INTERMODEL EU

Simulation using Building Information Modelling Methodology of Multimodal, Multipurpose and Multiproduct Freight Railway Terminal Infrastructures

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D3.2 – PILOT INNOVATIONS AND IMPROVEMENTS

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Executive Summary

The **INTERMODEL EU project** aims at establishing a methodology for multimodal freight terminals which allows taking the most of the BIM tool and its capacity for providing multi-dimensional models. For this purpose, four pilot cases will be modelled and analysed throughout the project, two of them will be studied in real terminals and the other two will be implemented into virtual ones.

The real terminals, La Spezia container seaport terminals and Milan-Melzo container dry port, besides from being used as pilot cases where to test the proposed new set of ICT tools, they will enable to calibrate and verify the BIM model and the operation simulation with raw data made available by the terminal operators.

In order to build these pilot cases, the Task 3.2 has been split in two different parts: 1. Identification of innovations and foreseeable improvements in construction and management of multimodal terminals area; 2. Definition of those scenarios in which developments chosen will be tested. Both to be developed during the first year of project. Then, the **aim of this deliverable** is to determine the improvements and innovations that will be applied in the case studies, corresponding to the first part of the task. In particular, they will be applied to La Spezia and Melzo terminals, together with the foreseen projects the terminals will developed in the short and mid-term, and in the virtual ones.

In a first step, a comprehensive analysis of relevant logistics trends has been carried out, followed by a questionnaire survey undertaken with relevant actors related to intermodal terminal and key experts within the Consortium in order to ascertain the relevance of different innovative solutions and improvements and views on own experience.

The table below includes the selected technological and operative innovations to be implemented into the four pilot terminals:

Real pilot cases	Virtual pilot cases
La Spezia seaport terminal - New railway terminal design; - Extension and improvement of the CMP; - Improved maintenance scheduling (railway interconnection).	*Virtual pilot case 1* - Internet of things; - Alternative container design for bulk cargo/reefer container – multi-purpose terminal; - LNG; - LCA – new materials.
Melzo inland terminal - Conversion of F3 warehouse into temperature controlled warehouse; - Implementation of a third gantry crane; - Four new shunting rail tracks; - Second gate in/out; - Improved maintenance scheduling (railway interconnection).	*Virtual pilot case 2* - Internet of things; - Automated and robotized equipment (automated cranes and AGV); - LNG; - LCA - New materials.

This information, together with the work carried out under the second part of this task, will allow to set the input data necessary to correctly define the design of the four pilot cases using BIM technology and incorporate all the relevant BIM dimensions.

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1. Introduction

1.1. Scope

The INTERMODEL EU project aims at establishing a methodology for multimodal freight terminals which allows taking the most of the BIM tool and its capacity for providing multi-dimensional models. For this purpose, four pilot cases will be modelled and analysed throughout the project, two of them will be studied in real terminals and the other two will be implemented into virtual terminals.

The real terminals, La Spezia container seaport terminals and Milan-Melzo container dry port, besides from being used as pilot cases where to test the proposed new set of ICT tools, they will enable to calibrate and verify the BIM model and the operation simulation with raw data made available by the terminal operators.

The first step previously done was establishing a set of KPIs that will be used to evaluate the use of BIM and associated models in achieving the strategic objectives of the project of multimodal terminals. Once established, it is necessary to define the pilot cases where the result developments from the INTERMODEL EU project will be applied.

In order to build these pilot cases the work has been split in two different parts: 1. Identification of innovations and foreseeable improvements in construction and management of multimodal terminals area; 2. Definition of those scenarios in which developments chosen will be tested. Then, the **aim of this deliverable** is to determine the improvements and innovations that will be applied in the case studies. In particular, they will be applied to La Spezia and Melzo terminals, together with the foreseen projects the terminals will developed in the short and mid-term, and in the virtual terminals.

In such context, in order to identify improvements and innovations, a review of published strategies and trends has been performed, together with a survey among the INTERMODEL EU project's main stakeholders. This survey has provided quantitative values concerning the appraisal that stakeholders attribute to the different innovations, giving at the same time qualitative elements related to their previsions about the future configuration and management of multimodal terminals.

