
# "Enhanced data management techniques for real time logistics planning and scheduling"

## Deliverable D7.4: System deployment and testing specifications

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# DOCUMENT INFORMATION

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## Document control

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## Document approval

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LOGISTAR project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement no. 769142.

# BASIC PROJECT INFORMATION

Horizon 2020 programme

H2020 - Mobility for Growth- 5-2-2017. Innovative ICT solutions for future logistics operations

Grant Agreement No. 769142

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LOGISTAR project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement no. 769142.

## Executive Summary

This document describes the deployment specification and the testing specification for the LOGISTAR system.

The deployment specification describes the deployment of the system from a technical or software component point of view. The document provides an overview over the different components of the LOGISTAR system and also over the partners within the consortium, who deliver those components. The software components will be described along the functional parts of the LOGISTAR system, which follows also the work-package structure as described in the Description of the action document (annex 1 of the Grant agreement).

Furthermore based on this information the interaction of the components is described, which finally forms the LOGISTAR system. The document will also cover the distribution of software components and the challenges arising from this. Finally, the proposal for the deployment of the system, including the first prototypes as well as the final demonstrator, are described.

The testing specification describes the testing of the system. This part of the document will be also based on the information presented in the deployment part and will distinguish between testing the first prototypes of the system and testing final demonstrators based on the three Living Labs.

As defining the deployment of the system and describing the testing specification is an ongoing process along the duration of the LOGISTAR project and deployment in the project is taking place in a dynamic environment, this document on hand is seen as a living document, this means that this document might be updated over time, if new intelligence appears.

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# 1. Introduction to the LOGISTAR system

The EU faces the challenge to maintain and increase its economic growth and cope with the problem of freight transport efficiency in Europe. Integration of transport volumes and modes, better use of capacity, flexibility, resource efficiency and cooperation between all actors along the logistic chain are required.

Aligned with the European policies and the ETP-ALICE roadmap (http://www.etp-logistics.eu/), LOGISTAR objective is to allow effective planning and optimizing of transport operations in the supply chain by taking advantage of horizontal collaboration, relying on the increasingly real-time data gathered from the interconnected environment. For this, a decision making support tool and a real-time visualization tool of freight transport will be developed, with the purpose of delivering information and services to the various agents involved in the logistic supply chain, i.e. freight transport operators, their clients, industries and other stakeholders such as warehouse or infrastructure managers.

LOGISTAR will address several advances beyond the State of the Art in the interdisciplinary field of the smart algorithms for data processing: Artificial Intelligence focused on prediction, parallel hybrid metaheuristics for optimization, automated negotiation techniques, and constraint satisfaction problem solving techniques. The resulting platform should outperform other market products and services such as Freight Exchange Systems, Collaborative Platforms, Transport Control Towers or Routing Systems.

LOGISTAR involves RTD organizations (DEUSTO, UCC, CSIC), technology developers (DNET, SWC), consultancy firms (MDST, PRESTON), ICT services developers (SAG, DBH, GENEGIS) and stakeholders from different stages of the supply chain (AHLERS, ZAILOG, NESTLÉ, PLADIS, CODOGNOTTO).

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# 2. Components of the LOGISTAR system

## 2.1. The LOGISTAR Platform Concept

The following Figure shows the platform concept of the LOGISTAR system.

If one tries to align the result of the LOGISTAR work packages with the picture, then roughly the following relations hold true:

- WP2 covers the “Data gathering & harmonization” layer.
- WP3 covers the “1) Event Identification Management” and also “2) Artificial Intelligence focussed on prediction”.
- In WP4 all components are produced, which are needed to realize the “3) Global Optimization”.
- All functionalities of “4) Automated negotiation and local reoptimization module” are produced within WP5
- Finally the bottom layer in the picture, namely the “Control & decision making tool in logistic operation” and the “Real time information on freight transport” is covered by WP6.

