce operation downtime.
Calculation:	Vehicle / equipment downtime (%) = = Total Vehicle or equipment downtime (h) x 100 / Total time (h).
Data requirements:	Total Vehicle or equipment downtime (h). Total time (h).
Units:	%

KPI RI-AM-5	Ratio of predicted failures to total breakdowns.
KPI definition:	The ratio of predicted failures to total breakdowns indicates the system's capacity to project potential breakdowns.
Calculation:	Ratio of predicted failures to total breakdowns (%) = = Predicted failures (#) x 100 / Total breakdowns (#).
Data requirements:	Predicted failures during the period (#). Total breakdowns during the period (#).
Units:	%

KPI RI-AM-6	Ratio of preventive maintenance interventions to total maintenance interventions.
KPI definition:	Similarly, the ratio of preventive maintenance interventions to total maintenance interventions (preventive + corrective) is appraised.
Calculation:	Ratio of preventive maintenance interventions (%) = = Preventive maintenance interventions (#) x 100 / Interventions (#). Where interventions refers to both preventive and corrective.
Data requirements:	Total preventive maintenance interventions (#). Total interventions (preventive and corrective) during the period (#).
Units:	%

KPI RI-AM-7	Failures in switch and crossing elements.
KPI definition:	This indicator monitors failure events in switch and crossing elements.
Calculation:	Ratio of failures ((#)/(100 km x year) = Number of failures (#) x 100 / / Infrastructure length (km). For a yearly period.
Data requirements:	Number of switch and crossing element failures in a year (#). Infrastructure length (km).
Units:	Failures (#)/(100 km x year)

KPI RI-AM-8	Failures in track profile elements.
KPI definition:	This indicator monitors failure events in track profile elements.
Calculation:	Ratio of failures ((#)/(100 km x year) = Number of failures (#) x 100 / / Infrastructure length (km). For a yearly period.
Data requirements:	Number of track profile element failures in a year (#). Infrastructure length (km).
Units:	Failures (#)/(100 km x year)

KPI RI-AM-9	Failures in slopes close to tracks.
KPI definition:	This indicator monitors failure events in slopes close to tracks.
Calculation:	Ratio of failures ((#)/(100 km x year) = Number of failures (#) x 100 / / Infrastructure length (km). For a yearly period.
Data requirements:	Number of slopes close to tracks failures in a year (#). Infrastructure length (km).
Units:	Failures (#)/(100 km x year)

KPI RI-AM-10	Poor quality track identified per 100 km and year.
KPI definition:	Improvements in track operation conditions may be attained identifying poor quality track prematurely.
Calculation:	Poor quality track identified (km/(100 km x year)) = = Poor quality track length x 100 / Infrastructure length (km). During a yearly period.
Data requirements:	Number of failures in a year (#). Infrastructure length (km).
Units:	km/(100 km x year)

KPI RI-AM-11	Ratios of maintenance costs per worker and maintenance costs to total costs.
KPI definition:	The relevance of the firm's maintenance activities is evaluated by means of the ratios of maintenance costs per worker and maintenance costs to total costs.
Calculation:	Ratio of maintenance costs per worker (€/(worker x year)) = = Total annual maintenance labour costs (€) / Workers (#). Ratio of maintenance costs to total costs (%) = = Total annual maintenance labour costs (€) x100 / Total annual costs (€).
Data requirements:	Total annual maintenance labour costs (€). Total annual costs (€). Average workers (#).
Units:	€/(worker x year) %

KPI RI-AM-12	Maintenance worker travel distance.
KPI definition:	This indicator measures the average annual distance travelled by a maintenance worker.
Calculation:	Average annual travel distance per worker (km/worker x year)) = $\sum_{i=1}^{n}$ (Workers$_i$ (#) x Distance travelled for intervention$_i$) / Workers (#). Where i represents each of the n annual interventions.
Data requirements:	Workers in each intervention (#). Distance travelled for intervention Average workers during the period (#).
Units:	km/(worker x year)

Energy Consumption (EC)

KPI RI-EC-2	Fossil fuel energy consumption.
KPI definition:	The use of Big Data may provide fuel savings due to an improved management and coordination of the organisation, thus resulting in fuel savings.
Calculation:	Average fossil fuel energy consumption (Litres/day) = = Total fuel consumption (Litres) / Days (#).
Data requirements:	Total fuel consumption (Litres). Number of days in the period (#).
Units:	Litres/day

Safety (SF)

KPI RI-SF-1	Track-side activities.
KPI definition:	Enhancing worker safety is an important attribute for all organisations, primarily those dedicated to construction and maintenance activities.
Calculation:	Ratio of track-side activities = Total track-side activities (#) x 100 / / (Number of months x Total infrastructure length (km).
Data requirements:	Total track-side activities (#). Number of months (#). Total infrastructure length (km).
Units:	Activities (#)/(month x 100 km)

Economic (EF)

KPI RI-EF-1	Total asset turnover ratio.
KPI definition:	For any firm, the ratio of sales to total assets is an interesting ratio as it values the company's revenues relative to the price of its assets. Such ratio is an indicator of the efficiency with which an organisation arranges its assets in order to obtain revenue.
Calculation:	Assets Turnover (%) = Sales (€) x 100 / Average total assets (€).
Data requirements:	Sales during the period (€). Average total assets (€).
Units:	%

KPI RI-EF-2	Maintenance cost of railway equipment.
KPI definition:	Costs derived from the maintenance of railway equipment have a significant share in the overall cost structure. Accordingly, these fees will be monitored during a pre-established period.
Calculation:	Maintenance cost (€/(100 km x day)) = Equip. maintenance cost (€) x x 100 / (Total infrastructure length (km) x Days (#)).
Data requirements:	Total equipment maintenance cost (€). Total infrastructure length (km). Number of days (#).
Units:	€/(100 km x day)

4. KPIs for Ports as Intelligent Logistic Hubs (WP7)

These pilots apply Big Data technologies to improve port operations by designing new cockpits, using predictive maintenance techniques and optimising port operation activities. The KPIs developed for this application assess time and cost savings, and measure the system's capacity to enhance equipment reliability.

4.1. Transversal KPIs for Ports as Intelligent Logistic Hubs

Operational Efficiency (OE)

KPI PLH-OE-1	Operating cost.
KPI definition:	Improvements in operational efficiency due to the implementation of the technical innovation will be evaluated using operating costs.
Calculation:	Operating costs for the total time period. Average operating costs per handled tonne (€/tonne) = = Operating costs for the total period (€) / Load handled (tonnes).
Data requirements:	Operating costs for the total time period (€/year). Total tonnes handled (tonnes/year).
Units:	€/(tonne x year)

KPI PLH-OE-2	Time savings.
KPI definition:	Time savings are calculated as the difference between the average time required for the port's operations during a predetermined period of time divided by the total load being handled. It includes both loading and unloading operations.
Calculation:	Average time required by port operations per tonne (h/tonne) = = Total time required by port operations (h) x 60 / Total load (tonnes).
Data requirements:	Total time required by port operations (hours). Number of tons handled in the specified period (tonnes).
Units:	Minutes/tonne

Asset Management (AM)

KPI PLH-AM-1	Average downtime per equipment item X.
KPI definition:	Average downtime for one or more key equipment items in the Port during a specific time period.
Calculation:	Average downtime (h) = Duration of downtimes (h) / / (number of operations / 10,000).
Data requirements:	Duration of downtime for equipment item X in the period (h). Volume of activity in the period (# operations).
Units:	Hours

KPI PLH-AM-2	Average breakdowns per equipment item X
KPI definition:	In order to assess asset management, the average breakdowns per equipment item X are evaluated.
Calculation:	Average number of breakdowns = Number of breakdowns in period / / (number of operations / 10,000).
Data requirements:	Number of breakdowns in the period for equipment item X (#). Volume of activity in the period (# operations).
Units:	Breakdowns (#)/10,000 operations (#). (Dimensionless)

KPI PLH-AM-3	Average daily time at depot of one or more key port assets.
KPI definition:	Asset use optimisation is measured using the average daily time at depot of one or more key port assets.
Calculation:	Average daily time at depot (%) = time at depot (h) x 100 / / total operation time (h).
Data requirements:	Time at depot (hours). Total operation time (hours).
Units:	%