Main innovations and improvements identified by reviewing logistics trends and the survey's results are:

- The application of the Internet of Things (IoT) to ITU's and goods tracking. The ability to control the position of moving elements and associated parameters, such as the temperature, and the ability to communicate this information to the final customer become one of the main areas of improvement in multimodal transportation. Accordingly, it will be necessary to foresee data capture and transmit networks with enough capacity to manage large volumes in the future multimodal terminals;
- The use of autonomous driving systems for moving machinery of intermodal terminals, specially gantry cranes and reach stackers. Automatic guidance elements should be foreseen for these mobile elements.
- Equipment for terminals with systems allowing the secure management of ITU's with controlled temperature. In other words, terminal's equipment with power supply system in order to plug reefer containers and semi-trailers.

Furthermore, improvements planned for Melzo and La Spezia terminals have been also included in order to build a model that will be used as input for the modelling allowing the assessment of the efficiency of those improvements during both the construction and exploitation phases of the terminal.

Next steps will be focused in defining each of the pilot cases in terms of their different attributes and setting a number of scenarios in order to represent the different casuistry to be tested in the models.

1.2. Audience

The intended audience of this document is any actor involved in activities related to intermodal freight terminals, both seaport and inland, such as public administrations, private terminal operators, logistics companies, shippers and rail operators.

The integrated tool developed within the project will allow a fast way to make decisions in the planning and operation, taking into account different improvements and innovations set in this document.

1.3. Definitions / Glossary

In the current section a short description of main terms used in the manuscript are described, that is:

Corridor management platform – Network of business interoperating platforms where shippers and other logistic actors can control their operations throughout the formalised supply chain.

Degradation index – Percentage of maintenance sections where geometric parameters exceed alarm thresholds. These alarm thresholds are the ones defined by the European standard as immediate action limits.

Integrated Life Cycle Assessment – Sustainability assessment of the structure within the whole life cycle – equivalent to LCSA – life cycle sustainability assessment.

Life Cycle - Consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to the final disposal.

Maintenance - Combination of all technical and associated administrative actions during the service life to retain a building or an assembled system (part of works) in a state in which it can perform its required functions.

Optirail index – Predicted time in which any of the geometric parameters will overpass its security threshold in the analysed section of the track.

Safety index – Percentage of maintenance sections where geometric parameters exceed safety thresholds. These safety thresholds are the ones defined by the European standard as immediate action limits.

1.4. Abbreviations

The following list contains the most common abbreviations used in this deliverable:

AEO: Authorised Economic Operator

AGV: Automated Guided Vehicles

APP: Application

B2B: Business-to-Business

BIM: Building Information Model

B/L: Bill of Lading

CMP: Corridor Management Platform

CNG: Compressed Natural Gas

D2D: Door-to-Door

EDI: Electronic Data Interchange

ETA: Estimated Time of Arrival

IoT: Internet of Things

ILCA: Integrated Life Cycle Assessment

ILCD: Integrated Life Cycle Design

IT: Information Technologies

LCSA: Life Cycle Sustainability Assessment

LNG: Liquefied Natural Gas

LSC: Logistic Services Client

LBS: Location Based Services

LSP: Logistic Services Provider

LSW: Logistic Single Window

OI: Optirail Index

PFRC: Polypropylene Fiber Reinforced Concrete

RC: Reinforced Concrete

ROI: Return On Investment

1.5. Structure

The present document is organized as follows:

- **Introduction**: contains an overview of this document, providing its scope, audience and structure.
- **Logistics strategies and trends review**: publications review carried out in order to select a number of improvements and innovations to be tested in the real and virtual terminals models. In addition, the proposed improvements of the previous WiderMOS and OPTIRAIL European projects will be included in this section.
- **Improvements foreseen for real pilot terminals**: includes the projects that Melzo and La Spezia terminals have planned to implement in the short and mid-term after a review of their actual performance of their terminals.
- **Methodology for improvements/innovations selection**: contains the methodological approach followed for the selection of the improvements and innovations that will be implemented in the pilot cases.
- **Selection of improvements and innovations**: includes the improvements and innovations that will be implemented in the pilot cases assessed throughout the project.
- **Conclusions**: gathers the improvements and innovations list proposed to be implemented in the pilot cases. It will be used as input data with the objective of correctly defining the design of the pilot cases.