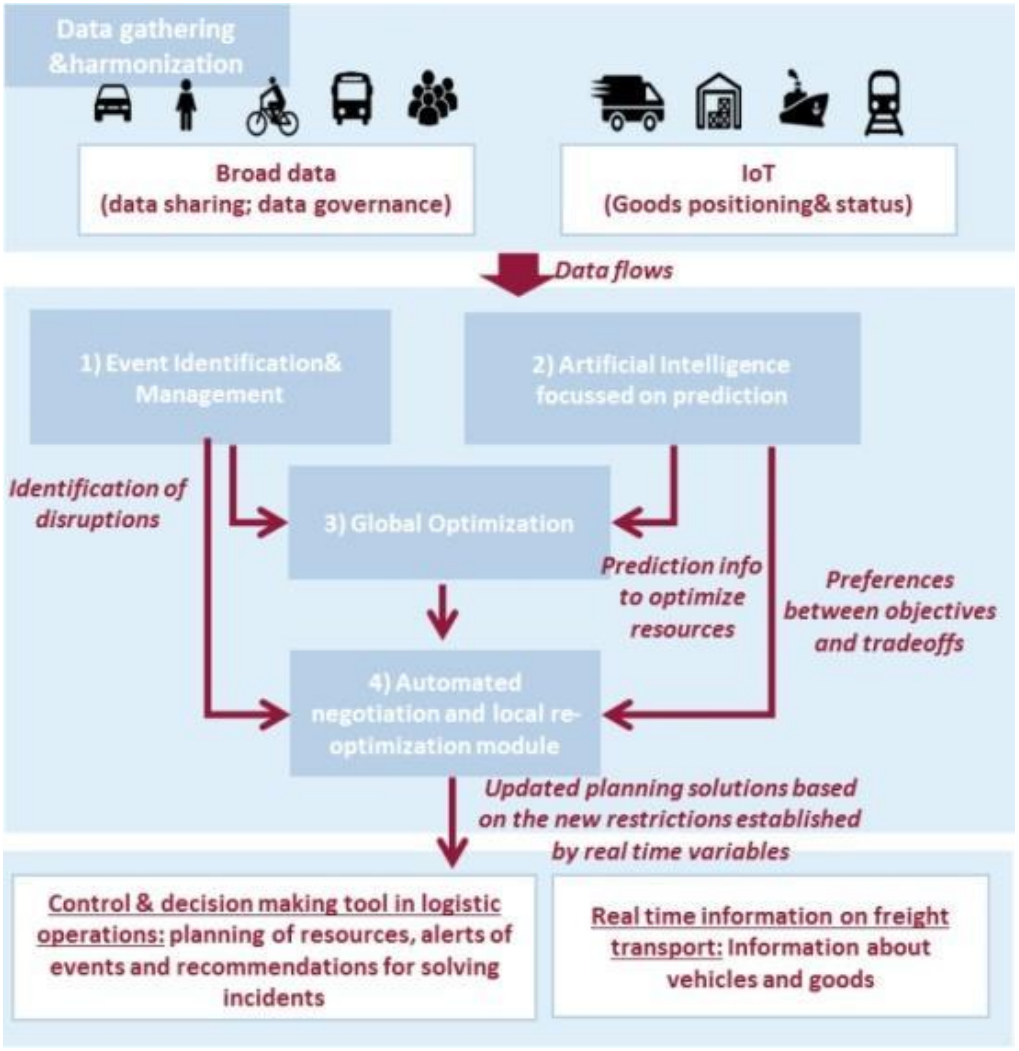


*Figure 1 The LOGISTAR platform concept*

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## 2.2. Who are the software providing partners and what is their role / task

LOGISTAR involves RTD organisations (DEUSTO, UCC, CSIC), technology developers (DNET, SWC), consultancy firms (MDST, PRESTON), ICT services developers (SAG, DBH, GENEGIS) and stakeholders from different stages of the supply chain (AHLERS, ZAILOG, NESTLÉ, PLADIS, CODOGNOTTO).

Out of these 15 partners the following are delivering one or more software components:

1. DEUSTO
2. UCC
3. CSIC
4. DNET
5. SWC
6. SAG
7. DBH
8. GENEGIS

## 2.3. The software components

As of today, we plan that the LOGISTAR system consists of 21 individual software components. A complete list of all components will be available in D6.1 and D6.2 “LOGISTAR architecture and detailed design V1 and V2”. In the following we list these components in a table format. For each component the table list the Component-Id, the deliverable it relates to and the partner, who is responsible for the component. Furthermore it shows the component’s name, its purpose, kind/type, manufacturer and the platforms, on which it can be deployed. However keeping in mind the relatively early state in the project we still anticipate changes in this list of components.

| **Component-ID** | SC-1 | |
|---|---|---|
| **Deliverable(s)** | D2.5 | DNET |
| **Component** | Protocol adapters | |
| **Purpose** | Translation of the data to compatible readable format | |
| **Kind/Type** | Custom developed communication enabler | |
| **Manufacturer** | DNET | |
| **Platform(s)** | Windows, Linux for embedded devices and other OS (depends on devices) | |

*Table 1 Component SC-1*

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| | | |
|---|---|---|
| **Component-ID** | SC-2 | |
| **Deliverable(s)** | D2.5 | DNET |
| **Component** | IoT Hub | |
| **Purpose** | Authentication and Collection endpoint for IoT devices/data | |
| **Kind/Type** | Cloud hosted managed service for bidirectional communication | |
| **Manufacturer** | Microsoft/Proprietary | |
| **Platform(s)** | Cloud hosted service/ services and application for IoT Hub development on Windows and Linux | |

*Table 2 Component SC-2*

| | | |
|---|---|---|
| **Component-ID** | SC-3 | |
| **Deliverable(s)** | D2.5 | DNET |
| **Component** | Azure Collection API | |
| **Purpose** | Authentication, Collection and Parsing of (non IoT) and unstructured data | |
| **Kind/Type** | Data collection enabler | |
| **Manufacturer** | DNET | |
| **Platform(s)** | Windows (.NET) | |

*Table 3 Component SC-3*

| | | |
|---|---|---|
| **Component-ID** | SC-4 | |
| **Deliverable(s)** | D2.6, D2.7 | SWC |
| **Component** | PoolParty Semantic Suite | |
| **Purpose** | Semantic analysis and metadata (ontology creation/consumption/mapping, data curation) | |
| **Kind/Type** | Product | |
| **Manufacturer** | Semantic Web Company | |
| **Platform(s)** | Linux (note: we will provide this component on one of our servers, accessibility is via http (either through our API and/or the SPARQL protocol)) | |

*Table 4 Component SC-4*

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| Component-ID | SC-5 | |
|---|---|---|
| Deliverable(s) | D2.6, D2.7 | SWC |
| Component | RDF Triple Store | |
| Purpose | Storage of semantic structures | |
| Kind/Type | Graph Database (Triple Store to be exact.. note that any graph database can be used as a triple store, but not any triple store can be used as what is widely understood as a graph database) | |
| Manufacturer | Apache Rya<br>(Note that this component relies on subcomponents, depending on the used backend: either Apache Accumulo + HDFS or MongoDB) | |
| Platform(s) | Docker | |