4.2. Specific KPIs for Ports as Intelligent Logistic Hubs

Operational Efficiency (OE)

KPI PLH-OE-3	Average Truck Turnaround Time in Terminal per week.
KPI definition:	Enhancing the port's operational efficiency should improve the terminal's productivity. Therefore, the Average Truck Turnaround Time in Terminal per week is evaluated.
Calculation:	Average Truck Turnaround Time in Terminal per week (Minutes) = = Total Truck Turnaround Time (Minutes) / Number of trucks (#).
Data requirements:	Total weekly Truck Turnaround Time (Minutes). Number of trucks handled per week (#).
Units:	Minutes/truck

KPI PLH-OE-4	Average time per transaction (container order).
KPI definition:	In addition, the average time per transaction (container order) is also monitored.
Calculation:	Average time per transaction (Minutes) = = Total time in transactions (Minutes) / Number of transactions (#).
Data requirements:	Total time in transactions (Minutes). Number of transactions during the period (#).
Units:	Minutes/transaction

KPI PLH-OE-5	Average Truck Turnaround Time from a port in-gate to a terminal gate per year.
KPI definition:	Advances in the management of the port's operations is expected to improve the terminal's productivity. Thus, Average Truck Turnaround Time from a port in-gate to a terminal gate per year is assessed.
Calculation:	Avg. Truck Turnaround Time from port in-gate to terminal gate (Min.) = = Total Truck Turnaround Time p i-g to t g (Minutes) / Trucks (#). On a yearly basis.
Data requirements:	Total Truck Turnaround Time port in-gate to term. gate (Minutes/year). Number of trucks handled in a year (#/year).
Units:	Minutes/truck

KPI PLH-OE-6	Average Truck Turnaround Time from a terminal gate to a port out-gate per year.
KPI definition:	As complementary indicator, the Average Truck Turnaround Time from a terminal gate to a port out-gate per year is also measured.
Calculation:	Avg. Truck Turnaround Time from terminal gate to port out-gate (Min) = = Total Truck Turnaround Time t g to p o-g (Minutes) / Trucks (#). On a yearly basis.
Data requirements:	Total Truck Turnaround Time term. gate to port out-gate (Min./year). Number of trucks handled in a year (#/year).
Units:	Minutes/truck

Asset Management (AM)

KPI PLH-AM-4	Average downtime per monitored terminal equipment.
KPI definition:	The use of Big Data for equipment maintenance management is expected to reduce its operational downtime.
Calculation:	Average Terminal equipment downtime (%) = = Total equipment downtime (h) x 100 / Total time (h).
Data requirements:	Total Vehicle or equipment downtime (h). Total time (h).
Units:	%

KPI PLH-AM-5	Average breakdowns per monitored terminal equipment.
KPI definition:	As supplementary information related with the previous indicator, equipment breakdowns are additionally accounted.
Calculation:	Number of breakdowns per terminal equipment per 10,000 hours = $= 10{,}000 \times \sum_{i=1}^{m}$ (equipment breakdowns$_i$ x time in operation$_i$) / m Where i represents each of the m equipments monitored.
Data requirements:	Total number of breakdowns per equipment (#). Total operating time per equipment (h). Number of monitored equipment (#).
Units:	Breakdowns (#)/(equipment x 10,000 hours)

KPI PLH-AM-6	Mean container handlings between failure (MMBF) per monitored terminal equipment.
KPI definition:	Equipment maintenance optimisation is likely to increase container handlings between failure (MMBF).
Calculation:	Mean container handlings between failure (MMBF) = $= \sum_{i=1}^{m}$ MMBF$_i$ / m Where i represents each of the m equipments monitored.
Data requirements:	Container handlings between failure per equipment (#). Number of monitored equipment (#).
Units:	Containers (#) (Dimensionless)

Energy Consumption (EC)

KPI PLH-EC-1	Average consumption of energy by monitored terminal equipment per container handlings
KPI definition:	Energy consumption is evaluated by monitoring the energy required during each container handling.
Calculation:	Average energy consumption (kWh/container) = = Total energy consumption (kWh) / Containers handled (#).
Data requirements:	Total energy consumption during the period (kWh). Number of containers handled (#).
Units:	kWh/container

Economic (EF)

KPI PLH-EF-1	Operating cost per container.
KPI definition:	The improvement of traffic and operation management systems should enable an operating cost reduction per container related to internal and external movements of the goods in port terminal.
Calculation:	Operating cost per container (€/container) = = Total operating costs (€) / Number of containers handled (#).
Data requirements:	Total operating costs (€). Number of containers handled (#).
Units:	€/container

KPI PLH-EF-2	Maintenance cost of port equipment.
KPI definition:	The integration of sensors in port equipment in combination with predictive maintenance systems will allow the minimisation of downtimes and breakdowns, so equipment operating time is improved, thus avoiding extra maintenance costs caused by non-predictive system damages. This ratio is usually calculated on an quarterly and annual basis.
Calculation:	Maintenance cost per equipment (€/equipment) = = Total maintenance costs (€) / Number of monitored equipment (#).
Data requirements:	Total maintenance costs (€). Number of monitored equipment (#).
Units:	€/equipment

5. KPIs for Smart Airport Turnaround (WP8)

The application of Big Data to airport management can deliver substantial advances to facilitate the operation's administration and improve its profitability and competitiveness. The main objectives of innovations proposed by the pilots are:

- Optimising the airport's operation with increased stakeholder satisfaction.
- Reducing the number of connecting passengers losing their flight.
- Lessening customer complaints.
- Enhancing passenger experience by offering personalised services.

Consequently, the related KPIs aim to measure reductions in the magnitude of delays, missed connections, passenger complaints, and customer satisfaction.

5.1. Transversal KPIs for Smart Airport Turnaround

Operational Efficiency (OE)

KPI SA-OE-1	Operating costs.
KPI definition:	Improvements in operational efficiency per passenger due to the implementation of the technical innovation will be evaluated for a specific period of time. Passenger traffic includes both departure and landing operations.
Calculation:	Operating costs per passenger (€/passenger x year) = = Total operating costs (€) / Number of passengers. On a yearly basis.
Data requirements:	Total operating costs (€). Number of passengers in a year (#).
Units:	€/(passenger x year)

KPI SA-OE-2	Terminal operating cost
KPI definition:	Similarly, operating costs per passenger and year are also computed for the Terminal building.
Calculation:	Terminal operating costs per passenger (€/passenger x year) = = Total Terminal operating costs (€) / Number of passengers. On a yearly basis.
Data requirements:	Total Terminal operating costs (€). Number of passengers in a year (#).
Units:	€/(passenger x year)

KPI PLH-OE-3	Flight delays.
KPI definition:	Average time savings to users will be measured by calculating flight delays. With this aim, the following ratios will be computed.
Calculation:	Average delay per flight = Σ Delay times (min) / Total number of flights. Average delay per passenger = Σ (Delay times (min) x x number of passengers affected) / Total passengers. Average delay time = (Σ (Delay times (min) x 100 / / Σ Flight time duration (min)) (%). For all indicators, calculations shall include both arrivals and departures.
Data requirements:	Delay time per flight (min). Flight duration (min). Total number of flights (#). Number of passengers per flight (#).
Units:	Minutes/flight Minutes/passenger Delay/duration (%)

5.2. Specific KPIs for Smart Airport Turnaround

Operational Efficiency (OE)

KPI SA-OE-4	Time at gate for the latest passenger.
KPI definition:	Improvements in the detection of late passengers is important to avoid the disturbance caused in the airport's scheduling. This indicator measures the arrival time at the gate for the latest passenger.
Calculation:	Average time at gate for the latest passenger (Minutes) = $= \sum_{i=1}^{m}$ Time at gate for the latest passenger$_i$ / m Where i represents each of the m flights being monitored.
Data requirements:	Time at gate for the latest passenger per flight (Minutes). Number of flights (#).
Units:	Minutes

KPI SA-OE-5	Late connected passengers.
KPI definition:	Similarly, the ratio of late connected passengers is also assessed for a predetermined period.
Calculation:	Ratio of late connected passengers (%) = = Late connected passengers (#) x 100 / Total passenger connections (#).
Data requirements:	Late connected passengers (#). Total passenger connections (#).
Units:	%