2. Logistics strategies and trends review

2.1. Introduction and objectives

The publications review carried out focuses on analyzing tendencies in logistics and innovations that can be applied in both intermodal freight terminals and rail connection between them. Firstly, this section reviews global trends which will tend to enhance efficiency of transportation and performance of intermodal freight terminals. Secondly, a brief description of the improvements proposed by the WiderMOS and OPTIRAL European projects is provided.

The **purpose of this section** is twofold: first, to list the identified logistical trends that can influence the organization, utilization and performance of the intermodal freight terminals (increasing capacity, reducing costs, etc.) and, second, to provide information to construct a survey that will be distributed among the INTERMODEL EU project potential stakeholders in order to know their opinion on these global trends.

Finally, all this will help to choose a number of potential improvements and innovations that will be implemented in the pilot cases modeled within the project.

This will contribute to improve the layouts and operational processes within the intermodal freight terminals assessed during the project, and will demonstrate the use of the decision-making tool, due to the achievement of improved KPIs dashboard.

2.2. General overview of tendencies in logistics

2.2.1. Purpose

This section is based upon a number of trends that are occurring in multimodal transport and that will have a profound impact on them in the next couple of years and will further increase on the mid-long term.

Some of the future challenges and target requirements that logistics will have to tackle are described as follows:

- Stricter rules regarding the environment impact and local emissions. Regulation regarding emissions for COx, NOx, but also for sound and light will become stricter and stricter. To comply with these regulations, terminals will need to use electrified 'green' equipment, but also optimize their activities (e.g. reduce

empty travelling of cranes and vehicles). This is especially the case for terminals that are located near residential areas.

- Characteristics of the trains and train services will change in the near future:
    - Longer trains will be used. Currently the maximum length in most countries is 750 meters. However, the actual length in reality is (much) shorter. The trend is that the average length is increasing, so terminals will need to have longer tracks to facilitate the use of longer trains.
    - The average weight of cargo (bulk and containers) will increase. This requires the use of stronger and heavier locomotives and terminal equipment.
    - New ways of scheduling and operating train services will be introduced, such as dedicated shuttle services and hub-and-spoke networks.
    - Train services will cover longer distances. An example of this is the new rail service between the Port of Rotterdam and several ports in China.
- Deep-sea vessels are becoming larger and larger to maximize benefits of scale economies. The same applies for barges in a smaller degree. The bigger vessels cause higher peak-demands on the terminals and higher storage requirements. Terminals need to have more equipment and room for storage to facilitate the arrival of larger vessels.
- Terminals are more and more operating in global (or European) terminals networks. In the past, terminals used to operate highly independent from each other and had separate owners. Each terminal only focused on their own activities and tried to perform as optimally as possible as a single entity. Nevertheless, there has been a strong consolidation in the last years. Bigger terminals operators are acquiring many of the small independent terminals. This fact changes the focus of terminal operators from single terminals towards networks of terminals. It is no longer enough to optimize the operations of one single terminal. The activities of terminals that operate together in a network have to be optimized and aligned.
- Land and space are becoming scarce resources for terminals. Many terminals are located close to residential and/or industrial areas. In the past, they could be easily extended, as there was no problem of space because of the abundance of land. In contrast, nowadays, most of that space is being used. So Terminals have

limited space to expand and need to make a better use of the existing land and space they have. Terminals operations are becoming denser. This requires terminals to stack or store goods closer and/or higher and reduce the staying time of vessels, trains and trucks at terminal.

- More terminals are being bought by big terminal operators and/or investment companies, whereas in the past, many terminals were owned by local municipalities. Bigger terminal operators and investment companies have a stronger focus in high profits and higher Returns-On-Investment. This is also leading to more and more initiatives to reduce operating and investment costs to an absolute minimum.

These trends ask for a new generation of terminals in Europe, requiring new terminal equipment, software and personnel.