*Table 5 Component SC-5*

| Component-ID | SC-6 | |
|---|---|---|
| Deliverable(s) | D3.5 | UCC |
| Component | Order predictor | |
| Purpose | Predict the next 5 days of orders. | |
| Kind/Type | Daily batch job based on machine learning. | |
| Manufacturer | self-developed (UCC) | |
| Platform(s) | Linux, Docker | |

*Table 6 Component SC-6*

| Component-ID | SC-7 | |
|---|---|---|
| Deliverable(s) | D3.5 | UCC |
| Component | Turnaround time predictor | |
| Purpose | Predict turnaround time at DCs and clients depending on the time of the day, the day of the week, the week of the year | |
| Kind/Type | Daily batch job based on machine learning for precomputing then public API. | |
| Manufacturer | self-developed (UCC) | |
| Platform(s) | Linux, Docker | |

*Table 7 Component SC-7*

LOGISTAR project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement no. 769142.

| | | |
|---|---|---|
| **Component-ID** | SC-8 | |
| **Deliverable(s)** | D3.5 | UCC |
| **Component** | Delivery risk predictor | |
| **Purpose** | Predict the risk of delivery failure based on lateness, client, etc. | |
| **Kind/Type** | Daily batch job based on machine learning then public API. | |
| **Manufacturer** | self-developed (UCC) | |
| **Platform(s)** | Linux, Docker | |

*Table 8 Component SC-8*

| | | |
|---|---|---|
| **Component-ID** | SC-9 | |
| **Deliverable(s)** | D3.5 | UCC |
| **Component** | Travel time predictor | |
| **Purpose** | Predict travel time between multiple origins and destinations depending on the time of the day, the day of the week, the week of the year. | |
| **Kind/Type** | Daily batch job based on machine learning for precomputing then public API. | |
| **Manufacturer** | self-developed (UCC) | |
| **Platform(s)** | Linux, Docker | |

*Table 9 Component SC-9*

| | | |
|---|---|---|
| **Component-ID** | SC-10 | |
| **Deliverable(s)** | D4.3 | DEUSTO |
| **Component** | Cooperative Vehicle Route Optimization | |
| **Purpose** | Optimization of routes of vehicle fleets from different companies, accounting for possibilities of horizontal collaboration | |
| **Kind/Type** | Individual web service application | |
| **Manufacturer** | Self-developed | |
| **Platform(s)** | Linux, Docker | |

*Table 10 Component SC-10*

LOGISTAR project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement no. 769142.

| Component-ID | SC-11 | |
|---|---|---|
| Deliverable(s) | D4.3 | DEUSTO |
| Component | Multimodal route planning optimization | |
| Purpose | Optimization of multi-modal routes (truck and/or train) from different companies, taking into account the possibilities of horizontal collaboration | |
| Kind/Type | Individual web service application | |
| Manufacturer | Self-developed | |
| Platform(s) | Linux, Docker | |

*Table 11 Component SC-11*

| Component-ID | SC-12 | |
|---|---|---|
| Deliverable(s) | T6.2.4 (D3.2) | SAG |
| Component | Apama [PAM] 10.3 | |
| Purpose | Execute rules for complex event processing (delivered in D3.2) | |
| Kind/Type | Programmable Complex Event Processing (CEP) engine | |
| Manufacturer | Software AG | |
| Platform(s) | Windows (8, 10, Server 2012, Server 2016), Linux (RHEL 7, SUSE 12), Docker (CentOS 7), Amazon EC2, MS Azure | |

*Table 12 Component SC-12*

| Component-ID | SC-13 | |
|---|---|---|
| Deliverable(s) | T2.2, T6 | SAG |
| Component | Software AG Universal Messaging [NUM] 10.3 | |
| Purpose | Channel Logistar messages to/from message store | |
| Kind/Type | Universal Messaging is a Message Oriented Middleware product that guarantees message delivery across public, private and wireless infrastructures based on Pub/Sub | |
| Manufacturer | Software AG | |
| Platform(s) | Windows (8, 10, Server 2012, Server 2016), Linux (RHEL 7, SUSE 12), Docker (CentOS 7), Amazon EC2, MS Azure, AIX 7.2, HP-UX 11i v3, Mac OS X 10.13, Solaris 11 | |

*Table 13 Component SC-13*

LOGISTAR project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement no. 769142.

| Component-ID | SC-14 | |
|---|---|---|
| Deliverable(s) | T6.2.2 | SAG |
| Component | Software AG MashZone NextGen [JBP] 10.3 | |
| Purpose | Provide easy tooling to build and display information in Logistar | |
| Kind/Type | Software AG MashZone NextGen provides dashboard functionality for self -service analytics for business users i. | |
| Manufacturer | Software AG | |
| Platform(s) | Windows (8, 10, Server 2012, Server 2016), Linux (RHEL 7, SUSE 12), MS Azure, | |

*Table 14 Component SC-14*

Please note that SC-15 and SC-16 are not listed here. They represent software libraries used in other components, rather than components of their own. So we internally need to keep track of them, but they are irrelevant in this description.

| Component-ID | SC-17 | |
|---|---|---|
| Deliverable(s) | T6.2.3 | GeneGIS |
| Component | PTV - xLocate | |
| Purpose | Simplify the complex process of converting address data into geocoordinates and validating address data | |
| Kind/Type | Standalone framework - Commercial product | |
| Manufacturer | 3rd Party – Commercial | |
| Platform(s) | Windows (8, 10, Server 2012, Server 2016), Linux (RHEL 7, SUSE 12) | |