KPI SA-OE-6	Economy checked passengers without boarding.
KPI definition:	Performance in the detection of missing passengers is evaluated by calculating the checked passengers without boarding. For Economy class, the ratio is:
Calculation:	Ratio of Economy checked passengers without boarding (%) = = Economy checked passengers without boarding (#) x 100 / / Total Economy passengers (#).
Data requirements:	Economy checked passengers without boarding (#). Total Economy passengers (#).
Units:	%

KPI SA-OE-7	Business checked passengers without boarding.
KPI definition:	Analogous calculations are performed for Business class.
Calculation:	Ratio of Business checked passengers without boarding (%) = = Business checked passengers without boarding (#) x 100 / / Total Business passengers (#).
Data requirements:	Business checked passengers without boarding (#). Total Business passengers (#).
Units:	%

KPI SA-OE-8	Checked passengers without boarding.
KPI definition:	And the following KPI is used for all passenger classes.
Calculation:	Ratio of checked passengers without boarding (%) = = Checked passengers without boarding (#) x 100 / Total passengers (#).
Data requirements:	Checked passengers without boarding (#). Total passengers (#).
Units:	%

KPI SA-OE-9	Economy passengers expected per time interval.
KPI definition:	Passenger behaviour prediction of relevant to manage the airport operation smoothly, reduce its costs, increase customer satisfaction and obtain higher revenues. Prediction figures versus actual results will be appraised.
Calculation:	Ratio of expected Economy passengers (%) = = Expected Economy passengers (#) x 100 / Actual Economy pass. (#).
Data requirements:	Expected Economy passengers (#) Actual Economy passengers (#).
Units:	%

KPI SA-OE-10	Business passengers expected per time interval.
KPI definition:	Analogous calculations are performed for Business class.
Calculation:	Ratio of expected Business passengers (%) = = Expected Business passengers (#) x 100 / Actual Business pass. (#).
Data requirements:	Expected Business passengers (#) Actual Business passengers (#).
Units:	%

KPI SA-OE-11	Passengers expected per time interval.
KPI definition:	And the following KPI is used to evaluate all passenger classes.
Calculation:	Ratio of expected passengers (%) = = Expected passengers (#) x 100 / Actual passengers (#).
Data requirements:	Expected passengers (#) Actual passengers (#).
Units:	%

KPI SA-OE-12	Dwell time for Economy passengers.
KPI definition:	Passenger dwell time measures the traveller's flow through the Terminal building and much information may be gathered related with passenger behaviour in accordance with various individual and social features.
Calculation:	Dwell time for Economy passengers (Minutes/passenger) = = Total Economy pass. dwell time (Min.) x 100 / Total Economy pass. (#).
Data requirements:	Total Economy passengers dwell time (Minutes). Total Economy passengers (#).
Units:	Minutes/passenger

KPI SA-OE-13	Dwell time for Business passengers.
KPI definition:	Analogous calculations are done for Business class.
Calculation:	Dwell time for Business passengers (Minutes/passenger) = = Total Business pass. dwell time (Min.) x 100 / Total Business pass. (#).
Data requirements:	Total Business passengers dwell time (Minutes). Total Business passengers (#).
Units:	Minutes/passenger

KPI SA-OE-14	Dwell time for passengers.
KPI definition:	And the following indicator is utilised to appraise all passenger classes.
Calculation:	Dwell time for all passengers (Minutes/passenger) = = Total passenger dwell time (Min.) x 100 / Total passengers (#).
Data requirements:	Total passenger dwell time (Minutes). Total passengers (#).
Units:	Minutes/passenger

KPI SA-OE-15	Average aircraft turnaround time.
KPI definition:	A critical parameter for the airport's operations is the airplane's turnaround time, as low values enhance higher productivity results.
Calculation:	Average aircraft turnaround time (Minutes/ aircraft) = = Total aircraft dwell time (Minutes) x 100 / Total flights (#).
Data requirements:	Total aircraft dwell time (Minutes).

	Total flights (#).
Units:	Minutes/aircraft

KPI SA-OE-16	**Number of flights complying TOBT (Target Off Block Time) to total departures.**
KPI definition:	Time slot compliance is evaluated by calculating the ratio of number of flights complying TOBT (Target Off Block Time) to total departures during a certain period.
Calculation:	Ratio of TOBT compliance (%) = Number of flights on TOBT (#) x 100 / / Total flights (#).
Data requirements:	Number of flights on TOBT (#). Total flights (#).
Units:	%

KPI SA-OE-17	**Missed connections per 100 passengers.**
KPI definition:	Improvements in operational efficiency may be evaluated by calculating the number of missed connections during a predetermined time period.
Calculation:	Missed connections per 100 passengers = Number of passengers missing a connection x 100 / Total number of passengers (#).
Data requirements:	Number of passengers with missed connections (#). Total number of passengers during the same period (#).
Units:	%

KPI SA-OE-18	**Ratio of identified transfer passengers with late arrivals to total transfer passengers.**
KPI definition:	A crucial operational parameter for airports is measured with the ratio of identified transfer passengers with late arrivals to total transfer passengers.
Calculation:	Ratio of identified transfer pass. with late arrivals (%) = Identified late transfer pass. arrivals (#) x 100 / Total transfer pass. (#).
Data requirements:	Number of identified transfer passengers with late arrivals (#). Total transfer passengers (#).
Units:	%

KPI SA-OE-19	Ratio of delays caused by late transfer passengers to total delays.
KPI definition:	The ratio of delays caused by late transfer passengers to total delays is also measured.
Calculation:	Ratio of delays caused by late transfer passengers to total delays (%) = = Delays caused by late transfer passengers (#) x 100 / Total delays (#).
Data requirements:	Number of delays caused by late transfer passengers (#). Total delays (#).
Units:	%

KPI SA-OE-20	Number of passengers arriving late to boarding to total passengers.
KPI definition:	Decreasing late passenger rate is a significant challenge for the operation. Being so, the project will evaluate the ratio of passengers arriving late to boarding to total passengers.
Calculation:	Number of passengers arriving late to boarding to total passengers (%) = = Number of pass. arriving late to boarding (#) x 100 / Total pass. (#).
Data requirements:	Number of passengers arriving late to boarding (#). Total passengers (#).
Units:	%

KPI SA-OE-21	Average passenger time at security control.
KPI definition:	Queueing at security control increases inefficient passenger dwell time and surges the probability of late arrivals at the boarding gate.
Calculation:	Average passenger time at security control (Minutes) = = Total passenger time at security (Minutes) x 100 / Total passengers (#).
Data requirements:	Total passenger time at security control (Minutes). Total passengers (#).
Units:	%

KPI SA-OE-22	Ratio of worker time to passenger volume at security control.
KPI definition:	Operational efficiency at security control is also assessed by calculating staff requisites during a certain period.
Calculation:	Ratio of worker time to passenger volume at security control = = Staff at security control (Man-hours) x 10,000 / Total passengers (#).

Data requirements:	Staff at security control (Man-hours). Total passengers (#).
Units:	Man-hours/10,000 passengers

KPI SA-OE-23	Reduce passenger time at passport control.
KPI definition:	As in the case of security control, queueing at the passport control increases inefficient passenger dwell time, surges the probability of late arrivals at the boarding gate, and transmits a poor image to visitors.
Calculation:	Average passenger time at passport control (Minutes) = = Total pass. time at passport control (Minutes) x 100 / Total pass. (#).
Data requirements:	Total passenger time at the passport control (Minutes). Total passengers (#).
Units:	%

KPI SA-OE-24	Average time required by passenger from Terminal entry to boarding gate.
KPI definition:	Customer transit time is evaluated by measuring the average time required by passenger from Terminal entry to boarding gate
Calculation:	Average passenger time from Terminal entry to boarding gate (Min.) = = Total passenger time (Minutes) / Total passengers (#).
Data requirements:	Total time required by pass. from Terminal entry to boarding gate (Min.) Total passengers (#).
Units:	Minutes/passenger

KPI SA-OE-25	Passenger Satisfaction Index.
KPI definition:	For airports, customer satisfaction is a crucial aspect to be monitored. Consequently, a customer service to evaluate the customer's level of satisfaction should be implemented.
Calculation:	Customer satisfaction index: Score rated 1-5.
Data requirements:	Customer satisfaction index via a survey: (1-5).
Units:	CSI: Dimensionless.

