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 Cleaner and better transport in cities

DESTINATIONS



D8.5

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Abstract

The testing and acceptance phase of an ITS system plays a key role into the whole deployment process. It determines whether the performance of the ITS system from the technical, functional and operational point of view is good enough to enable the operation of the system and the launch of the service supported by the system itself.

In particular the testing phase of an ITS system is a process dealing with technical issues (to assess if the system has been implemented by the Contractor according to the requirements and specifications stated in the contract) but it also reflects on the management of the contract and related obligations. Due to this reason, the testing phase is very demanding for the Contracting Organization. This is in terms of time and resources required to prepare the tests, to carry out them, to collect and to evaluate the results and to apply the contract prescriptions based on the final assessment of the tests' results.

Being aware of these framework conditions, the CIVITAS DESTINATIONS consortium planned a deliverable to act as guidelines to the Site Managers and Measure Leaders to manage this critical phase in the management of ITS implementation and to assess the ITS technical viability to launch the demonstration measures included in the project.

The guidelines included in this deliverable come from the large experience consolidated by MemEx technical team in providing consultancy over the last 25 years to Public Administrations, Mobility Operators and Statutory Authorities in ITS testing and certification: the experience (and the guidelines as well) cover both technical issues and the management of the contractual prescriptions for ITS acceptance.

The testing process is divided in four main steps and the “core” guidelines included in this deliverable suggest a methodology to be applied to all of them. Then specific recommendations are provided as implementation of the general methodological approach to each testing phase.

Finally, the contractual recommendations are provided on how to manage the acceptance of the system based on the results of the testing process.

Project Partners

Organisation	Country	Abbreviation
Horários do Funchal, Transportes Públicos	HF	PT
Agência Regional da Energia e Ambiente da Região Autónoma da Madeira	AREAM	PT
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Glossary

Acceptance criteria – the criteria adopted to decide if a test is successful or not

Acceptance of the system – all the testing process is successful, it states that the system complies with the defined technical specifications allowing the acceptance by the Contracting Organisation

Contracting Organisation – the Entity signing the supply/service contract with the Contractor (eventually related to a part of the supply/service previously tendered)

Contractor – the Entity (company or consortium of companies) signing the supply/service contract with the Contracting Organisation

ITS (Intelligent Transport System) – ICT systems supporting the planning/operation of mobility/transport services

Sign Off: after the positive testing/acceptance process the system goes into operation

Sw: software

Technical specifications – document included in the tendering package and consisting of the technical, functional, operational characteristics/features of the tendered system

Tender requirements – the technical requirements and the contractual obligations included in the tendering package.

Test specifications – they define testing steps, sessions, procedures and modalities, timing and how the tests should be carried out

Testing/acceptance process – is the process which ends/follows the implementation of the system. It states if the system provided by the Contractor is fully responsive to all the requirements defined in the technical specifications by the Contracting Organization

Testing step – each phase, to be developed in the testing/acceptance process. They are different on the basis of the defined testing specifications. Each testing step consists of various testing sessions

Testing session – a specific execution of one or more dedicated tests.

1 Executive Summary

The introduction (section 2) helps to set the technical and contractual framework of this deliverable.

The deliverable starts from the identification of the four main steps of a testing/acceptance process for an ITS system (section 3):

- (1) Verification of the quantitative and technical compliance of the supply;
- (2) Verification of the technical and operational responsiveness of the installations;
- (3) Development of the functional tests;
- (4) Verification of the system performance (performance tests).

Section 3 highlights how these four steps are cross-related and it also provides recommendations to Site Managers and Measure Leaders how to prioritize (and to schedule) their execution.

Section 4 represents the core part of the deliverable where the methodology to be adopted for tests planning and execution is presented through a synthetic table. The methodology is based on the definition of the compliance matrix listing all the components/parts of the Contract and detailing the specific functional, technical and operational requirements related to each of them. The matrix guides the whole testing/acceptance process, it can be used to report/track the testing results (step-by-step) and it supports the assessment of the final results. Then the methodology is specified in terms of means of verification, expected results, supporting material and background preparation and acceptance criteria.

Section 5, 6, 7 and 8 provide detailed recommendations to Site Managers and Measure Leaders how to plan and carry out the tests related to each of the phase identified in section 2: the methodology presented in section 4 is then implemented for the verification of the quantitative and technical compliance of the supply (section 5), for the verification of the technical and operational responsiveness of the installations (section 6), for the functional tests (section 7) and lastly for the performance test (section 8).

Section 9 provides recommendations to Site Managers and Measure Leaders on the timing to be scheduled and the resources to be allocated to carry out the testing process.

Section 10 supports the Site Managers and Measure Leaders in managing contractual prescriptions about ITS implementation based on the results of the testing process.

2 Introduction

The testing and acceptance phase of an ITS system play a key role not only for the management of the contract but also for the success of the whole deployment phase.

From the contractual point of view, the positive acceptance process leads to:

- The certification of the system's compliance with the technical, functional and operational specifications defined in the contract;

- The release of the final (last) payment defined in the contract;
- The beginning of the operation of the system in the real environment;
- The beginning of warranty period (and related contractual obligations);
- The beginning of the time period when the system is in charge of the Contracting Organization (or, alternatively, the organization, Mobility/Transport Operator, Agency, Public Administration, etc. in charge of system operation on behalf of the Contracting Organization).

From the technical/operational point of view, the acceptance of the system assures that:

- The functional specifications of the system fully comply with the requirements of the design phase;
- The operational specifications of the system comply with the procedures and daily workflow which has been defined in the design phase (feasibility study) and tuned during the testing phase;
- The technical performance of the system comply with the minimum level required to assure the service/system operation in the real environment.