*Table 15 Component SC-17*

LOGISTAR project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement no. 769142.

| | | |
|---|---|---|
| **Component-ID** | SC-18 | |
| **Deliverable(s)** | T6.2.3 | GeneGIS |
| **Component** | PTV – xMap Server | |
| **Purpose** | Transfer and integrate customer and supplier data to create highly visual and interactive route maps (vector maps, topographic and aerial maps). Using data from leading map providers such as Tom Tom , AND and HERE | |
| **Kind/Type** | Standalone framework - Commercial product | |
| **Manufacturer** | 3rd Party – Commercial | |
| **Platform(s)** | Windows (Server 2012, Server 2016), Linux (RHEL 7, SUSE 12) | |

*Table 16 Component SC-18*

| | | |
|---|---|---|
| **Component-ID** | SC-19 | |
| **Deliverable(s)** | T6.2.3 | GeneGIS [PTV Group] |
| **Component** | PTV – xRoute | |
| **Purpose** | Calculate the shortest or quickest routes, tolls, emissions, distances and travel time between two or more points, giving the data to plan the most cost-effective routes. | |
| **Kind/Type** | Standalone framework - Commercial product | |
| **Manufacturer** | 3rd Party – Commercial | |
| **Platform(s)** | Windows (Server 2012, Server 2016), Linux (RHEL 7, SUSE 12) | |

*Table 17 Component SC-19*

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| | | |
|---|---|---|
| **Component-ID** | SC-20 | |
| **Deliverable(s)** | T6.2.3 | GeneGIS [Microsoft] |
| **Component** | Asp.Net SignalR | |
| **Purpose** | Allows bidirectional communication between server and client. Servers can push content to connected clients instantly as it becomes available | |
| **Kind/Type** | Standalone framework - Open Source | |
| **Manufacturer** | 3rd Party – Open Source | |
| **Platform(s)** | Windows (Server 2012, Server 2016) | |

*Table 18 Component SC-20*

| | | |
|---|---|---|
| **Component-ID** | SC-21 | |
| **Deliverable(s)** | D5.3 | CSIC |
| **Component** | Global optimizer | |
| **Purpose** | Computation of a global optimized plan on the basis of the information (empty legs, delivery requests) shared by collaborating companies. During the optimization process, this component will adjust its knowledge by negotiating with the companies involved. | |
| **Kind/Type** | Standalone framework - Open Source | |
| **Manufacturer** | Self-developed (CSIC) | |
| **Platform(s)** | Linux, Windows | |

*Table 19 Component SC-21*

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| | | |
|---|---|---|
| **Component-ID** | SC-22 | |
| **Deliverable(s)** | D5.3 | CSIC |
| **Component** | Local Optimizer | |
| **Purpose** | A copy of this component will work in every company. The component will know all the plans of this company, and the current state of all trucks, load, etc… involved in this plan. The component will get proposals of changes in this plan (generated by the negotiator component) and will return a (set of) tentative new plan(s) with estimations of the cost(s) to the negotiator. | |
| **Kind/Type** | Standalone framework - Open Source | |
| **Manufacturer** | Self-developed (CSIC) | |
| **Platform(s)** | Linux, Windows | |

*Table 20 Component SC-22*

| | | |
|---|---|---|
| **Component-ID** | SC-23 | |
| **Deliverable(s)** | D5.3 | CSIC |
| **Component** | Negotiating Agent | |
| **Purpose** | Decide, on behalf of one single company, whether or not to accept proposed co-loading/backhauling plans and generate counter-proposals. | |
| **Kind/Type** | Standalone framework - Open Source | |
| **Manufacturer** | Self-developed (CSIC) | |
| **Platform(s)** | Java | |

*Table 21 Component SC-23*

## 2.4. How the software components relate to work packages

### 2.4.1. WP2 - Data Gathering and Harmonization

In terms of software deliverable, WP2 describes the data acquisition and storage layer. The storage layer consists of the following components:

- SC1 - Protocol adapters (DNET)
- SC2 – IoT Hub (DNET)
- SC3 - Azure Collection API
- SC4 - PoolParty Semantic Suite

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- SC5 - RDF Triple Store
- SC13 - Software AG Universal Messaging

### 2.4.2. WP3 - Artificial Intelligence Focused on Prediction

The main objectives of WP3 are to develop:

- algorithms which infer the important characteristics of real logistics supply networks;
- algorithms and an architecture which identify disruptive events in logistics networks in real time; and
- algorithms which predict future events, timings and reactions in logistics networks in real time

All of these functionalities compute their results based on information provided by WP2. The prediction layer consists of the following components:

- SC6 – Order predictor
- SC7 – Turnaround time predictor
- SC8 – Delivery risk predictor
- SC9 – Travel time predictor
- SC12 – Software AG Apama
- SC13 - Software AG Universal Messaging

### 2.4.3. WP4 - Global Optimization Planning

WP4 focuses on the design and development of the global optimization system. To achieve that purpose, its specific objectives involve the development of a software module for providing the global optimization functionalities foreseen in LOGISTAR. The global optimization layer consists of the following components:

- SC10 - Cooperative Vehicle Route Optimization
- SC11 - Multimodal route planning optimization