KPI SA-OE-26	Complaints per 100 passengers.
KPI definition:	Furthermore, the number of customer complaints per 100 passengers is also an aspect that must be assessed.
Calculation:	Passenger Satisfaction Index = Number of customer complaints (#) x 100 / Total number of passengers (#).
Data requirements:	Number of customer complaints (#). Total number of passengers during the same period (#).
Units:	%

KPI SA-OE-27	Number of data sources used (before and after).
KPI definition:	Since the use of Big Data involves the processing of significant volumes of data gathered from numerous sources, this KPI, together with the following indicators will measure overall IT related parameters. In this case, the number of data sources used is monitored.
Calculation:	Number of data sources used (before) (#). Number of data sources used (after) (#).
Data requirements:	Number of data sources used (before) (#). Number of data sources used (after) (#).
Units:	Data sources (#) (Dimensionless)

KPI SA-OE-28	Average data volume collected daily (Gb) (before and after).
KPI definition:	The information volume compiled daily from the various sources is appraised.
Calculation:	Information volume collected daily (before) (Gb/day). Information volume collected daily (after) (Gb/day).
Data requirements:	Information volume collected daily (before) (Gb/day). Information volume collected daily (after) (Gb/day).
Units:	Gb/day

KPI SA-OE-29	Ratio of time with data source interface accessibility.
KPI definition:	A reliable system interconnectivity for a prolific data transmission process is a crucial feature which requires being assessed.
Calculation:	Ratio of time with data source interface accessibility (%) = = Time with functional interconnection (hours) x 100 / Total time (hours).
Data requirements:	Time with functional interconnection (hours). Total elapsed time (hours).
Units:	%

KPI SA-OE-30	Ratio of data processed vs. collected.
KPI definition:	As complementary evaluation, the proportion of data processed as of total collected is also supervised during a predetermined period.
Calculation:	Ratio of data processed vs collected (%) = = Total data processed (Tb) x 100 / Total data collected (Tb).
Data requirements:	Total data processed during the period (Tb). Total data collected during the period (Tb).
Units:	%

Asset Management (AM)

KPI SA-AM-1	Number of turn-arounds per day.
KPI definition:	Improvements in an efficient use of available technical and human resources would deliver a higher amount of aircraft daily turn-arounds, thus favouring higher productivity, more passengers, lower costs and increased profitability.
Calculation:	Number of aircraft turn-arounds per day (#/day) = = Total aircraft turn-arounds (#) / days (#). For a certain time period.
Data requirements:	Total aircraft turn-arounds (#). Number of days (#).
Units:	Turn-arounds (#)/day

KPI SA-AM-2	Number of in-time turn-arounds to total turn-arounds.
KPI definition:	Turn-around punctuality is also appraised with the Number of in-time turn-arounds vs total turn-arounds.
Calculation:	Ratio of in-time turn-arounds to total turn-arounds (%) = = Number of in-time turn-arounds (#) x 100 / Total turn-arounds (#).
Data requirements:	Number of in-time turn-arounds (#). Total turn-arounds (#).
Units:	%

KPI SA-AM-3	Gate time use efficiency.
KPI definition:	This indicator evaluates the improvement in gate time use efficiency.
Calculation:	Gate time use efficiency (%) = = Total time with gate in use (hours) x 100 / Total time (hours).
Data requirements:	Total time with gate in use (hours). Total time (hours).
Units:	%

KPI SA-AM-4	Ratio of aircrafts using finger-pier gate as of total aircrafts.
KPI definition:	Improving finger-pier gate use is another objective of the operation which needs to be assessed.
Calculation:	Ratio of aircrafts using finger-pier gate as of total aircrafts (%) = = Number of aircrafts using finger-piers (#) x 100 / Total aircrafts (#).
Data requirements:	Number of aircrafts using finger-piers (#). Total aircrafts (#).
Units:	%

KPI SA-AM-5	Passenger transit through commercial spaces.
KPI definition:	From a business perspective, increasing passenger transit through commercial spaces brings higher revenues to the organisation.
Calculation:	Passenger transit through commercial spaces (Passengers/day) = = Total transit through commercial spaces (Passengers) / days (#).
Data requirements:	Total passenger transit through commercial spaces (#). Number of days (#).
Units:	Passengers/day

KPI SA-AM-6	Passenger Satisfaction Index.
KPI definition:	The level of customer satisfaction with the commercial spaces is likewise evaluated.
Calculation:	For the commercial area: Customer satisfaction index: Score rated 1-5.
Data requirements:	Customer satisfaction index via a survey: (1-5).
Units:	CSI: Dimensionless.

KPI SA-AM-7	Ratio of commercial space to total Terminal surface.
KPI definition:	The proportion of commercial space to total terminal surface provides an indication of commercial area density.
Calculation:	Ratio of commercial space to total Terminal surface (%) = = Commercial space area (m^2) x 100 / Total Terminal surface (m^2).
Data requirements:	Commercial space area (m^2). Total Terminal surface (m^2).
Units:	%

Environmental Quality (EQ)

KPI SA-EQ-1	Number of daily announcements made over the public-address system.
KPI definition:	Reduction of acoustic emissions at the Terminal may be achieved by decreasing the number of daily announcements made over the public-address system.
Calculation:	Number of daily announcements made over the public-address system = = Total daily announcements on PA system (#) / Days (#).
Data requirements:	Total daily announcements (#). Number of days (#).
Units:	Announcements (#)/day

Economical (EF)

KPI SA-EF-1	Profit margin.
KPI definition:	From an economic perspective, the capacity of Big Data analysis to increase business profitability is evaluated by means of the profit margin.
Calculation:	Profit margin (%) = Net income (€) x 100 / Sales (€).
Data requirements:	Net income for the period (€). Sales (€).
Units:	%

6. KPIs for Integrated Urban Mobility (WP9)

These pilots assess potential of Big Data in supporting urban traffic managers to recognise disturbances, alleviating the impact of roadworks and exceptional situations. Furthermore, Big Data provides drivers with current traffic information and assists them in optimising route selection and available parking space.

Thus, indicators to evaluate these technologies will evaluate aspects concerning disruption prediction, optimal route design, parking space management and system-driver communication enhancements.

6.1. Transversal KPIs for Integrated Urban Mobility

Operational Efficiency (OE)

KPI IU-OE-1	Time used by freight vehicles in the city centre for driving and parking.
KPI definition:	In order to evaluate the improvement in operational efficiency provided by this technical innovation, the reduction in delivery travel time will be measured during a specific period of time.
Calculation:	Average time used by freight vehicles for driving and parking = $= \sum_{i=1}^{m}$ (Total daily time required for driving and parking (h) / / number of daily vehicles)$_i$) / Number of days (#). Where i represents each of the m days during which the measurements are performed for either scenario ("ex-ante" or "ex-post" the innovation).
Data requirements:	Total daily time required by the freight vehicles in the city centre for driving and parking (h). GPS-track of participating vehicles, geo-referenced by a bounding box in the city centre. Time slots for delivery, derived from GPS-track (i.e. where vehicle speed < *x* km/h for a minimum of *y* seconds). Number of vehicles participating in the pilot (#). Number of days (#).
Units:	h/(vehicle x day)

KPI IU-OE-2	Average delivery time.
KPI definition:	The average delivery time will be monitored to assess the reduction of delivery time.
Calculation:	Average delivery time in the period (Minutes) = = Total delivery time in the period (Min.) / Total number of deliveries (#).
Data requirements:	Total delivery time in the period (Minutes). Time slots for delivery derived from GPS-track (see above). Total number of deliveries (#).
Units:	Minutes/delivery

Environmental Quality (EQ)

KPI IU-EQ-1	NOx emissions.
KPI definition:	The average emissions of NOx per km will be assessed to identify the reduction in pollutant emissions achieved by the innovation during a predetermined period.
Calculation:	NOx emissions (g/km) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ (W$_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g NOx/kg fuel)). Where i represents each of the m vehicle classes (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), and j its type of fuel (gasoline, diesel, LPG or CNG), and W$_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g NOx/kg fuel).
Units:	g NOx/km

Energy Consumption (EC)