The testing and acceptance phase of an ITS system consists of an overall process where:

- The technical and the contractual issues are closely cross-related and mutually influenced;
- The Contractor and the Contracting Organization (and/or the organization¹ who is in charge to operate the system) need to cooperate, despite their different roles, responsibilities, commitments and interests;
- The reasonableness and the transparency must be assured as a safeguard for both the involved parties (Contractor and Contracting Organization);
- The steps, the rules, the acceptance criteria and the indicators must be defined in the contract. In any case the whole process should be also detailed by both the parties at the beginning of the realization process.

The testing procedures should be conducted either in-house or by an independent firm/consultant with the relevant expertise (appointed by the Contracting Organization).

¹ As indicated in D8.4, the contract could be signed by an organization which is not (the only) involved in the system operation

3 Steps of testing/acceptance process

In general, the testing and acceptance process consists of 4 main steps:

- (1) Verification of the quantitative and technical compliance of the supply;
- (2) Verification of the technical and operational responsiveness of the installations;
- (3) Development of the functional tests;
- (4) Verification of the system performance (performance tests).

The objectives, actions and results of each step are detailed in sections 5, 6, 7, 8.

It is recommended that the testing steps should be carried out separately (at least for steps 2), 3) and 4) and managed as a sequence (without overlapping them):

- The success of step 2) should allow the starting of step 3);
- The success of step 3) should allow the starting of step 4);
- The success of step 4) leads to the system final acceptance.

It is up to the Contracting Organization to modify this approach: for example, the functional tests (step 2) related to a component of the system can start when the verification of installations' responsiveness have been completed (only for that component and not for the whole system). The same should occur when the verification of the performance (step 4) related to a set of system's functionalities starts before the functional tests (step 3) have been successfully completed for all the functionalities. Anyway, these exceptions make sense only when the system's component or functionality whose testing goes to phase n+1 does not have any cross-relations (both from functional and operational point of view) with the system's components/functionalities whose testing is still in phase n.

These modifications must be carefully evaluated/considered by the Contracting Organization and introduced only in limited cases and/or due to appropriate motivations (reflecting in clear advantages of the Contracting Organization).

As step 1) has mostly a "contractual" meaning/relevance, this can be separate from the others and then it can be managed at any progress stage of the testing process, even at the end. It could start at the beginning of the testing process and run in parallel to the other steps with the constraint to be ended before the end of the testing process.

Based on the considerations above, Figure 1 provides a graphic representation of the four main steps of the testing/acceptance process.

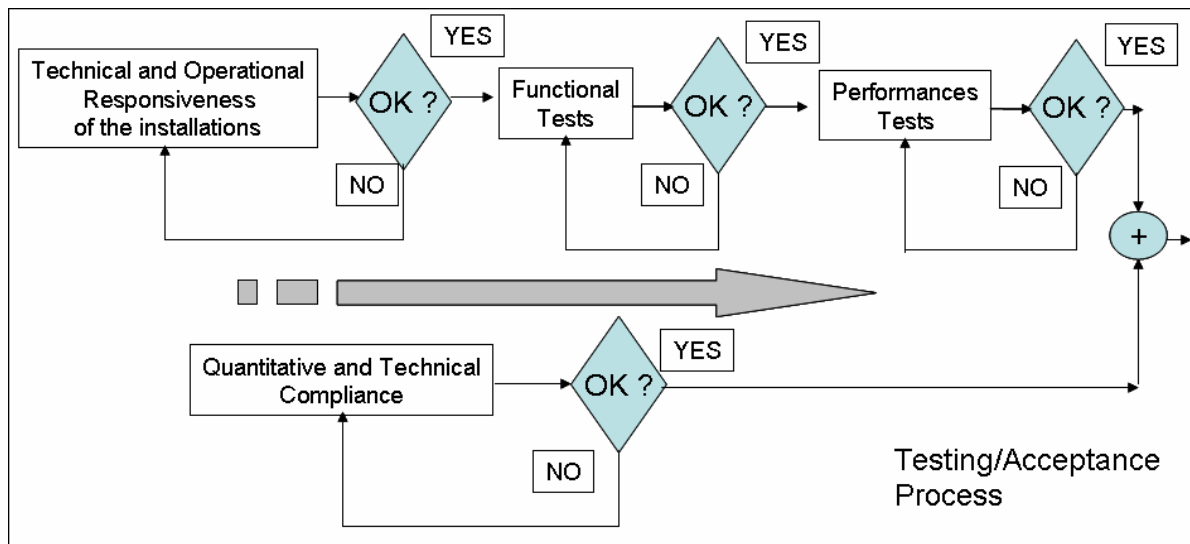


Figure 1: The main steps of testing/acceptance process and their relations

4 Methodology to be adopted

Table 1 details the methodological approach to be adopted for the definition of the testing and acceptance phase.

ACTION	DESCRIPTION
<p>Definition of a compliance matrix</p>	<p>A compliance matrix should be defined based on the requirements of technical specifications of the Contract. Basically, the matrix lists all the components/services included in the Contract and, for each of them (where applicable), the specific functional, technical and operational requirements. For each requirement the matrix maps what has been provided by the Contractor (in terms of devices/equipment, functionalities provided, professional services which have been carried out etc.) and then the matrix specifies what is required to be tested/certified. An example of implementation of compliance matrix is provided in the following.</p>

ACTION	DESCRIPTION
Definition of means for verification	<p>It defines the modalities how each test/verification should be carried out. Three categories can be envisaged:</p> <ul style="list-style-type: none"> - visual inspection (I); - test (T); - check (C). <p>(I) should be carried out for the verification of the technical specifications of the devices and related installations, (T) should be carried out for the verification of the functional specifications and their performance over time, (V) is applied to the verification of the technical documentation (user’s manual, datasheet, specifications, licenses) and the provision of supporting services (on-site activities carried out by the Contractor, training activities, etc.).</p>
Definition of tests / verifications to be carried out	<p>This action is finalized to identify which are the tests/verifications to be carried out, to define the testing scenarios, the resources to be involved, supporting conditions and the activities to be carried out (on field and on desk)</p>
Expected result of the test/verification	<p>For each test/verification identified, the expected result is detailed. The related action is carried out using the compliance matrix.</p>
Identification of reference documentation (for expected result)	<p>For each test/verification, the reference document (where the expected results of the test are specified) is defined. The expected results come mainly from the Contract obligations and technical specifications annexed but also from all the specifications produced by the Contractor as result of the contractual works (e.g. the “as-built” schemes for the installations).</p>
Definition of supporting material	<p>It defines all the material (check list, sheets for data collection, instructions, etc.) to be used for the tests.</p>
Time scheduling	<p>A timeplan for the whole testing process should be defined, differentiated for each of the process steps identified in section 3.</p>
Definition of acceptance criteria	<p>The criteria (and related indicators) to be used for evaluating the test/verification success should be defined.</p>

Table 1: Detail of the methodology to carry out the testing/acceptance phase

Figure 2 details the methodology proposed for the definition of the specifications to carry out the testing/acceptance process.