2.2.2. Logistics trends and innovations

In this section, the different logistical improvements and innovations identified are described. Firstly, though, these trends have been grouped and classified as follows:

- ✓ Technology
  - o Alternative container design for bulk cargo
  - o Modular container construction
  - o Automatic coupling
  - o Autonomous driving and assistance systems in rail transportation
  - o Alternative propulsion technologies (CNG, LNG, hybrid technology, etc.)
- ✓ Digitization
  - o Internet of things and IT solutions
  - o Intelligent freight cars, new handling machinery and processes
- ✓ New materials
- ✓ New track maintenance processes
- ✓ Integrating modes of transport and consolidating transport volumes

2.2.2.1 Technology

ALTERNATIVE CONTAINER DESIGN FOR BULK CARGO

One kind of intermodal transport unit that is to some extent used in Europe is truck trailers on road and rail.

Standard ISO containers are, however, by far, the most popular intermodal transport unit. Beginning after WWII, ISO containers have revolutionized world freight transports. Many shipping corridors have been prepared with adjusted railroad gauges and intermodal terminals for convenient transshipment of containers between road, railroad and ships.

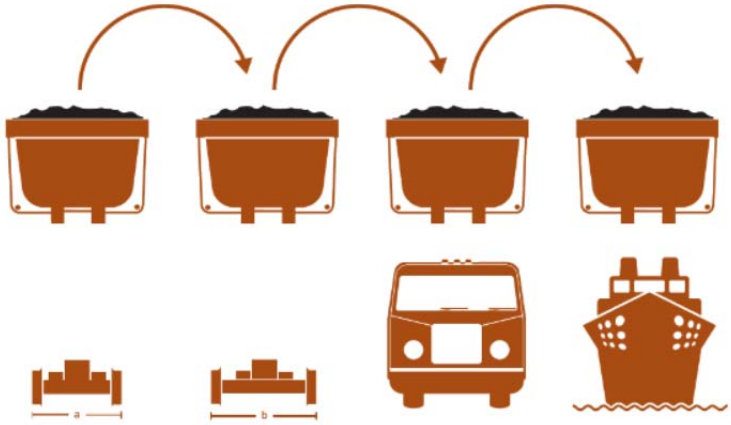
The popularity of container shipping is many times not due to their suitability for the cargo that they are used for. Instead, the cargo is actually in many cases adapted for the containers. No, instead their popularity is due to that they allow for intermodal transport, where the mode of transport is easily changed without any handling of the cargo itself. This greatly reduces cargo handling and so improves security, reduces damages and loss, and increases shipping speed. This has the added benefit of making rail transport more attractive at the cost of the more environmentally hazardous road transports.

Containers come in many standard sizes and for different kinds of goods. There are regular containers for piece-goods, so-called 'tanktainers' for fluids and refrigerated containers for perishables.

Although a large amount of European goods is shipped with containers, some goods do not suit containers and are therefore hard to adapt for intermodal transports. This is the case of dry bulk and timber.

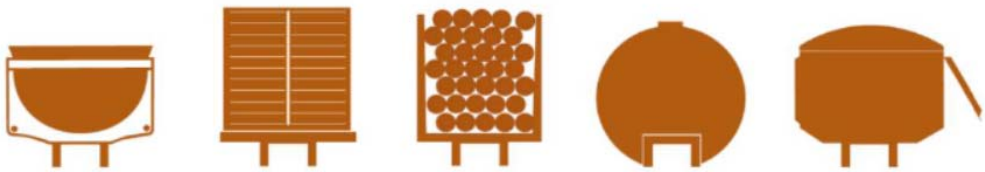
Kiruna Wagon has filed for a patent on a system with modular load carriers for intermodal transports of any kind of goods (EPO 13154208.6). The modular load carriers can for example be transshipped between rail wagon chassis made for different track gauges, road trucks and ships, see figure 1 below. Loaded and unloaded load carriers can also be stored on the ground, waiting to be shipped.