KPI IU-EC-1	GHG emissions.
KPI definition:	CO_2 emissions per km will be evaluated as an indicator of energy savings, as these are proportional to the vehicle's energy consumption.
Calculation:	CO_2 emissions (g/km) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ ($W_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g CO_2/kg fuel)). Where i represents each of the m vehicle classes (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), and j its type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g CO_2/kg fuel).
Units:	g CO_2/km

KPI IU-EC-2	Vehicle energy consumption per 100 km.
KPI definition:	In order to assess the reduction of energy consumption, the average amount of energy consumed referred to distance will be monitored.
Calculation:	Energy consumption (kWh/100 km) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ ($W_{i,j}$ x 100 x x Fuel consumption$_{i,j}$ (l/km) x Fuel energy content$_{i,j}$ (kWh/l)). Where i represents each class of vehicle and j its type of fuel (gasoline, diesel, ethanol, biodiesel, biogas LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel energy content for each type of fuel (kWh/l).
Units:	kWh/100 km

6.2. Specific KPIs for Integrated Urban Mobility

Operational Efficiency (OE)

KPI IU-OE-3	Number of vehicles which have used the parking spaces.
KPI definition:	In order to assess the optimal use of parking areas, the number of vehicles using the parking spaces is evaluated.
Calculation:	Average number of vehicles (vehicles/(parking space x day)) = Total number of vehicles parked (#)/(parking spaces (#) x Days (#)).
Data requirements:	Total number of vehicles parked during the period (#). Parking spaces (#). Number of days (#).
Units:	Parking spaces (#)/Number of days (#). (Dimensionless)

KPI IU-OE-4	Route optimisation.
KPI definition:	Big Data analysis should provide route planners with information that will empower their decision-taking process to modify courses and optimise the fleet's journeys. Ideally, the distance travelled per delivery should be reduced. This indicator will be measured during a prearranged period of days.
Calculation:	Average daily distance travelled per delivery (km/(delivery x day)) = $= \sum_{i=1}^{m}$ (Total daily distance travelled by the vehicles in the fleet (km) / / Total daily deliveries (#))$_i$ / Number of days (#). Where i represents each of the m days during which each of the transport scenarios is tested ("ex-ante" or "ex-post" the innovation).
Data requirements:	Total daily distance travelled by the vehicle (km). GPS-track of vehicles (georeferenced by bounding box), with identification of delivery slots. Total daily deliveries (#). Number of days (#).
Units:	km/(delivery x day)

KPI IU-OE-5	Traffic data sources used for managing services.
KPI definition:	Traffic data sources used for the situational awareness and managing the logistic services should increase because of Big Data analysis implementation. Therefore, the integration of new data supply networks will be assessed.
Calculation:	Number of traffic data sources (#).
Data requirements:	Number of traffic data sources (#).
Units:	Data sources (#) (Dimensionless)

KPI IU-OE-6	Customer satisfaction with the service.
KPI definition:	For any logistic service provider, customer satisfaction is a key aspect to be monitored. Consequently, a customer service to evaluate the customer's level of satisfaction will be carried-out.
Calculation:	Customer satisfaction index: Score rated 1-5.
Data requirements:	Customer satisfaction index via a survey: (1-5).
Units:	CSI: Dimensionless

KPI IU-OE-7	Orders delivered by vehicle per day.
KPI definition:	Logistic activity performance will be measured by calculating the number of orders delivered by vehicle per day.
Calculation:	Average daily orders delivered by vehicle (# orders/(vehicle x day)) = $\sum_{i=1}^{m}$ (Total daily orders delivered (#) / Number of daily vehicles (#))$_i$ / / Number of days (#). Where i represents each of the m days during which each of the transport scenarios is tested ("ex-ante" or "ex-post" the innovation).
Data requirements:	Total daily orders delivered (#). GPS track of the vehicles with identification of delivery slots. Number of days (#).
Units:	# orders/(vehicle x day)

KPI IU-OE-8	Average commercial speed.
KPI definition:	The expected improvement in logistic efficiency is evaluated by measuring the fleet's average commercial speed during a specific period; both before, and once the innovation has been implemented.
Calculation:	Average commercial speed (km/h) = Distance travelled by fleet (km) / / Total travelling time (h).
Data requirements:	Total distance travelled by the fleet (km). Total travelling time (h).
Units:	km/h

KPI IU-OE-9	Fleet traffic flow.
KPI definition:	As complementary information to KPI IU-OE-8, it is interesting to calculate the fleet's overall traffic flow during the same periods.
Calculation:	Average fleet traffic flow = Total fleet's traffic flow (vehicle-km) / / Total travelling time (h).
Data requirements:	Total fleet's traffic flow (vehicle-km). Total travelling time (h).
Units:	Vehicle-km/h

KPI IU-OE-10	Number of traffic disruptions detected per hour.
KPI definition:	A relevant feature of the system is its capacity to detect traffic disturbances, therefore generating improvements in traffic flow patterns.
Calculation:	Number of traffic disruptions detected per hour (disruption (#)/hour) = = Total traffic disruptions detected (#) / Hours (#).
Data requirements:	Total traffic disruptions detected (#). Hours (#).
Units:	Disruptions (#)/hour

KPI IU-OE-11	Average number of vehicles affected by traffic disruptions.
KPI definition:	In addition, the average number of vehicles affected by traffic disruptions is also appraised.
Calculation:	Average vehicles affected by disruptions (vehicles (#)/disruption (#)) = = Total vehicles affected by disruptions (#) / Total traffic disruptions (#).
Data requirements:	Total vehicles affected by traffic disruptions (#) Total traffic disruptions detected (#).
Units:	Dimensionless: Vehicles (#)/Disruption (#)

KPI IU-OE-12	Number of daily vehicles using freight delivery areas.
KPI definition:	Increasing the use of freight delivery areas is a key objective within the project, so parking space turnover is examined during a certain period.
Calculation:	Number of daily vehicles using freight delivery areas = = Total number of vehicles using freight delivery areas (#) x 100 / / (Total parking spaces (#) x Days (#)).
Data requirements:	Total number of vehicles using freight delivery areas during the complete period (#). Total parking spaces (#). Days (#).
Units:	Vehicles (#)/(100 places x day)

KPI IU-OE-13	Average parking time in freight delivery areas.
KPI definition:	Furthermore, the average parking time in the freight delivery areas is also assessed.
Calculation:	Average parking time in freight delivery areas = = Total vehicle parking time at freight delivery areas (Minutes) / / Total vehicles (#).
Data requirements:	Total vehicle parking time at freight delivery areas during the complete period (Minutes). Total vehicles (#).
Units:	Minutes

KPI IU-OE-14	Ratio of advance booking for freight delivery areas.
KPI definition:	An objective concerning freight delivery areas is to increase advance booking for the service.
Calculation:	Ratio of advance booking for freight delivery areas (%) = = Advance bookings (#) x 100 / Total bookings (#).
Data requirements:	Number of advance booking for freight delivery areas (#). Total bookings for freight delivery areas (#).
Units:	%

KPI IU-OE-15	Ratio of advance bookings for car sharing and average time in advance.
KPI definition:	Car sharing indicators are also developed to evaluate market trends for this transport mode.
Calculation:	Ratio of advance booking for car sharing (%) = = Advance bookings (#) x 100 / Total bookings (#). Average time in advance (Minutes).
Data requirements:	Number of advance booking for car sharing (#). Total bookings for car sharing (#). Average time in advance (Minutes).
Units:	% Minutes

KPI IU-OE-16	Ratio of planned roadwork to total roadwork events.
KPI definition:	The proportion of planned roadwork to total roadwork events is evaluated.
Calculation:	Ratio of planned roadwork to total roadwork events (%) = = Planned roadwork (#) x 100 / Total roadwork events (#).
Data requirements:	Ratio of planned roadwork to total roadwork events
Units:	%

KPI IU-OE-17	Average data volume collected daily (Gb) (before and after).
KPI definition:	The information volume compiled daily from the various sources is appraised.
Calculation:	Information volume collected daily (before) (Gb/day). Information volume collected daily (after) (Gb/day).
Data requirements:	Information volume collected daily (before) (Gb/day). Information volume collected daily (after) (Gb/day).
Units:	Gb/day