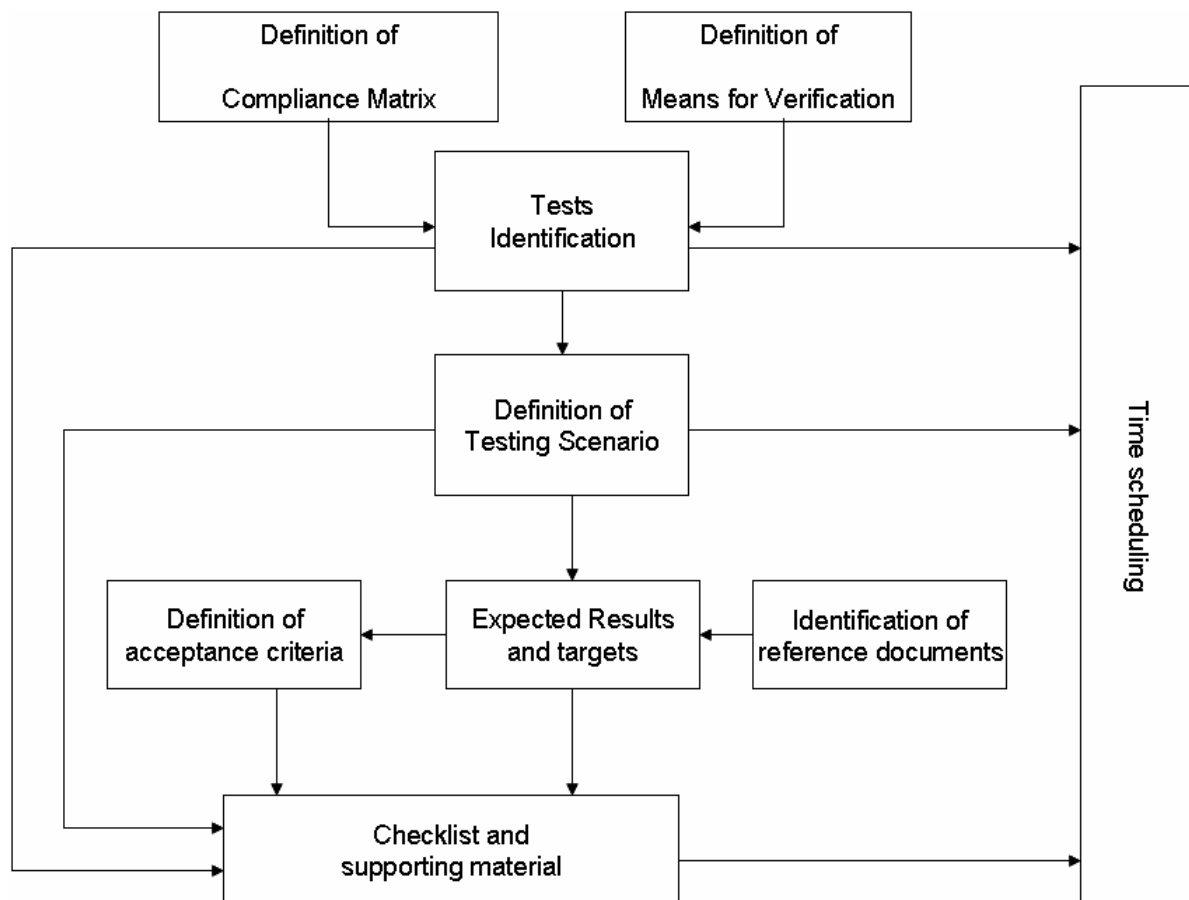


Figure 2: Detail of the methodology to carry out the testing/acceptance phase

Table 1 shows that the Compliance Matrix (CM) is the first essential element to be defined in order to set the testing/acceptance process. CM plays a key role in the whole process allowing:

- To *link each requirement* defined in the Contract with the solutions/activities to be tested/verified/certified and to *identify which are the tests/verifications* taking place during the testing/acceptance process (to certify these solutions);
- To *check the overall level of compliance* to the Contract obligations which has been achieved by the Contractor (and duly tested/verified/certified). This compliance level can be iteratively checked during the testing/acceptance process once the test/verifications progress status goes on;
- To *resume the testing results* in brief, acting as a synthetic “storyboard” of the testing/acceptance process.

Table 2 provides an example how a Compliance Matrix can be structured for a contract related to the implementation of an AVL (Automatic Vehicle Location) system. The example relates to the on-board terminal and it can be duly transferred also to a car sharing system.

ID_REQUIREMENT	CONTRACT REQUIREMENT	DOCUMENT REFERENCE	WHAT HAS BEEN PROVIDED BY THE CONTRACTOR TO ANSWER	MEANS OF VERIFICATION (I/T/C)	ID_TEST_	LEVEL OF COMPLIANCE	NOTE
ID_1_1	Provision of XX on-board unit including:						
ID_1_2	n.1 display						
ID_1_3	n.1 GPS						
.....							
ID_1_n	XX installation of on-board terminal including:						
ID_1_nn	YY cables, etc.						
.....							
ID_1_nnn	On-board localization						
ID_1_nnnn	Alert notification to driver						
.....							