Figure 1. Transhipment of one of Kiruna Wagon's modular load carrier between different modes of transport



The modular railroad wagons as well as adapted truck chassis fit with the different modular load carriers which in turn can be exchanged within minutes. This allows users to have several different load carriers for each of the more expensive wagon chassis or road trucks, which in turn allows for easy adaption of the fleet depending on the transport demand of the day or season.

Figure 2. Different modular load carriers including one for containers.



The modular system hence makes railroad transports cheaper and more attractive in general. It also makes railroad transports a good alternative for a larger number of different cargo types. In addition, it reduces the distance where it becomes attractive to use railroad instead of pure road transports.

The modular railroad chassis are in themselves very simple and robust. To make them even simpler, safer and quicker to couple with other wagons, they should preferably be fitted with central buffer couplers. In order to maximize the possible cargo volume, the coupler height should be minimized, i.e. lower than normal today.

The modular system allows selecting several applications in order to adapt the intermodal transport unit according to multipurpose uses.

The main feature of the system proposed is that it is modular from top to bottom so that it can be adapted and thus, fit all transport conditions.

The benefits that offers the modular system are described as follows:

- Lowest possible tare weight
- Standardized at the right level
- Flexibility over time
- Modular maintenance
- Fits well in an intermodal environment

Europe is the most expensive place in the world to transport on railway. Containerized bulk will lower the train load due to lower utilization. Expensive rail transports will be even more expensive and more shares will be lost to trucking. Bulk must be handled as free bulk from source to consumer with highest possible axle load.

Transport costs on railway are 6-8 Eurocent per tonnekm in Europe.

The modular system is based on the following lean principles:

- Standing in line is waste so terminal handling must be quick.
- Tare weight is waste so it must be as low as possible without negative effects on safety, function and life length.
- Installation depth and lifting and dropping material is a waste of energy. Hoppers must be small, utilization must be high, just in time must be used and momentum capacity must be high.
- Wagons not in use is waste so solutions must be flexible over time.
- Half full wagons operating is waste so full axle load or volume must be used.
- Speed creates exponential forces and wear. High axle load is safer and more environmental friendly than high speed.

From this perspective, terminals must meet some requirements if the **innovation proposed for bulk transportation** and handling wants to be implemented. Some general recommendations are listed below:

- Terminal must be built for containers, free bulk and free liquid. This is dominating transport assets that must be handled as efficient as possible. Containerized assets has a minimum value affordable to ship and bulk is not one of them.
- Terminal railway hoppers should allow side dumping in one direction and bottom dumping. Also a crane and a stockyard that can replace load carriers and containers.
- Unloading of wagons should be automatically controlled by the train control system. Manual handling must be avoided due to safety and efficiency.
- Hoppers should be designed as shallow as possible with reclaiming capacity from unloading to buffer storage at 6.000 - 12.000 tonne/hour.
- Buffer storages should be designed so they can be reclaimed automated to truck, vessels or containers (for door to door handling).
- Advanced measurement systems to verify full loads should be installed in all bigger terminals. Full volume or full axle load.
- Bulk handling should be designed so shock loads are minimized to prevent dust spreading. It must be taken into consideration that bulk can not be handled in open air.
- Buffer storages must be able to handle various type of bulk and this bulk must be categorized.
- Terminals must be equipped with advanced logistic planning and control systems to allow maximum *just-in-time* handling of all big volume assets. Hitherto, terminals tend to sub optimize to containers without the need of previous planning.
- Terminals should be equipped with advanced diagnostic systems for wagon maintenance inspection.
- Workshop for lighter maintenance must be available in all terminals.
- Big terminals must be able to clean wagons both inside and outside.

MODULAR CONTAINER CONSTRUCTION

In recent times, consignment sizes are decreasing due to e-commerce and individuality, this is why the europallet seems no longer the ideal load carrier. Considering that load carriers are the mainstay of all freight transportation, it looks reasonable to think that

the lack of standardization of the load carriers is leading both to greater handling costs in transshipment and inefficient use of load space.

Therefore, in order to address this problem, the approach is to design a modular system of load carriers, based on that different container sizes form whole number divisors or multiples of the next-smallest/next-largest container. This would allow combining them without losing load space.