KPI IU-OE-18	Average daily collected events/observations per data set (before and after).
KPI definition:	The average daily collected events/observations per data set are monitored before and after.
Calculation:	Average daily collected events/observations (Events (#)/day) = = Total collected events/observations (#) / Days (#).
Data requirements:	Total collected events/observations per data for the period (#). Days (#). For before and after conditions.
Units:	Events (#)/day

KPI IU-OE-19	Data quality of observations per data set (ratio of outliers).
KPI definition:	It is also important to assess the quality of the information that has been gathered. The ratio of outliers is calculated.
Calculation:	Ratio of outliers (%) = Total outlier registers (#) x 100 / Total registers (#).
Data requirements:	Total outlier registers (#). Total registers (#).
Units:	%

KPI IU-OE-20	Ratio of time with data source interface accessibility (per data source).
KPI definition:	This indicator evaluates the proportion of time with source interface accessibility, and is calculated for each data source. The final representative figure will be the average value for all sources.
Calculation:	For each source: Ratio of time with data source interface accessibility (%) = = Total time with accessibility (hours) x 100 / Total time (hours).
Data requirements:	Total time with data source interface accessibility (hours). Total time (hours).
Units:	%

KPI IU-OE-21	Average number of daily future events assessed.
KPI definition:	This KPI intends to appraise the technology's predictive capacity by monitoring the average number of daily future events assessed.
Calculation:	Average number of daily future events assessed (Events (#)/day) = = Total number of future events assessed (#) / Days (#).
Data requirements:	Total number of future events assessed (#). Days (#).
Units:	Events (#)/day

KPI IU-OE-22	Average number of daily unplanned events assessed.
KPI definition:	Similarly, this indicator assesses the system's capacity to handle efficiently daily unplanned events.
Calculation:	Average number of daily unplanned events assessed (Events (#)/day) = = Total number of unplanned events assessed (#) / Days (#).
Data requirements:	Total number of unplanned events assessed (#). Days (#).
Units:	Events (#)/day

KPI IU-OE-23	Ratio of data processed vs. collected.
KPI definition:	As complementary evaluation, the proportion of data processed as of total collected is also supervised during a predetermined period.
Calculation:	Ratio of data processed vs collected (%) = = Total data processed (Tb) x 100 / Total data collected (Tb).
Data requirements:	Total data processed during the period (Tb). Total data collected during the period (Tb).
Units:	%

KPI IU-OE-24	Average daily number of events reported by the Traffic Management Centre (TMC).
KPI definition:	A reasonable outcome of the innovation's implementation should result in an increase of events reported by the Traffic Management Centre (TMC).
Calculation:	Average daily number of events reported by the TMC (Events (#)/day) = = Total events reported by the TMC (#) / Days (#).
Data requirements:	Total events reported by the TMC during the period (#). Days in the period (#).
Units:	Events (#)/day

KPI IU-OE-25	Average number of daily messages sent to social media.
KPI definition:	In order to measure social communication volume, the average number of daily messages sent to social media is accounted.
Calculation:	Average number of daily messages to social media (Messages (#)/day) = = Total messages sent to social media (#) / Days (#).
Data requirements:	Total messages sent to social media during the period (#). Days in the period (#).
Units:	Messages (#)/day

KPI IU-OE-26	Average number of social media followers receiving information.
KPI definition:	The number of followers, and related interactions, is an important parameter, since it provides feedback on the organisation's communication connectivity in the social media.
Calculation:	Average number of social media followers (#).
Data requirements:	Average number of social media followers during the period (#).
Units:	Dimensionless: Followers (#)

KPI IU-OE-27	Average daily number of website visitors.
KPI definition:	Likewise, this indicator measure the average daily number of website visitors.
Calculation:	Average number of daily website visitors (Visitors (#)/day) = = Total number of website visitors (#) / Days (#).
Data requirements:	Total number of website visitors during the period (#). Days (#).
Units:	Website visits (#)/day

KPI IU-OE-28	Average daily messages displayed in variable messages signs (VMS).
KPI definition:	The volume of messages shown in variable messages signs (VMS) is another communication channel with drivers that is assessed.
Calculation:	Average daily messages displayed in VMS (Messages (#)/day) = = Total number of messages displayed in VMS (#) / Days (#).
Data requirements:	Total number of messages displayed in VMS (#). Days (#).
Units:	Messages (#)/day

KPI IU-OE-29	Number of regulations proposed by the City Council related to logistic loading and unloading protocols on public roadways.
KPI definition:	Policy decisions made by regulators affecting road transport logistic services is an important issue to be monitored by logistic firms.
Calculation:	Number of regulations proposed by the City Council related to logistic loading and unloading protocols on public roadways (#).

Data requirements:	Number of regulations proposed by the City Council related to logistic loading and unloading protocols on public roadways for the period under evaluation (#).
Units:	Dimensionless

Asset Management (AM)

KPI IU-AM-1	Length and percentage of road with data gathering systems.
KPI definition:	Complete and precise data collection requires the presence of an adequately monitored infrastructure.
Calculation:	Length of road with data gathering systems (km). Proportion of road with data gathering systems (%) = = Length of road with data systems (km) x 100 / Total road length (km).
Data requirements:	Length of road with data gathering systems (km). Total road length (km).
Units:	km, %

KPI IU-AM-2	CCTV camera installations
KPI definition:	The proportion of road with CCTV camera coverage is also calculated.
Calculation:	Number of cameras per intersection = Total number of cameras (#) / / Intersections (#). Number of cameras per 10 km = Total number of cameras (#) x 10 / / Total road length (km).
Data requirements:	Total number of cameras (#). Number of intersections (#). Total road length (km).
Units:	Cameras (#)/intersections (#) Cameras (#)/10 km

KPI IU-AM-3	Total number of existing freight delivery places.
KPI definition:	This KPI registers the total number of infrastructure's number of freight delivery places available for use.
Calculation:	Total number of existing freight delivery places (#).
Data requirements:	Total number of existing freight delivery places (#) (before and after).
Units:	Dimensionless (#)

KPI IU-AM-4	Number of variable messages signs (VMS) per 100 km.
KPI definition:	Also, related with the infrastructure and the capacity to transmit information to users, the number of variable messages signs (VMS) per 100 km is calculated.
Calculation:	Number of VMS per 100 km = Total number of VMS (#) x 100 / / Total road length (km).
Data requirements:	Total number of variable messages signs (VMS) (#). Total road length (km).
Units:	VMS (#)/100 km

Environmental Quality (EQ)

KPI IU-EQ-2	Occupied surface while delivering.
KPI definition:	This KPI measures a combined ratio which takes into consideration both the vehicle dimensions and the time length of stops for deliveries taking place per hour.
Calculation:	Occupied surface while delivering (m^2/h) = $= \sum_{i=1}^{m}$ (Vehicle area$_i$ (m^2) x Proportion of time parked for delivery$_i$ (p.u.) In which, for vehicle i, the proportion of time in each delivery's process final stage (parked vehicle) (p.u.) is total time parked during the period, divided by the total time (in circulation and parked).
Data requirements:	Vehicle area (m^2). Total time parked during the period per vehicle (delivering) (hours). Total time (circulation and parked) per vehicle for the period (hours)
Units:	m^2

KPI IU-EQ-3	Occupied surface by cargo.
KPI definition:	The road's surface occupied by the vehicle per delivery indicates the innovation's capacity to reduce roadside space occupation.
Calculation:	Average occupied surface by cargo (m^2) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ (Surface occupied by vehicle $_j$ / Total orders delivered$_{i,j}$ (#)) / Days (#). Where i represents each of the m days during which each of the transport scenarios are tested ("ex-ante" or "ex-post" the innovation), and j each of the vehicles which compose the fleet.
Data requirements:	Total daily surface occupied by each vehicle (m^2/day). Total orders delivered per day and vehicle (#). Days (#).
Units:	m^2

Economic (EF)

KPI IU-EF-1	Ratio of cost performance of defined routes through data monitoring.
KPI definition:	Predictive analysis, mobility patterns and decision supports systems will allow vehicle fleets to assess the cost reduction of defined routes due to the optimisation of parameters involved in routes choices of vehicle owners such as velocity, alternative routes, congestion, etc.
Calculation:	Average cost of logistic defined routes per unit distance (€/km) = = Total cost of logistic defined routes (€) / Length of route system (km).
Data requirements:	Total cost of all logistic defined routes (€). Total length of route system (km).
Units:	€/km

7. KPIs for Dynamic Supply Networks (WP10)

This pilot's goal is to develop guidelines regarding the potential use of Big Data in e-commerce logistics and deliver a roadmap to define how Big Data solutions can be managed and implemented. As main objectives, the project pretends to:

- Use Big Data techniques to quantify the impact of shared logistics in e-commerce deliveries to reduce costs, energy consumption and emissions.
- Enhance shared logistics at the reverse logistics supply chain.
- Evaluate alternative shipping methods.