Table 2: Example of compliance matrix (on board terminal in AVL contract)

The following sections highlight how this methodological approach is implemented for each of the phase of the testing/acceptance process specified in section 3.

5 Quantitative and technical compliance

This step of the testing/acceptance process aims to verify:

- The quantitative compliance with the Contract in terms of number of devices, number of installations, number of released sw (software) licenses, released documentation, etc;
- All the device specifications comply with the Contract requirements;
- The quality of the technical documentation and of the professional services provided complies with the Contract requirements.

5.1 Means of verification

The means of verification are highlighted in Table 3.

Test/Verification activity	Means of verification
Number of devices supplied/installed	I – Inspection
Release of technical documentation and system's specifications	C – Check
Provision of professional services (quantity/quality)	C – Check

Table 3: Means of verification for step 1) Verification of the quantitative/technical compliance

5.2 Definition of tests/verifications to be carried out

In this step, the following compliance, among the others, should be verified/certified:

- Have all the devices and equipment required by the Contract been supplied?
- Have all the installations required by the Contract been carried out?
- Are the technical specifications of the devices compliant with the Contract?
- Have the system's specifications been provided by the Contractor?
- Have the "as-built" schemes related to the installations been provided by the Contractor?
- Have the user manuals been provided by the Contractor?
- Has all the technical documentation (e.g. database specifications, data format, communication protocol, smart card structure, etc.) required by the Contract been provided by the Contractor?
- Have the sw licenses been provided by the Contractor?

- Have the training courses been provided by the Contractor?
- Have the professional services (e.g. the training) been provided with the level of quality required by the Contract?

5.3 Expected result

The expected “successful” result of this phase involve the following aspects:

- The whole supply has been provided in terms of components and services;
- The technical specifications of the provided devices comply with the Contract requirements;
- The quality of the technical documentation and professional services complies with the Contract requirements.

5.4 Reference documentation

The reference documentation to be used in this phase is detailed in Table 4.

Test/Verification activity	Reference Documentation
Number of devices supplied/installed	Contract specifications
Release of technical documentation and system’s specifications	Contract specifications System specifications Datasheet
Provision of professional services (quantity/quality)	Contract obligations Contract specifications

Table 4: Reference documentation for step 1) Quantitative/technical compliance

5.5 Supporting material

Not applicable

5.6 Acceptance criteria

The acceptance criteria are detailed in Table 5.

Test/Verification activity	Acceptance Criteria
Quantity of devices supplied/installed	Number of devices supplied/installed = Number of the devices to be supplied/installed defined in the Contract
Release of technical documentation and system's specifications	Typology and number of technical documentation = Typology and number of technical documentation defined in the Contract
Quality of technical documentation and system's specifications	All the Contract's requirements have been answered
Provision of professional services	Typology of activities and person-days of professional services = Typology and man-days defined in the Contract
Quality of professional services	All the Contract's requirements have been answered

Table 5: Acceptance criteria for step 1) Verification of the quantitative/technical compliance

6 Technical congruency of installations

This step of the testing/acceptance process aims to verify the responsiveness of the installations to the technical and operational requirements.

The objective is to assess that the installations of all the components of the system have been carried out:

- According to the technical specifications of the Contract;
- As specified in the “as-built” schemes released by the Contractor;
- According to national and international technical regulations and standards (e.g. automotive certification in case of on-board installation, CE mark, electrical compatibility, etc.);
- In such a way to guarantee high quality performance of the system during its operation;
- In such a way not to affect the operational procedures of system's operators and not to damage third parties (e.g. passengers on buses, etc.).

The involved installations could be ones of the following (depending clearly on the contracted system typology):

- On-road installations (e.g. info-panels for PT and parking guidance, automatic vending machines, cameras, bike stations, etc.);
- On-board installations (in-vehicle unit, driver console, validators, etc.);

- Indoor installations (e.g. server farms, electrical cabinet, etc.).

6.1 Means of verification

This step of the testing/acceptance process is carried out through inspection tests (I).

6.2 Definition of tests/verifications to be carried out

Usually the verification of the technical congruency of the installations is carried out for all the devices/components of the system. It is not recommended to carry out a verification by sample also when the installations are carried out as a replication of a common “prototype” (e.g. the installation of on-board devices on buses which belong to the same manufacturer model). If the installations to be verified are a lot, it is not feasible to carry out all the verifications in the final testing/acceptance process (which takes place at the end of the implementation). In the same way, when devices are installed on the vehicles (i.e. buses, etc.), it is required to allocate them to service operation once the installations are completed. In these cases, the following procedure can be adopted:

- The Contractor is required to provide the “as-built” scheme before starting the installation of the specific device. The Contractor must provide one “as-built” scheme for each type of device and installation conditions (e.g. in case of on-board units to be installed on the buses, the “as-built” scheme must be released for each bus typology);
- The Contracting Organization must accept the “as-built”, revising it when necessary (the revisions are mandatory to be considered by the Contractor);
- The installations are carried out by the Contractor, according to the “as-built” scheme, only for the devices to which the “as-built” is applicable;
- Once an installation is completed, the Contractor and the Contracting Organization verify its congruency. From the contractual point of view, it must be highlighted that **the positive result of this verification does not mean the final acceptance of the overall devices installation** (which is postponed to the final testing process starting when the whole system is ready to be signed off);
- When the whole system is ready to be signed off (see section 10 for more details, within the final testing/acceptance phase, verifications by sample can be repeated. This procedure will allow to test again the technical effectiveness of the installations at a later stage after the supply of the device and then to also measure the robustness over time.

The verification to assess the technical congruency of the installations requires:

- The definition of the testing procedures;
- The definition of the check-list;
- The identification of the team involved both on Contractor and Contracting Organization’s side (strong technical skills are required);

- The identification of the resources required (e.g. in case of verification of the installations of on-board devices, a vehicle must be available to carry out the tests).