However, the potential of this modular system could only be realized if it becomes an international standard.

AUTOMATIC COUPLING

The implementation of automatic coupler systems in railway vehicles may allow an automatic, safe and fast connection between different cars, without manual work by operators. This coupling system achieves a total connection of cars, giving electrical supply, mechanical and pneumatic connections without additional operations.

The automatic coupling might connect the cabin with all the cars. For instance, freight cars may be controlled, monitored and also uncoupled remotely only pushing a button, which may simplify operations.

By speeding up train formation, better use can be made of freight car resources, the system and turnaround speed of the cars can be increased and cost savings in staff and materials realized. Automatic coupling enables longer and heavier trains and thus, increase capacity. Moreover, these couplers have a longer operational life than screw couplers.

AUTONOMOUS DRIVING AND ASSISTANCE SYSTEMS IN RAIL TRANSPORTATION

Driver-assistance systems can help to reduce accidents. In addition, trucks used in road freight also feature special systems such as active roll stabilization, minimizing instability.

Autonomous transportation systems enable saving on drivers and the frequency of trains can be increased and flexibly adapted to meet demand without needing to consider staff availability. It also allows save power by optimizing acceleration and braking patterns. Consequently, CO_2 emissions and the energy consumption might be reduced.

ALTERNATIVE PROPULSION TECHNOLOGIES

In order to reduce petroleum and greenhouse gas emissions, several energy-efficient technologies and renewable energy sources can be used in transportation. Progress is being made in the areas of electromobility, hybrid solutions and natural gas propulsion.

Liquefied natural gas (LNG)

An alternative to the use of conventional gas is liquefied natural gas (LNG). It offers some advantages over diesel such as the combustion process emit less carbon dioxide in relation to the energy produced, and its burning is very clean.

Despite the fact that few commercial trucks are in service with LNG propulsion, the trend shows that LNG represents a promising alternative and enables quieter and more environmentally friendly engines.

2.2.2.2 Digitization

INTERNET OF THINGS and IT SOLUTIONS

Innovation and the use of technology have become a factor of competitiveness in transportation and logistics sectors. The use of new cyber-physical systems enable more efficient use of resources and offer an opportunity to address the increasing volumes of freight traffic and avoiding infrastructure bottlenecks.

The integration of all types of physical objects into a universal digital network, known as Internet of Things (IoT), permits the generation of efficient services, providing competitiveness to the transportation and logistics sectors, while at the same time guarantees a sustainable increase of the logistics activities.

In such context, l'Autorità Portuaria della Spezia participated in the WiderMOS European project, whose aim was improving the interface between maritime transport and other modes, mainly rail, by:

- Developing new port/ship/train interfaces and efficient port-hinterland connections;
- Connecting ports and integrate origins and destinations; and
- Bridging gaps in and between different trade corridors.

WiderMOS project developed an IT Corridor Information Pipeline acting as a Logistic Single Window (LSW) for the integration of sea-based transport services in the logistic chain, considering all types of freight operations, in order to allow a seamless shipment management and communication between all the actors of the supply chain. In this sense, the implementation of the Logistic Single Window aims at overcoming specific bottlenecks with a focus on paperless logistics and e-costumes processes and with priority for the integration of inland terminals and rail.

In this sense, WiderMOS aims at facilitating the homogeneous connection between Motorways of the Sea and the TEN-T core network.

<u>Innovations developed within WiderMOS project</u>

In order to improve interoperability between the sea and the other transport modes through the development of new port/ship/train/inland interfaces, five pilot projects were deployed in five European ports. These are La Spezia in Italy, Barcelona in Spain, Rostock and Kiel in Germany and Leixoes in Portugal. The pilot projects were focused in the development of an IT based Corridor Management Platform (CMP), acting as a Logistic Single Window (SLW), in order to allow a seamless shipment management and communication within the supply chain.

The CMP is defined as a network of business interoperating platforms where shippers and other logistic actors can control their operations throughout the formalised supply chain. Thus, increasing the visibility of all stakeholders involved in a commercial transaction, mainly businesses, requiring transport and logistics services, such as freight owners, train traders, railway companies, railway infrastructure managers, shipping companies, port infrastructure administrators, short and long-distance transport

companies; and allowing the collaboration among them by the use of collaborative tools and shared decision organizations or stakeholders.