### 2.4.4. WP5 - Automated Negotiation and Planning Reoptimization

The work of WP5 is closely tied to the optimization in WP4 and to the development of the control and decision support tool. When constraints change due to unexpected situations, it is necessary to re-optimize the solution obtained in WP4, but also taking into account to affect the minimum number of agents. The expected results include a re-optimization and a negotiation algorithm incorporating advanced Artificial Intelligence techniques. WP5 consists of the following components:

- SC21 - Global optimizer
- SC22 - Local Optimizer
- SC23 - Negotiating Agent

### 2.4.5. WP6 - Implementation and Integration of the Services

This Work-Package will integrate and implement the services of the LOGISTAR platform with the aim to provide the stakeholder with quasi real-time information referenced to the transport and to support him with a set of transport alternatives in case of raised events. The implementation will be primarily based on the results of the background modules of the Data processing / Business layer

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elaborated in WP3/WP4 and WP5 as well as on additional data provided by WP2. WP6 consists of the following components:

- SC13 - Software AG Universal Messaging
- SC14 - Software AG MashZone NextGen
- SC17 - PTV - xLocate
- SC18 - PTV – xMap Server
- SC19 - PTV – xRoute
- SC20 - Asp.Net SignalR

# 3. Deployment scenarios envisioned with the LOGISTAR system

Development and deployment of a complex software system like the LOGISTAR system, requires a stepwise approach. Also various factors have to be taken into account, when designing especially the scenario for the final demonstrator. Besides looking at the requirements of the users as well as the technical requirements of the system, it is extremely important to also consider legal and data protection aspects.

It is to be expected that the deployment approach will need to differentiate for the 3 living labs in WP7. Each living lab will operate in a different environment and will have different expectations from the Logistar technology toolbox. We propose to develop 3 “prototypes”, one for each living lab. Each of these prototypes will be consisting of components out of the toolbox. They will be similar, but most probably not 100% equal.

## 3.1. Prototype scenario

This work will start according to the planning outlined in the DoA.

The Living Labs will be a key element for applying the “Applied Learning Cycle” methodology in LOGISTAR, aiming an early deployment and evaluation of innovative concepts in the living labs (Month 12) for further improvements and experimentation, enabling the continuous reception of feedback from the stakeholders:

Starting in M16, the different subsystems (WP2, 3, 4, 5) will be deployed, for testing some of the functionalities implemented so far. Starting in month 22, an upgraded version will be deployed. A final version of the subsystems will be released in M26 for its final testing and validation, assuring the optimal results for system integration.

Starting in M22, the integration of the overall system will be deployed (outcoming from WP6), getting a first release of the overall system (D6.2). Upgraded versions will be released until the final version of the overall system will be deployed in M33 (D6.2 final release).

During this process different SW tools, such as GitLab (software repository), Jenkins (continuous integration), Slack (project-oriented instant messaging), Ansible (deployment automation), etc., will be used for controlling the SW versions released in the Living Labs.

In the beginning of the development phase the different components are developed by the various software providers and most likely also hosted in a first version within the software providers own environments. This can be on premise within the software provider’s own network or in the cloud. This results in a very distributed scenario, most likely also not very effective in terms of processing power and speed. However it will be very easy to test initial communication between components and fix errors fast with small turnaround times. As soon as components have to communicate with each other, they have to run in a cloud scenario. It doesn’t matter if this is in the software providers’ own cloud, in a commonly available cloud service, like AWS or Azure or in an individual virtual machine provided by a provider of such services (like for example Hetzner, https://www.hetzner.com/). The important aspect is that each component needs to be reachable via the Internet and in turn can reach all other components via the Internet. However, the downside of such a scenario are high latency times, as all components will need to talk to each other via the Internet.

In the course of the project we expect the prototyping scenario to change over time. As we learn about the interaction between components and the expected communication overhead and load, we will iteratively improve the distribution of the components, ultimately resulting in the deployment scenario of the final demonstrators. Also this can be done on historical data, i.e. without the need to connect to any real-time systems from the living lab companies.

## 3.2. Final demonstrator scenario

Later steps and specifically the final demonstrator will most probably result in a scenario, where as many components as possible are hosted within one server environment, to avoid as much communication overhead over the Internet as possible. This scenario will make managing of all components, the necessary resources and processing power much easier. We acknowledge though, that the demonstrators for the different Living Labs might be deployed in different specific scenarios, as required by the involved companies.

## 3.3. Flexible distribution as design principle

Although it is worth striving on installing demonstrators on as little as possible different servers, still a flexible distributed deployment should be the basis for all design decisions in LOGISTAR. In order to be as adaptable as possible to the specific requirements of each Living Lab, it is paramount to keep the LOGISTAR deployment as flexible as possible. Communication will be implemented by sending messages from one component to the next via an universal messages bus. This will greatly unify the communication and decouple individual components from each other.

## 3.4. Deployment scenarios for the three living labs

Generally the deployment basics for the three Living Labs shouldn't be much different from the general description of the deployment scenario above. However it is expected that these use cases have some specific requirements only related to their specific details. As we are rather early in the process to know the exact requirements, we need the flexibility in the deployment as described above.

It is already acknowledged that the data collected by the LOGISTAR system, which is provided by the different stakeholders is confidential and can't be made visible to everybody. Data protection is of utmost importance here. The directly participating partners are willing to provide data from their operations (e.g. trucks, trains, order systems). Since this system processes specific data of the involved companies, it might be required to have parts or the whole system running within control of the participating stakeholders.