Table 6 provides an example of check-list to be used for the verification of the technical congruency of the installations. The example relates to the installation of on-board units or terminal (vehicle, bus, tram, etc.) requested by some different systems (e.g. fleet monitoring, e-ticketing, car sharing, demand responsive transport services, etc).

Tests
Are the cables accessible?
Are the cables protected?
Are the cables labelled as described in the “as-built” scheme?
Are the connectors stable and fixed?
Is the device duly protected against over current, over voltage, short circuit?
Are the materials used for the installation the same described in the “as-built” scheme?
Is the device and its support (where applicable) duly fixed to ground/base floor?
Is the device accessible by the operators in case of intervention (e.g. maintenance)?

Table 6: Example of check-list for step 2) Technical congruency of the installations

6.3 Expected results of the test/verification

The expected results of this phase are to assess the compliance of the installations with the “as-built” schemes, the compliance with applicable regulation and the effectiveness for guaranteeing the system’s operation with high quality performance (over time).

6.4 Reference documentation

The reference documentation to be used is:

- Contract’s specifications;
- “As-built”;
- National/international technical normative.

6.5 Supporting material

The supporting material consists of:

- Check-list;

- “As-built” to be used during the verification as reference documentation to assess the compliance of the installations;
- Electrical equipment (instruments to access cabinet, voltage tester, etc.).

6.6 Acceptance criteria

The acceptance criteria are detailed in Table 7.

Tests	Acceptance Criteria			
	OK The device can be put under operation	Acceptable, minor improvements to be done and verified. The device can be put under operation	Acceptable, improvements to be done. A new verification to be done for the whole device. The device can be put under operation	KO A new verification to be done for the whole device. The device cannot be put under operation
Test n				
Test nn				
Test nnn				
Test nnnn				
.....				

Table 7: Acceptance criteria for step 2) Technical congruency of the installations

7 Functional test

The functional test phase aims to assess the functional and operational responsiveness and compliance of system to the functional and operational specifications of the Contract.

This phase should guarantee that the different implemented functionalities are working well. For functional tests this means that all the functionalities are working well, at least at the moment the test is carried out (please underline the differences with the following step of performance tests, see section 8).

A first recommendation is to carry out the functional test **in the real system operational environment** and **not on “prototypes”** running in laboratory, protected environment or, in general, under operational conditions which are different from the real/final ones faced by the Contracting Organisation.

The functional tests can be divided into three levels:

- Test involving a single device;
- Test involving the whole system (e.g. Central system and peripheral devices, Central system and end-users APP, etc.);
- Test involving the integration with external systems and data sources.

An useful approach consists in identifying two categories for the functional tests:

- The first category is represented by the functionalities which are mandatory to start the system operation;
- The second category is represented by the functionalities which are “a plus” in system’s operation.

7.1 Means of verification

This step of the testing/acceptance process is carried out through tests (T).

7.2 Definition of tests to be carried out

The test specifications include:

- The definition of the testing scenario;
- The definition of the testing conditions;
- The definition of the results expected at the end of the test;
- The definition of the preparatory actions required to carry out the tests;
- The identification of the team involved both on Contractor and Contracting Organization’s side;
- The identification of the resources required.

7.2.1 Definition of the testing scenario

The testing scenario details the sequence of operations which must be carried out in the test. This sequence is defined in order to avoid errors occurring in the test execution (these errors could be the motivations why the test results could not be accepted by the Contractor or not agreed between the involved parties, Contractor and Contracting Organization).

Usually the scenario is described in terms of test “use cases”.

7.2.2 Definition of the testing conditions

The testing conditions represent any possible “variation” of the test: “variation” means a different use case sequence which can belong to the same testing scenario. These variations generate a set of expected test results which can be different case by case.

The test “variations” are generated by:

- Different operational conditions which can take place in the test (e.g. credit value available during a payment operation, etc.)
- Irregular conditions such as:
 - Wrong operation in the interactions of the users/operator, it is recommended to simulate the errors which could most frequently occur (e.g. the smart card is removed before to complete the validation, error in the data entry, partial data entry followed by a cancel operation to clean up the entered data, etc.);
 - Technical conditions which could affect the test results (e.g. data communication not available or interrupted, etc.).

The test must cover all the range of operational conditions for the reference functionality, including the “irregular” ones.

7.3 Definition of the expected results

The expected results of the test consist in what the system “generates” after the sequence of operations detailed in the testing scenario.

The results could be one or more “events” listed in the following:

- Notifications/messages which are visualized (e.g. by APP, on-board terminal, on-board displays, etc.);
- LEDs which are lighted (on/off) (e.g. on-board display, validators, automatic vending machines, bike sharing stations, etc.);
- Buzzer signals (e.g. validators, audio announcements, etc.);
- “Logic” status of the devices to be changed (on/off/waiting status) (e.g. on-board devices, like sharing stations, etc.);
- Data entry into the system (e.g. user registration, etc.);
- Change of data/info coded on the supports (e.g. smart cards, etc.);
- Change in the data/info coded in system’s log file or tables (e.g. log in, identification of the operator who made a certain operation on the system, etc.);
- Report to be displayed/printed by the system (e.g. web applications, client sw, etc.);
- Other kind of operations such as cash/coins management (e.g. automatic vending machine), etc.

7.4 Preparatory actions

The preparatory actions for running the tests aim to set the testing conditions from which the test is developed. For example, the test related to the on-board ticket validation with smart cards requires that a ticket is previously coded in the smart card (e.g. by the selling workstation in a ticket office).

7.5 Examples of checklist

Table 8 provides an example of check-list to be used for the functional tests. The example refers to the testing of an info-mobility platform. The platform consists of: data adapting interfaces (to gather data from external sources), data integration module and APP info-channel, see Deliverable D8.3 for the system architecture).

The example details five cases:

- the first is an “optional”² functionality (Dashboard) related to a single component (back office module);
- the second and the third are “mandatory” functionalities (On-line ticket payment and Multimodal Journey Planner) both related to the whole system;
- the fourth is a “mandatory” functionality (Monitoring of data gathering flows) related to the integration of the platform with external sources;
- the fifth is a “optional” functionality (Configuration of data gathering procedures) related to the integration of the platform with external sources.