Obviously, an important aspect of information flows between computers and stakeholders are the actual interfaces, message formats and information exchange protocols utilised. The problem found when developing the CMP was that different standards exist and there was a need to link them with an agreed framework covering aspects such as semantics (meaning of information elements and the relationship among them), vocabularies, etc. to ensure that the information is understood in the same way by different organizations or stakeholders.

CMP Italy

The actors involved in the Italian pilot project were a port, two inland terminals, a port terminal, an MTO, a shunting operator and a railway operator.

The table below shows the type of data and information exchanged through the CMP:

Table 1. Data and information exchanged through the Italian CMP.

Inland	Port
- Train loading list - Train loading list operative (export) - Train loading list final (export) - Train position (tracking) - Train gate in (import) - Train gate out (export)	- Train loading list operative (import) - Train loading list final (import) - Train gate in (export) - Train gate out (import)

Before the development of the Italian CMP, goods destined to the port had to follow a long bureaucratic process, where hardly the computer systems were integrated with paper ones. After the CMP, a good system of information flows has been achieved, integrated with the almost total savings of paper and manual management. There are several benefits:

- Shorten the distance between the supplier and the end customer by improving the delivery, delivery times and customs clearance;
- Availability of goods: when and as required by the customer;
- Reduction time and cost in the ports of arrival;

- Reduced administrative time and increased accuracy of data with a direct flow that draws from systems;
- Create a single information with data exchanges between final client and Customs Agency and/or Shipping Companies;
- Pursue excellence in the 'data quality' as provided by an Authorised Economic Operator (AEO).

The Italian CMP allows an exchange of railway information in import and export with the inland terminals, and a customs rail corridor with them.

CMP Spain

In the Spanish pilot project, the actors involved were two port authorities, the customs agency, forwarding and transport agents and providers, good providers, logistics platforms, information and communication technology providers (e.g. Port Community System provider), multimodal transport operators and technology suppliers (CMT developers and implementers).

The table below shows the type of data and information exchanged through the CMP:

Table 2. Data and information exchanged through the Spanish CMP.

Inland	Port	Maritime
- Booking (train) - Haulage - Train information (wagon, position, etc.)	- Pre-arrival notifications - Approaching the port (roughly up to 6 hours before arrival) - In port (when the vessel is at berth) - After departure (once the vessel leaves the berth)	- Booking - B/L (Bill of Lading)

The Spanish CMP was built following these leading principles:

- Interconnectivity – at least 3 systems involved
- Interoperability – data exchange, redirection of messages and so on
- Multimodality – sea / rail / road
- Multiservice – at least 2 services to be published

Owing to these criteria, the CMP allows managing the corridor information flow through the corridor infrastructures from the goods supplier to the end customer, along the whole elements of the logistic chain: hinterland at origin, port of origin, sea carrier, port of destination and hinterland at destination.

Due to the Spanish CMP, the achievements obtained were:

- An efficient and intelligent transport, that is economically and environmentally sustainable;
- Demonstration of the economic and operative feasibility of the Corridor from Spain to Central/North Europe passing through Italy;
- Suitable instruments like a CMP interoperable among the transport operators, the different countries covered by the corridors combinations and the end users (customers and agents);
- Improving the way how business can be smarter.

CMP Germany

Actors involved in the German CMP are several logistics service providers, an intermodal inland terminal, two port operators, two shipping lines, three railway operators, one intermodal operator and two software companies.

Data and information exchanged through the CMP is:

- Estimated Train Time of Arrival (Estimated Time of Arrival, ETA)
- Train time table
- Booking
- Transhipment order (Electronic Data Interchange, EDI)

In this case, the CMP was designed in two main parts: the inland part managed by an intermodal operator, and the maritime part managed by several operators.