### 3.4.1. Living Lab 1: Backhauling and Co-loading (NESTLÉ & PLADIS)

This Living Lab will be led by the two consortium partners of Nestle and Pladis. They have distribution centres fairly close to each other at Bardon and Ashby in the central part of the UK, but all relevant Nestle & Pladis UK manufacturing and distribution centres will be considered in the Living Lab to maximise the opportunities of backhauls. Chocolate tanker movements will be excluded.

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This Living Lab will attempt to minimise empty running and improve asset utilization, as well as reduce costs for Nestlé, Pladis and possibly other FMCG companies involved in the living lab. To achieve this, data from planned demand to be delivered will be collected from Nestle, Pladis and other involved FMCG companies. In addition, characteristics and costs from own fleet and carriers will be also integrated. Predictions of travel times and processing times at each client/distribution centre based on hour, day of the week and week of the year will be taken into account to provide optimised routes.

### 3.4.2. Living Lab 2: Synchromodality (ZAILOG & CODOGNOTTO)

This Living Lab will be led by Zailog partner, with the close collaboration of Codognotto. This Living Lab will involve the movement of full truck loads, probably of furniture and white goods, from various origins in Italy to various destinations in Germany. The LOGISTAR system will assess the options of moving the goods via the Interporto of Verona and rail freight terminals in Germany such as Rostok, by rail and road, or directly between countries by road, taking into account timings and cost, including known or predicted disruptions or incidents. The LOGISTAR system will make recommendations and then monitor the real time movements of the goods across all modes of transport ensuring stakeholders such as carriers, train operating companies and rail freight terminal operators have the information to ensure a smooth transition of the goods from origin to destination.

### 3.4.3. Living Lab 3 - Real-time logistics in Chemical Industries (AHLERS)

Living Lab 3 will be led by Ahlers. This Living Lab will detect quick win situations and horizontal collaboration between different chemical companies operating in nearby locations to look for transport synergy and bundling opportunities. Using both static and dynamic information about transports schedules and constraints will improve loading factors and empty kilometers running.

**Disclaimer:** Due to internal decisions in Ahlers, the scope of Living Lab 3 is under re-definition. This section will be updated in an upcoming version of the report when the information become available.

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# 4. Deployment Methodology

The deployment scenarios as outlined above are based on the perception that we need flexibility. There are a number of factors that supports this statement.

- In LOGISTAR we have not less than 8 partners providing different software components.
- Currently we expect the system to be built out of 21 different components, however this number might even increase as we go forward, simply because we learn more about the detailed usage scenarios.
- Furthermore we expect the components to be built based on various software platforms, programming languages, development technologies, maybe even different operating systems.

With this wide range of possibilities and specific attributes of the software components, an abstraction layer and also a common denominator for the software components have been decided to be the best option. This will allow to basically handle all software components the same way and to control and administer all these components with one application using standard tooling.

After preliminary studies of the architecture it has been decided that the Docker technology (https://www.docker.com/) has been selected as the most suitable. Nevertheless other alternatives have been considered.

## 4.1. Docker

Docker is a computer program that performs operating-system-level virtualization. It was first released in 2013 and is developed by Docker, Inc.

Docker is used to run software packages called containers. Containers are isolated from each other and bundle their own application, tools, libraries and configuration files; they can communicate with each other through well-defined channels. All containers are run by a single operating-system kernel and are thus more lightweight than virtual machines. Containers are created from images that specify their precise contents. Images are often created by combining and modifying standard images downloaded from public repositories. [1]

We will encapsulate the software components in Docker containers. The easiest approach would be to wrap each and every software component in one Docker container. It might also be a solution to collect several software components of a single software providing partner in only one Docker container. However, in order to prevent components, which malfunction or even crash, from disturbing other components, it is advisable to avoid such a scenario and rather encapsulate one component with one Docker container.

Having said that it becomes clear that the final LOGISTAR system will consist of several Docker containers running on one or multiple host systems (servers) either collocated of distributed over the Internet.

It should be noted here that encapsulating software components in Docker container needs some extra effort from the partners, who provide the software. Also the aspect of security and data protection will need some additional effort from all software partners.

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## 4.2. Orchestration Framework

In order to keep control over such a software scenario, specific software programs exist, which are commonly known as Orchestration Framework. These programs serve the purpose of starting, running and also shutting down such a complex software system, as envisioned for LOGISTAR. Beside these basic services, the Orchestration Framework adds network capabilities for all running containers, furthermore also monitoring and control of all nodes (servers), on which containers are running.

In the past several such Orchestration Frameworks emerged. We believe that the following Orchestration Frameworks are suitable for the purpose of LOGISTAR:

- DC/OS by Mesosphere (https://dcos.io/)
- Kubernetes by The Kubernetes Authors (https://kubernetes.io/)
- OpenShift by Red Hat (https://www.openshift.com/)

We have some experience within the partner consortium with all of those three, however, very good experience with DC/OS suggests that we are going to use DC/OS to control the LOGISTAR distributed system.

Docker as the platform and the Orchestration framework will give us the needed flexibility as outlined in chapter 3. It will allow the individual software providing partners to independently develop their software components. Whenever they provide new releases of their components, it will be relatively easy to replace that functionality in the running LOGISTAR systems by replacing the Docker container, which contains it.

## 4.3. The user's view at LOGISTAR deployment

Besides the technical specification of the deployment, we shall also describe the user experience of the LOGISTAR system. Although the different Living Labs might considerably differ in term of the participating software components, the actual user experience will be quite similar. A potential user will access the LOGISTAR system as a web-application via a standard browser. He will work with a dashboard type of user interface offering additional control over the data displayed and even possibilities to feedback decisions, he has taken based on the data displayed, back into the LOGISTAR system.