Tests n) Dashboard functionality
Test category: Mandatory
Components involved: Back-office module of info-mobility platform
Testing scenario: The tester logs in as administrator, they access the back office application, they open the dashboard tool, etc.
Test conditions A): Generation of report on APP use over time
Test expected result: The report is displayed
Preparatory actions: Tests of APP use already done to generate the data to be reported
Test conditions B): Generation of report on APP use by ID APP
Test expected result: The report is displayed
Preparatory actions: Tests of APP use already done to generate the data to be reported

² Optional means that the functionality could not be strictly required to launch the system then it could be ready later on without any impacts on the “basic” running of the system itself

Tests nn) Ticket payment
Test category: Mandatory
Components involved: Back-office + APP
Testing scenario: The tester opens the APP, they select the on-line payment functionality, they select the origin and the destinations of the trip, they select the ticket typology, etc.
Test conditions A): Phone credit is higher than the ticket price
Test expected result: The operation of ticket purchase is completed, the ticket notification is sent by the platform to the APP, the phone credit is decreased by the ticket price
Preparatory actions: Device's connection active and on, phone credit recharged
Test conditions B): Phone credit is lower than the ticket price
Test expected result: The operation of ticket purchase is not completed, the error notification is sent by the platform to the APP, the phone credit is not decreased by the ticket price
Preparatory actions: Device's connection active and on, phone credit recharged
Test conditions C): Communication went down
Test expected result: The operation of ticket purchase is not completed, the error notification is sent by the platform to the APP, the phone credit is not decreased by the ticket price
Preparatory actions: Device's connection went off during the test
Tests nnn) Multimodal Journey Planner
Test category: Mandatory
Components involved: Whole system
Testing scenario: The tester opens the APP, they select the Journey Planner functionality, they select the origin and the destinations of the journey, they select the search criteria, etc.
Test conditions A): The tester sets the "transport modes" criteria to "bus" and "train" and he configures the APP to list the results ordered by "number of interchanges"
Test expected result: The APP returns the journey solutions from the selected origin and destination which complies with the selected criteria. The journey solutions are sorted by the interchanges' number (from the solution with the lower number on the top of the screen to the solution with the higher number on the bottom of the screen)

Preparatory actions: Device's connection active and on
Test conditions B): The tester sets the "transport modes" criteria to "bus" and "train" and they configure the APP to list the results ordered by "travelling time"
Test expected result: The APP returns the journey solutions from the selected origin and destination which complies with the selected criteria. The journey solutions are sorted by travelling time (from the solution with shorter travelling time on the top of the screen to the solution with longer travelling time on the bottom of the screen)
Preparatory actions: Device's connection active and on
Tests nnnn) Monitoring of data gathering procedures from external sources
Test category: Mandatory
Components involved: Whole system
Testing scenario: The tester logs in as administrator, they open the back office module, they access the administration tool, etc.
Test conditions A): The last operation of data import was successful related to all the data sources were successful
Test expected result: The status of data gathering operation is OK
Preparatory actions: Last operation of data gathering run as scheduled.
Test conditions B): The last operation of data import was successful related to data source X and Y but not for data source Z
Test expected result: The status of data gathering operation is KO. The log file highlights the interface generating the error and the error details.
Preparatory actions: Last operation of data gathering run as scheduled.
Tests nnnnn) Configuration of scheduled time for data gathering from external sources
Test category: Optional
Components involved: Adapting interfaces + back office
Testing scenario: The tester logs in as administrator, they open the back office module, they access the administration tool, etc.
Test conditions A): The frequency of data gathering is increased (shorter time) compared to the current value.

<p>Test expected result: The time elapsing from the last data gathering operation and the next one is equal to the configured value.</p>
<p>Preparatory actions: The time between two following operation of data gathering has been previously set.</p>
<p>Test conditions B): The frequency of data gathering is decreased (longer time) compared to the current value</p>
<p>Test expected result: The time elapsing from the last data gathering operation and the next one is equal to the configured value.</p>
<p>Preparatory actions: The time between two following operation of data gathering has been previously set.</p>

Table 8: Example of check-list for step 3) Functional tests

7.6 Expected result of the test/verification

The expected result of this phase are as follows:

- All the functional and operational requirements of the Contract are guaranteed;
- The functional tests show that all the system's functionalities work as indicated in the system's specifications (released by the Contractor as contractual obligation) and as detailed in the user manuals;
- All the uses cases and the operational conditions are guaranteed by the system's functionalities (this means the system's functionalities are also responsive to irregular operation conditions which may occur).

7.7 Reference documentation

The reference documentation to be used is:

- Technical specifications of the Contract;
- System's detailed specifications released by the Contractor;
- User manuals;
- Tests specifications.

7.8 Supporting material

The supporting material consists of a check list to be used to steer the tests execution and track the results. This check-list could be prepared adapting Table 8 to the specific system's functionalities and combining it with cells to track the tests results (as indicated in the following paragraph).

Furthermore, other supporting material could be required (depending on the system's typology): for example, smart cards for validators, coins/cash for automatic vending machines, etc.

7.9 Acceptance criteria

The acceptance criteria are detailed in Table 9.

Tests	Acceptance criteria			
	Is the functionality "mandatory" or "optional" ?	OK The functionality is ready for system's launch	Acceptable, improvements to be done. The improvements do not affect the system's launch. Once improvements are available, a new test to be repeated during system's operation	KO The functionality is not ready for system's launch
Test n				
Test nn				
Test nnn				
Test nnnn				
.....				

Table 9: Acceptance criteria for step 3) Functional tests

8 Performance verification

The performance verification aims to assess if the functionalities (already tested in the functional tests, step 3 of the verification/acceptance process) run over time complying with the defined target values of the performance indicators.