Hence, the set of indicators proposed for these innovations intend to measure those features related with route optimisation and traffic flow management, energy and time efficiency improvements in the delivery process, potential benefits provided by novel logistic methodologies, and overall operational cost reductions for the organisation.

7.1. Transversal KPIs for Dynamic Supply Networks

Operational Efficiency (OE)

KPI SN-OE-1	Operating costs.
KPI definition:	The average operating cost per delivery will be observed during a specific period of time.
Calculation:	Average operating cost per delivery (€/deliv.) = Total operating cost (€) / / Total deliveries (#).
Data requirements:	Total operating cost in the specified period (€). Total number of deliveries during the period (#).
Units:	€

KPI SN-OE-2	Average delivery time.
KPI definition:	The average delivery time will be monitored to assess the reduction of delivery time.
Calculation:	Average delivery time in the period (min) = = Total delivery time in the period (min) / Total number of deliveries (#).
Data requirements:	Total delivery time in the period (min). Total number of deliveries (#).
Units:	Minutes

Environmental Quality (EQ)

KPI SN-EQ-1	NOx emissions.
KPI definition:	NOx emissions per km will be assessed to identify the reduction in pollutant emissions achieved by the innovation during a predetermined period.
Calculation:	NOx emissions (g/km) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ ($W_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g NOx/kg fuel)). Where i represents each of the vehicle classes (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), and j its type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g NOx/kg fuel).
Units:	g NOx/km

KPI SN-EQ-2	PM emissions.
KPI definition:	Similarly, particle (PM) emissions per km will be evaluated to recognise improvements in the reduction of these pollutant emissions.
Calculation:	PM emissions (g/km) = $\sum_{i=1}^{m} \sum_{j=1}^{n}$ ($W_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g PM/kg fuel)). Where i represents each of the vehicle classes (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), and j its type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g PM/kg fuel).
Units:	g PM/km

Energy Consumption (EC)

KPI SN-EC-1	GHG emissions.
KPI definition:	CO_2 emissions per km will be evaluated as an indicator of energy savings, as these are proportional to the vehicle's energy consumption.
Calculation:	CO_2 emissions (g/km) = $\sum_{i=1}^{m}\sum_{j=1}^{n}$ ($W_{i,j}$ x Fuel consumption$_{i,j}$ (l/km) x x fuel density$_{i,j}$ (kg/l) x Emission factor$_{i,j}$ (g CO_2/kg fuel)). Where i represents each of the vehicle classes (two-wheel vehicles, passenger cars, light commercial vehicles (LCV) or heavy-duty vehicles), and j its type of fuel (gasoline, diesel, LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel density for every type of fuel (kg/l). Emission factor per vehicle class and fuel type (g CO_2/kg fuel).
Units:	g CO_2/km

KPI SN-EC-2	Vehicle energy consumption per 100 km.
KPI definition:	In order to assess the reduction of energy consumption, the average amount of energy consumed referred to distance will be monitored.
Calculation:	Energy consumption (kWh/100 km) = $\sum_{i=1}^{m}\sum_{j=1}^{n}$ ($W_{i,j}$ x 100 x x Fuel consumption$_{i,j}$ (l/km) x Fuel energy content$_{i,j}$ (kWh/l). Where i represents each class of vehicle and j its type of fuel (gasoline, diesel, ethanol, biodiesel, biogas LPG or CNG), and $W_{i,j}$ the weight of its fuel consumption divided by the total fuel consumed.
Data requirements:	Fuel consumption per vehicle class and engine type (litres). Distance travelled by each vehicle class and engine type (km). Fuel energy content for each type of fuel (kWh/l).
Units:	kWh/100 km

7.2. Specific KPIs for Dynamic Supply Networks

Operational Efficiency (OE)

KPI SN-OE-3	**Number of daily orders handled.**
KPI definition:	This indicator measures the innovation's influence on the amount of daily orders handled by the operation.
Calculation:	Average daily orders handled (orders (#)/day) = = Total orders (#) / Days (#).
Data requirements:	Total orders handled (#). Number of days in the period.
Units:	Orders (#)/day

KPI SN-OE-4	**Number of daily deliveries per vehicle.**
KPI definition:	The use of Big Data to optimise route planning is expected to increase the number of deliveries achieved per vehicle.
Calculation:	Average daily deliveries per vehicle = $= \sum_{i=1}^{m}$ (Total daily deliveries (#) / Daily vehicles (#))$_i$ / Days (#). Where i represents each of the m days during which each of the transport scenarios is tested ("ex-ante" or "ex-post" the innovation).
Data requirements:	Total number of deliveries (#). Average number of vehicles in the fleet for the period (vehicles). Number of days in the period (#).
Units:	Deliveries (#)/(vehicle x day)

KPI SN-OE-5	**On-time deliveries to customers.**
KPI definition:	Order delivery punctuality is a key aspect for any supplier organisation involved in logistic services. Thus, On-time monitoring is crucial for logistic firms.
Calculation:	On-time deliveries (%) = Number of deliveries on-time (#) x 100 / / Total number of deliveries (#).
Data requirements:	Number of deliveries on-time (#). Total number of deliveries (#).
Units:	%
KPI SN-OE-6	**Average number of vehicles in the delivery fleet.**
KPI definition:	In addition, it is interesting to evaluate the number of vehicles in the fleet, as route optimisation could result in vehicle reductions.

Calculation:	Average number of vehicles in the delivery fleet (#) = $=\sum_{i=1}^{m}$ Daily vehicles$_i$ (#) / Days (#). Where i represents each of the m days during which each of the transport scenarios is tested ("ex-ante" or "ex-post" the innovation).
Data requirements:	Daily number of vehicles in the fleet (# vehicles). Number of days in the period (#).
Units:	Dimensionless: Vehicles (#)

KPI SN-OE-7	**Average number of daily consolidated pick-ups and deliveries per vehicle.**
KPI definition:	Big Data analysis could provide logistic planners supplementary information which could improve consolidated pick-ups and deliveries per vehicle.
Calculation:	Average daily consolidated pick-ups and deliveries per vehicle = $=\sum_{i=1}^{m}$ (Consolidated pick-ups & deliv. (#)/ Daily vehicles (#))$_i$ / Days (#) Where i represents each of the m days during which each of the transport scenarios is tested ("ex-ante" or "ex-post" the innovation).
Data requirements:	Total consolidated pick-ups and deliveries (#). Average number of vehicles in the fleet for the period (vehicles). Number of days (#).
Units:	Deliveries (#)/(vehicle x day)

KPI SN-OE-8	**Ratio of consolidated pick-ups and deliveries to total deliveries.**
KPI definition:	Complementing the prior indicator, the ratio of consolidated pick-ups and deliveries to total deliveries is also assessed during a certain period.
Calculation:	Ratio of consolidated pick-ups and deliveries to total deliveries (%) = = Total consolidated pick-ups and deliveries (#) x 100/ Total deliveries (#)
Data requirements:	Total consolidated pick-ups and deliveries (#). Total number of deliveries (#).
Units:	%

KPI SN-OE-9	**Orders using shared logistics.**

KPI definition:	Big Data analysis could offer logistic planners additional information that would foster the organisation's capacity to enhance shared logistics, thus improving the deliveries that could be achieved per vehicle. This indicator will be measured during a prearranged period of days.
Calculation:	Average daily deliveries per vehicle using shared logistics = $= \sum_{i=1}^{m}$ (Total daily deliveries (#) / Daily vehicles (#))$_i$ / Days (#). Where i represents each of the m days during which each of the transport scenarios is tested ("ex-ante" or "ex-post" the innovation).
Data requirements:	Total daily deliveries (#). Number of daily vehicles (#). Number of days (#).
Units:	Deliveries (#)/(vehicle x day)

KPI SN-OE-10	Orders using alternative shipping methods.
KPI definition:	Complementing KPI SN-OE-5, Big Data examination may also offer supplementary information that would increase the organisation's capacity to use alternative shipping methods This indicator will be evaluated during a pre-set period of days.
Calculation:	Ratio of orders using alternative methods (%) = = Orders using alternative methods (#) x 100 / Total orders (#).
Data requirements:	Number of orders using alternative shipping methods (#) Total number of orders (#).
Units:	%

KPI SN-OE-11	Drops per route.
KPI definition:	In order to measure logistic operational efficiency, the number of drops per route and per unit distance is assessed.
Calculation:	Drops per route (#/km) = Average number of drops per route (#) / / Average route length (km).
Data requirements:	Average number of drops per route (#). Average route length (km).
Units:	Drops (#)/km

KPI SN-OE-12	Load factor.