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# 5. Testing

## 5.1. Testing methodology

The LOGISTAR system is a distributed system by design. So it is the less likely case that all LOGISTAR components are deployed on one machine. This makes testing of the whole system rather difficult - nevertheless black-box testing of the whole system must be carried out regularly.

Although it is important to strive for automation of the system testing as much as possible, it is yet unclear to what extend the black-box testing of the whole system and also the testing of specific use-cases can be carried out automatically.

In addition we need to do white-box testing (testing on a component basis) of the LOGISTAR system. We are certain that testing on a component basis is much easier and also can be automated. Most probably we will also have automated tests for certain group of components, especially those components that have only contact to other components in the system, do not produce a user interface and are not handling the actual data input into the system.

So testing of the components which handle the user interaction (WP6 related components) is a much bigger challenge. Here we most certainly must rely on manual testing, since automated testing of graphical user interfaces is a challenging task and creates very high effort in maintaining the test procedures. However since the black-box testing of the whole LOGISTAR system can only be done through interacting with the system through the user interfaces, this already covers a big part of the WP6 related component testing.

Components handling the data input (WP2 related components) can be tested automatically, but need careful setup of a test environment with reproducible and controllable data input. Only if the system is put to the test with the same input data, then an automated test can verify that the LOGISTAR system produces the correct system status and the correct output data.

## 5.2. Testing metrics

A distributed system like the LOGISTAR system can be verified using various metrics. Currently we are looking at the following metrics:

- Verification of output produced, e.g. same input to the system and to individual components produce always the same output
  - After resetting the system under test in a defined state, we will feed the same set of input messages into the system. We will then verify that this scenario always produces the same set of output data.
- Technical performance of the tool.
  - The orchestration framework provides tooling, which allows to monitor the distributed system. This will be used to survey and test the behaviour of the system under specific conditions and to verify that it is acceptable.
- Time of response of the various functionalities of the pilots, varying the number of concurrent users.
  - Like above the monitoring functionality will be used to verify acceptable response times with varying numbers of concurrent users.
- Stress tests

- Like above the monitoring functionality will be used to verify acceptable response times under stress conditions.

- Interoperability between different systems integrated within the project.
  - Interoperability will be verified by monitoring the system under the different test scenarios above. If interoperability of subsystems doesn't work, the different test scenarios will fail.
- Communications, required minimum bandwidth, delay times.
  - This metrics will be covered by the test described above, namingly stress tests, response time tests, interoperability tests.

## 5.3. Testing environment

Testing a distributed system, like the LOGISTAR system requires specific tools and testing strategies. While individual components will be tested using state-of-the-art testing tools (e.g. gitlab, jenkins, slack, Ansible), the testing of the whole system requires more complex test environments. The distribution of the system will evolve over time in an iterative way, therefor also the test environment has to be flexible enough to adapt to the system under test.

Orchestration Frameworks, like for example DC/OS, provide helpful tools for testing, like for example service discovery and load balancer. In addition Mesosphere, the company behind DC/OS offers a very useful testing library called Shakedown.

Testing of the individual components depends on the environment they actually run in. It is important, whether the component runs on-premise in the software provider's environment or somewhere in the cloud. The tooling for testing of the individual component is also highly dependent on the processes of the respective software provider. The software providers will test their components based on their individual testing frameworks and tools. Once the components are released to interact with the other components of the LOGISTAR system, the testing strategy needs to change.

As the LOGISTAR system will be composed of software components encapsulated in Docker containers running in some cloud services across Europe, the testing of the system needs to also use the Internet as main access path to the LOGISTAR system and also to parts of it, which are under tests individually. Communication within the LOGISTAR system will be message based and the communication infrastructure used will be a messaging system called the message bus. This will help considerably to setup test environments. Components can be tested by sending messages to the message bus and verifying that expected messages are send back.

## 5.4. Testing and different phases

Testing of the individual components will start right away, as the respective software providers are working on the implementation of the component. They will need to ensure a high software quality level of their components, when releasing components into the integrated LOGISTAR system, therefore they need automated regression tests to ensure the overall system is not corrupted by a faulty component released.

Testing of the LOGISTAR system as a whole or testing of meaningful parts of it, can only start, when the system is actually available. Thus activities, like:

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- T6.2 LOGISTAR platform development and integration (M14-M34),
- T6.3 Software quality assurance and testing of LOGISTAR platform (M16-M34),
- T7.2 Setting up of the living labs (M13-33),
- T7.3 Testing and evaluation (M18-M36)

have great influence, when testing of the system or of meaningful parts can actually start. So while testing of individual components can start already in M10, the testing of the whole LOGISTAR system will take place from M16 on.

## 5.5. System testing and validation

The objective is to develop a validation of the LOGISTAR platform and its related services. The evaluation of the implemented prototype will be based on the users´ evaluation strategies, metrics and defined scenarios in WP1. The task is to ensure a tight coupling between the defined requirements in WP1 and the developed services in WP6, thus to involve the evaluation of the system and its services in three Living Labs:

- Backhauling and Co-loading led by Nestlé.
- Synchromodality led by ZAILOG.
- Real-time logistics in Chemical Industries led by Ahlers.