Thus, this step can be also considered as a "stress" test consisting in the repetition of the functional tests on long time frame. The performance verification certifies that the system runs properly, also considering the impacts of the operational conditions in the real environment (over time).

8.1 Means of verification

This step of the testing/acceptance process is carried out through tests (T).

The tests are repeated over time.

8.2 Definition of tests to be carried out

The test specifications include:

- Definition of the performance indicators;
- Definition of the target values of the performance indicators;
- Definition of data collection procedures;
- Definition of methods to calculate the achieved values of the performance indicators;
- Definition of staff and resources to be involved in the data collection procedures.

In the following some guidelines are provided related to the key activities previously mentioned.

8.2.1 Definition of the performance indicators

The performance indicators can be divided into two categories:

- “*Reliability*” of the system (or sub-system). This category of indicators can be calculated as the ratio between the time when the system or sub-system provides all the functionalities in a proper way and the total planned operational time. (A server may be rated on 24/7 availability; an AVM/AVL workstation may be rated against the operational hours of the Control Centre, etc.);
- “*Level of performance*” guaranteed by the main functionalities of the whole system over a defined monitoring time period. These indicators are strictly related to the functionalities of each kind of system and then they are specifically defined for each system typology. Some examples of performance indicators are provided in the following (the selected ITS come from D8.3):
 - Info-mobility (platform for the aggregation of contents, APP, web portal, etc.)
 - *Response time Index*: time (seconds) required to display information upon the request sent by the user;
 - *Load Index*: number of simultaneous info requests generated by client (end users) devices which are processed by the system;
 - Fleet Monitoring and Users Information System
 - *Monitoring Index*: number of trips which are monitored by the system over the total number of service operated trips;
 - *Event Identification Index*: number of events generated during the operated service which are correctly identified over the total number of occurred events;

- *Real-time information provision Index*: number of real-time information which are correctly generated over the total number of real-time information generated during the operated service;
- E-ticketing system
 - *Completed Transactions Index*: number of validation/selling operations not completed and not annulled by the users over the total number of validation/selling operations which have been started;
 - *Progressive Transactions Index*: verification of the congruency of the sequence of the progressive ID codes assigned by the system to the transactions. This sequence should not include any replication of codes (there cannot be two operations with the same ID code) and any missing ID code (there is an operation managed by the system which has not been registered);
- Shared Vehicle Management System:
 - *Pick up/release Index*: number of pick/up/release operations correctly completed over the total number of operations;
 - *Monitoring Index*: number of trips which are monitored by the system over the total number of operated trips;
 - *Event Identification Index*: number of events which are correctly identified over the total number of events occurring during the service.
- Parking Management System
 - *Occupancy Index*: number of available lots identified by the system compared to the real number of available lots.

8.2.2 Definition of target values of the performance indicators

The target values of the performance indicators should be defined in terms of percentage to be estimated considering:

- the total number of events corresponding to 100%;
- the number of errors or irregular cases which are assumed as acceptable in the real operational conditions in order not to affect the system/service demonstration.

8.2.3 Definition of data collection procedures

The data collection procedure can be as follows:

- Data collected automatically (e.g. by the monitoring tools of the system itself);
- Data collected manually through targeted tests;
- Data collected by the requests of maintenance interventions (e.g. to calculate the reliability indicators). When a troubleshooting application is used to manage the

interactions between Contracting Organization and Contractor for the maintenance, this data become automatically collected too.

The procedure to be selected depends on the type of the system and the category of indicator.

8.2.4 Methods to calculate the values of the performance indicators

The methods to calculate the values of the performance indicators must take into account that failures of the system occurring for reasons which are out of the responsibilities of the Contractor must be left out. These cases should not affect the achieved value of the performance indicators.

8.3 Expected result of the test/verification

The expected result of the performance tests (step 4 of the test/acceptance process) is that the achieved value of the performances' indicators is equal or higher to the target value defined in the test specifications. This is for each of the indicator defined.

The achieved values of the performance indicators are calculated on the basis of the data collected during the tests leaving out the data corrupted by the impact of operational conditions which are out of the responsibility of the Contractor.

8.4 Reference documentation

The reference documentation is the same adopted for functional tests:

- Technical specifications of the Contract;
- System's detailed specifications released by the Contractor;
- User manuals;
- Tests specifications.

8.5 Supporting material

The supporting material consists of check-lists similar to those prepared to carry out the functional tests. They are used to steer each testing session and to track the results of each of them. In addition to functional tests, an Excel file (duly configured) is required:

- To report the results of each testing session;
- To set the formula related to the performance indicators;
- To calculate the achieved value of the performance indicator based on the results of the testing sessions.

It could be good to structure the file with a set of sheets, each of them related to a single performance indicator.

Other supporting material could be required to carry out the test as indicated in the description of the functional tests.

8.6 Acceptance criteria

The acceptance criteria are detailed in Table 10.

Performance Indicator 1		Acceptance Criteria
Target Value (TV) YY %	Achieved value (AV) ZZ %	If AV => TV, performance test (related to this indicator) is OK
		If AV < TV - (tv1 ³) and AV > TV - (tv2) performance test (related to this indicator) is KO. The test (related to this indicator) needs to be repeated. Testing/Acceptance process is still open.
		If AV < TV – (tv3) performance test (related to this indicator) is KO. The test (related to this indicator) needs to be repeated. Testing/Acceptance process is still open. Penalties to the Contractor can be applied according to the Contract obligations (where duly included)
Performance Indicator 2		Acceptance Criteria
.....
	
	

Table 10: Acceptance criteria for step 4) Performance tests

9 Definition of test timeplan/resources

As indicated in the introduction, each step (n) of the testing/acceptance process (at least from step 2 to step 4) should be considered as “pre-condition” to be achieved before to start the following step (n+1).

³ tv1, tv2 and tv3 are percentage values where tv1 < tv2 < tv3

The testing specifications must include a timeplan of the whole testing/acceptance process divided (and detailed) per step.