Load factor (%) = $\sum_{i=1}^{m}$ ((Vehicle load$_i$ (m^3) / Max. vehicle load$_i$ (m^3)) x

x vehicle-km$_i$) x 100 / $\sum_{i=1}^{m}$ vehicle-km$_i$

KPI definition:	This indicator measures the ratio of the average load to total vehicle capacity in a vehicle expressed in terms of vehicle-km. Empty running is excluded from the calculation.
Calculation:	Where i represents any of the m trips performed by each vehicle of the firm's fleet during a predetermined time period.
Data requirements:	For every trip, the following information is required: Vehicle load (m^3). Maximum vehicle load (m^3). Distance travelled: vehicle-km. Total number of trips (#).
Units:	%

KPI SN-OE-13	**Daily distance travelled per delivery.**
KPI definition:	Big Data analysis should provide route planners with information that will empower their decision-taking process to modify courses and optimise the fleet's journeys. Ideally, the distance travelled per delivery should be reduced. This indicator will be measured during a prearranged period of days.
Calculation:	Average daily distance travelled per delivery (km/(delivery x day)) = $= \sum_{i=1}^{m}$ (Total daily distance travelled by the fleet (km) / / Total daily deliveries (#))$_i$ / Days (#). Where i represents each of the m days during which each of the transport scenarios is tested ("ex-ante" or "ex-post" the innovation).
Data requirements:	Total daily distance travelled by the fleet (km). Total daily deliveries (#). Number of days in the period (#).
Units:	km/(delivery x day)

KPI SN-OE-14	**Average distance travelled per route.**

KPI definition:	As supplementary information for the previous indicator, the average distance travelled per route is also calculated.
Calculation:	Average distance travelled per route (km/route) = $= \sum_{i=1}^{m}$ (Daily distance travelled by the fleet (km) / Daily routes (#))$_i$. Where i represents each of the m days during which each of the transport scenarios is tested ("ex-ante" or "ex-post" the innovation).
Data requirements:	Total daily distance travelled by the fleet (km). Number of daily routes (#).
Units:	km/route

KPI SN-OE-15	Ratio of problematic deliveries.
KPI definition:	The efficacy of the logistic process can be improved by reducing the number of problematic procedures, which also increases customer satisfaction.
Calculation:	Ratio of Number of problematic deliveries = Number of problematic deliveries (#) x 100 / Total deliveries (#).
Data requirements:	Number of problematic deliveries (#). Total deliveries (#).
Units:	%

KPI SN-OE-16	Ratio of forecasted problematic deliveries to actual problematic deliveries.
KPI definition:	Operational efficiency may be enhanced by augmenting the organisation's capacity to predict problematic deliveries and decrease its impact on distribution ineffectiveness.
Calculation:	Ratio forecasted problematic deliveries to actual prob. deliveries (%) = = Forecasted problematic deliveries (#) x 100 / / Actual problematic deliveries (#)
Data requirements:	Total forecasted problematic deliveries for the period (#). Total problematic deliveries for the period (#).
Units:	%

KPI SN-OE-17	Number of click and collect points per area
KPI definition:	The number of click and collect points density will be monitored to evaluate customer pick-up point availability and convenience.
Calculation:	Click and collect point density (#/km^2) = = Total click and collect points in area (#) / Area surface (km^2).
Data requirements:	Total click and collect points in area (#). Area surface (km^2)
Units:	Click and collect points (#)/km^2

KPI SN-OE-18	Orders served by click and collect
KPI definition:	The proportion of orders served in click and collect points will be assessed to measure the utilisation of such delivery procedure.
Calculation:	Ratio of orders served by click and collect (%) = = Orders served by click and collect (#) x 100 / Total orders delivered (#).
Data requirements:	Total orders served by click and collect during the period (#). Total orders delivered in the period (#).
Units:	%

KPI SN-OE-19	First time delivery ratio.
KPI definition:	The ratio of first time deliveries is an important indicator in logistic services because, not only provides increased customer satisfaction, but additionally reduces logistic costs, as return trips are avoided.
Calculation:	First time delivery ratio (%) = Deliveries completed first time (#) x 100 / / Total number of deliveries (#).
Data requirements:	Number of deliveries completed the first time (#). Total number of deliveries (#).
Units:	%

KPI SN-OE-20	Customer satisfaction with the service.
KPI definition:	For any logistic service provider, customer satisfaction is a key aspect to be monitored. Consequently, a customer service to evaluate the customer's level of satisfaction will be carried-out.
Calculation:	Customer satisfaction index: Score rated 1-5.
Data requirements:	Customer satisfaction index: (1-5).
Units:	CSI: Dimensionless

KPI SN-OE-21	Number of data sources used (before and after).
KPI definition:	Since the use of Big Data involves the processing of significant volumes of data gathered from numerous sources, this KPI, together with the following indicators will measure overall IT related parameters. In this case, the number of data sources used is monitored.
Calculation:	Number of data sources used (before) (#). Number of data sources used (after) (#).
Data requirements:	Number of data sources used (before) (#). Number of data sources used (after) (#).
Units:	Data sources (#) (Dimensionless)

KPI SN-OE-22	Average data volume collected daily (Gb) (before and after).
KPI definition:	The information volume compiled daily from the various sources is appraised.
Calculation:	Information volume collected daily (before) (Gb/day). Information volume collected daily (after) (Gb/day).
Data requirements:	Information volume collected daily (before) (Gb/day). Information volume collected daily (after) (Gb/day).
Units:	Gb/day

KPI SN-OE-23	Ratio of time with data source interface accessibility.
KPI definition:	A reliable system interconnectivity for a prolific data transmission process is a crucial feature which requires being assessed.
Calculation:	Ratio of time with data source interface accessibility (%) = = Time with functional interconnection (hours) x 100 / Total time (hours).
Data requirements:	Time with functional interconnection (hours). Total elapsed time (hours).
Units:	%

KPI SN-OE-24	Ratio of data processed vs. collected.
KPI definition:	As complementary evaluation, the proportion of data processed as of total collected is also supervised during a predetermined period.
Calculation:	Ratio of data processed vs collected (%) = = Total data processed (Tb) x 100 / Total data collected (Tb).
Data requirements:	Total data processed during the period (Tb). Total data collected during the period (Tb).
Units:	%

Economic (EF)

KPI SN-EF-1	Order delivery cost.
KPI definition:	As a crucial economic indicator for the activities performed by this pilot, the cost per order is assessed during a certain period.
Calculation:	Average order delivery cost (€/delivery) = = Total order delivery costs (€) / Number of delivery orders (#).
Data requirements:	Total order delivery costs during the period (€). Number of order deliveries achieved during the period (#).
Units:	Cost (€)/order (#)

KPI SN-EF-2	Delivery cost.
KPI definition:	Complementarily, this indicator specifically evaluates the variation in delivery costs.
Calculation:	Average delivery cost (€/delivery) = = Total delivery costs (€) / Number of deliveries (#).
Data requirements:	Total order delivery costs during the period (€). Number of order deliveries achieved during the period (#).
Units:	Cost (€)/delivery (#)

KPI SN-EF-3	Cost of returns.
KPI definition:	For logistic operators, cost of returns represent an avoidable expense that should be minimised.
Calculation:	Average cost of returns (€/return) = = Total return costs (€) / Number of returns (#).
Data requirements:	Total return costs during the period (€). Number of returns accounted during the period (#).
Units:	Cost (€)/return (#)

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