Therefore, the main objectives of the system validation are:

- To validate the solution in real environments as defined by the three Living Labs.
- To validate against user evaluation strategies and metrics to understand how well the chosen software solution meets (and anticipates) user needs.
- To execute a technical test and validation of the subsystem prototype outcomes, for subsystems testing and validation (WP2, WP3, WP4 and WP5) and the overall LOGISTAR system (WP6).
- To assess the usability of the services from the point of view of different stakeholders.
- To estimate the efficiency of services developed within the project.

## 5.6. Testing and evaluation

Ultimately the testing should prove that the system delivers the functionality envisioned in the D1.1 and D7.1 documents.

The three usage scenarios, a.k.a. the Living Labs, will be the basis for testing the LOGISTAR system. Each of the Living Labs is different, so testing based on these usage scenarios covers different aspects of the system. In order to get the testing scenarios quickly up and running, we need to test the software components in laboratory environment based on historical data. With the results and also the feedback from the users of the different Living Labs the LOGISTAR system and the software components it is built from can be improved in an iterative way.

At a later point, when the iterations converge to an improved system, the living Labs should be combined with the real world, which will lead to the connection and activation of the validated prototypes on their real-live ICT systems.

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Then LOGISTAR partners will collect on a regular basis the data and feedback from each user, focusing on the following aspects:

- Technical performance of the tool.
- Monitor the operational changes inferred of the uses of the LOGISTAR services.
- Level of the efficiency of targeted operations: loading process optimization; loading factors improvement, transhipment operations, transhipment timing reduction.
- Transit time improvement, route distance reduction (km; timing), empty running kilometres improvement.
- Level of reliability of the information services delivered.
- Cost benefit, environmental impact.
- Usability aspects: satisfaction time of response, usefulness of the tool for decision making, efficiency of use, learning easiness, error frequency/ severity.
- "acceptance/resistance level" of each component with each living lab participant

From the technical point the following aspects will be assessed:

- Conformance: are the implementations according to the architecture and specified interfaces.
- Correctness: is the provided information correct, i.e. consistent with the real situation.
- Reliability: is the system and the provided information reliable over time.
- Accuracy: is the provided information sufficiently accurate.
- Fit for purpose: given the factors above and the objectives, is the system able to do its task in an effective way.

To analyse all these aspects, the following indicators/tests will be checked:

- Time of response of the various functionalities of the pilots, varying the number of concurrent users.
- Stress tests
- Interoperability between different systems integrated within the project.
- Communications, required minimum bandwidth, delay times.
- Variations of results depending on peak/ off peak season.

## 5.7. Test the Living Labs environments

At the center of Logistar are three living labs or test cases in WP7.

We need to differentiate the testing for the 3 living labs. We will start with the earliest possible living lab as soon as it becomes defined and historical test data is available. The other living labs will be added as soon as they become available.

Therefore we should focus all technical efforts and testing on the 1st living lab as soon as it becomes available, and use the learning from this exercise to support, stimulate and accelerate the testing of the other 2 living labs.

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### 5.7.1. Living Lab 1: Backhauling and co-loading:

Here the ambition is to bundle and optimize in real-time the outbound shipments of Nestlé and Pladis.

With the introduction of the LOGISTAR system Nestlé and Pladis would be looking for a 10% improvement on the following KPI values:

- (i) Empty running;
- (ii) Asset utilisation – how many hours the vehicle is used compared to the maximum available hours;
- (iii) Vehicle fill;
- (iv) Delivered cost per case;
- (v) Failed to arrive – a delivery arrived outside of the delivery window and was or was not accepted by the customer;
- (vi) Delivery timeliness – the delivery was made within the customer delivery time window.

As this list is already a list of KPIs, they represent the KPIs, which will be looked at in order to verify this use case. In addition the following KPIs will also be looked at during testing the Living Lab:

- Truck fill rate
- Empty kilometres
- Transport cost
- CO2

### 5.7.2. Living Lab 2: Synchromodality:

Here the ambition is to create operational visibility, predictability and optimization with regard to the rail terminal of Verona and its freight movements to and from Germany.

Objectives for ZAILOG and CODOGNOTTO for the introduction of the LOGISTAR system:

- (i) 20% modal shift (from road to rail);
- (ii) reduction of departures and arrivals delays (train) < 60 minutes;
- (iii) reduction of waiting times in terminal (from gate in to out) < 30 minutes;
- (iv) increase loading factor> 90%.

The following KPIs will be looked at in order to verify this use case:

- Fill rate of trucks
- Fill rate of the train
- Number of trains managed per railway track
- Number of train departures on time

### 5.7.3. Living Lab 3: real-time logistics in Chemical Industries:

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# 6. Conclusions

This deliverable has examined the deployment structure of the LOGISTAR system based on input collected from all project partner delivering software components. Furthermore prototyping and further discussions lead to decisions regarding the deployment infrastructure as described in this report. The technologies involved will be Docker and DC/OS as orchestration framework.

The testing from the LOGISTAR system is described from different point of views. The testing of the more technical aspects of the system as well as the testing from the use cases' point of view is investigated. Furthermore the testing scenarios have been examined and testing metrics have been described. Finally testing scenarios in relation with the three Living Labs have been discussed.

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# List of abbreviations and acronyms

| | |
|---|---|
| DC/OS | The Distributed Cloud Operating System, by Mesosphere (https://dcos.io/) |
| EDC | European Distribution Center |
| FMCG | Fast Moving Consumer Goods |
| ICT | Information and Communication Technologies |
| KPI | Key Performance Indicator |
| SC | Software Component |
| WP | Work Package |

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## References

[1] https://en.wikipedia.org/wiki/Docker_%28software%29 (as of March 27th, 2019)