The testing/acceptance process starts when the system is declared “ready to be tested” by the Contractor (see the following section for details). From the Contracting Organization’s point of view the previous condition means the system is declared “ready to be signed off and launched in the operational environment”.

It is recommended to allocate appropriate time for the execution of testing/acceptance process. An estimation is at least one month up to two months for more complex/impacting system (e.g. the systems consisting of a wide range of devices/sub-systems where the number of installations is higher – the fleet monitoring or e-ticketing system are some examples).

The allocation of time for each step should take into account:

- The time required to carry out the tests;
- The time required to assess/analyze the tests’ results, hopefully with the contribution of the Contractor;
- A safeguard time period for the repetition of tests which are not successful.

The timeplan should include:

- The identification of the testing/acceptance step;
- The definition of the test sessions and their planned scheduling (at least start/end time). The detailed scheduling of each testing session can be scheduled step by step or also in short at the end of each test session;
- The identification of staff and the resources/material which is required to carry out the tests;
- The responsibilities allocated to Contracting Organization and Contractor (if any).

Related to the staff to be involved, it must be highlighted that the testing/acceptance process is not only a time-consuming task, but it is resources-consuming too. The Contracting Organization must budget the allocation of appropriate resources (person-days) over time.

The resources to be involved are various and their number increases when the systems is more complex in terms of components/devices/sub-system, for example:

- System’s administrator/supervisor;
- Control Centre/Call Centre/Workstations operators;
- IT specialist (long-range and short-range communication network, data servers, etc.);
- Technicians (e.g. devices’ or vehicles’ maintenance, etc.) ;
- Service planners;
- Accounting area/office.

10 Contractual impacts of testing process

The definition of the whole testing/acceptance process must be shared/agreed between the Contracting Organization and the Contractor in terms of procedures, rules, acceptance criteria and timeplan during the contract phase (or better defined in the call for tender in the case of procurement process). The Contracting Organization can ask the Contractor to provide the tests specifications (detailing the testing/acceptance process) to be included in the system's specifications. Alternatively, the Contracting Organization can lead the task for defining the tests specifications drafting a first version (general approach and structure, etc.) and asking the Contractor to contribute from its side up to the final (agreed) version.

Despite the roles and responsibilities adopted for defining the tests specifications, the Contracting Organization can integrate/revise the proposal of tests specifications issued by the Contractor. The Contracting Organization is allowed to tune the testing/acceptance process taking into account the progress status of the testing activities and the intermediate results. The Contracting Organization can also add any new test session which is required to certify the responsiveness of the system to the contractual specifications.

The Contractor is obliged to communicate in a formal way that the system is “ready to be tested”. The communication takes place duly in advance compared to the contractual deadline (or, before if applicable). After that, the Contracting Organization communicates to the Contractor, in a formal way, the starting date of the testing/acceptance process. The Contractor is allowed (and also welcome) to attend to the testing/acceptance process: its presence is very useful to assist the staff of the Contracting Organization to carry out the tests and to assess/validate the results: furthermore its presence helps to avoid misunderstanding in the results interpretation between the two parties and get a fruitful agreement on how the process is going and what it is required to do in the short. Anyway, the presence of the Contractor to the testing sessions of the whole acceptance process is not mandatory.

The testing/acceptance process must be considered successful when the 4 steps (identified in section 3) are positively completed and all the tests planned in the tests specifications confirmed the expected results. A formal report must be produced by the Contracting Organization (or by the consultants/firm in charge of the process). This report must be signed by the Contracting Organization and the Contractor. The date of the report states the acceptance of:

- The **final payment scheduled** in the contract;
- The **start-up of warranty period** (and related contractual obligations);
- The **beginning of the time period when the system operation is fully in charge** of the Contracting Organization (or the organization, Mobility/Transport Operator, Agency, Public Administration, etc. in charge of system operation on behalf of the Contracting Organization).

Before the date of the system's acceptance, **the system should not be “officially” in charge of the Contracting Organization** but it should be **considered as a “provided** for acceptance testing. Any intermediate test which could occur during the implementation time aims to assess the progress status of the system's realization and the achievements of the contractual obligations related to each implementation milestone (e.g. this kind of tests

enables the payment related to each implementation milestone but they don't mean that the system is accepted at this implementation stage). The acceptance of the system takes place with the final testing/acceptance phase at the end of the whole implementation.

Each testing session must be reported in a specific report (testing minute) where:

- The participants are listed;
- The test carried out are described according to the test specifications;
- The result of each test is tracked;
- The final assessment of the session's results is summarized including the updated progress status of the involved testing step and of the whole testing/acceptance process (when required, e.g. when a testing step is completed).

When the test is not successful, the test needs to be repeated.

The "negative" results must be reported too in the minutes of the related testing session. The testing minutes must highlight the request of modifications which the Contractor must apply/introduce to solve the problems highlighted in the testing session. The minutes must specify the time agreed to carry out the modifications and the scheduled date for the test repetition. The costs for system's modifications/improvements are up to the Contractor unless the Contractor can demonstrate the request of modifications/improvements is not duly motivated by the Contract and by the system's specifications released during the contract's implementation.

When a test session is not successful and needs to be repeated, the time of the testing/acceptance procedure becomes longer than planned. When various repetitions take place, the testing/acceptance procedure could become longer than the maximum deadline defined in the Contract for its end. In such a case the penalties defined in the Contract for delay can be applied. According to the Contract obligations, when a maximum delay is reached, the Contract can be terminated.

11 Conclusions

The adoption of a consistent and transparent methodology to carry out the testing and acceptance process for an ITS implementation is a safeguard condition for both contractual parties: the Contracting Organization and the Contractor. This is even more true as the testing phase requires strong cooperation between the parties, despite their conflicting objectives/role in the contract management.

For this reason, it is very important that both parties agree on the testing specifications (compliance matrix, identification of tests to be carried out, modalities of tests execution, expected results, acceptance criteria) in order to have a common understanding before to start the process.