On the one hand, the online booking tool provided by the intermodal operator for the inland section was implemented in the CMP pilot phase had the following main functions:

- Capturing bookings
- Completeness check (mandatory to fill in all details required)

- Registration of unit information (weight, measurements and code of units are recorded)
- Overview over the commenced bookings
- Booking confirmation
    - PDF document with relevant booking information is being generated automatically
- Overview over the transmitted bookings
- Templates
    - Information for reoccurring bookings can be saved

Further functions were available at a later stage of the project:

- Order amendments by the respective customer
- Order amendments by the agency
- Cancellation
    - The piloting phase allows cancellations via e-mail or telephone only
- Status information
    - Information regarding the routing and departure date will be provided by the agency
- Multi-lingual user interface
- Help text
    - Mouse-over activates assisting help text for the data entry

On the other hand, the key features regarding the maritime section were:

- Building a Live system (TOS) with a big amount of data
- To separate company specific data
- Informing about the company specific status (gate-in, loaded-unloaded, etc.)
- Linking multi company data at a later point
- Informing about the status list (location can be merged when all data is available)
- To extend Data Model to company specific data

Through the CMP it was also possible to manage the operating effects of the train loading based on:

- An electronic data interchange
- A schematic version of train wagon

- a touch support, current assignment
- Loading processes for reach stacker and gantry cranes

Both operators, inland and maritime, were interconnected and could interchange data through the platform service developed by the intermodal operator.

CMP Portugal

Main actors involved in the development of the Portuguese CMP were four ports authorities, two shipping agents, a customer and two Logistic Services Providers (LSP)

Data and information exchanged through the Portuguese CMP developed is as follows:

Table 3. Data and information exchanged through the Portuguese CMP.

Inland	Maritime

- Planning – available services
  - Cost
  - Performance
  - Performance of LSP
  - Expected carbon footprint
- Booking
	- Planning – available services
	  - Cost
	  - Performance
	  - Performance of LSP
	  - Expected carbon footprint
	- Transport tracking
	  - Alert system
	  - Transport status

The Portuguese CMP should provide strategic and operational support to EU Corridor Coordinators and enable the connection between Location Based Services (LBS), and LSPs.

The CMP supports the interaction between the LBS layer and the Business Layer by providing service catalogues, accreditation and qualification of Logistic Single Windows (LSW), and the overview of what is being done in the operational layer to support European decisions.

The EU Coordination layer is composed by:

- Corridors Coordinators IT platform (strategic supervisors)
- Integration between Operational layer (LBS) and Business layer (Network of interoperable LSWs and other B2B (Business-to-Business) platforms – Define interoperability contracts/rules

- Service Providers (LSP) accreditation
- Location Based Services (LBS) accreditation
- Services Catalogue (LBS and LSP)
- Sustainability ecosystem management (Carbon-footprint design, guidelines and certification services)

The Business Layer is composed by:

- Network of interoperable LSWs and other B2B platforms (e.g. shipping portals)
- Logistic Service Client's (LSC) interface for sourcing and booking D2D (Door-to-Door) solutions and controlling their operations throughout the formalized supply chain
- LSW service catalogue and routing algorithms
- Business processes (sourcing, booking, execution, monitoring, completion, etc.)
- EcoBonus management (on behalf of EU)

The LBS layer is composed by:

- LBS Infrastructures (Motorways, Railways, Inland waterways, Logistic Platforms, Ports …)
- Transport regulators/country specific issues
- Port Community Systems
- Operators legacy systems
- Regulators legacy systems
- Constraints / Rules definition

The collaboration between LSWs/LIs and shipping portals allows LSC to search for door-to-door transport solutions combining services of multiple catalogues.

The main characteristics of the Logistic Single Window (LSW) are listed in the table below:

Table 4. Logistic Single Window (LSW) main characteristics.

Products / Services	Description	Objectives / Mission
1. Logistic Service Client Front Office	LSW module for Logistic Service Clients, supporting Sourcing, Planning, Booking, Execution, Completion and Monitoring operational processes. Support interoperability with client's legacy systems.	Providing Logistic Service Clients means to interact with LSWs, namely solutions for sourcing, supported by routing, planning and contract standard logistics services from a catalogue and customized door-to-door / multi-modal service solutions. Electronic booking service will support clients' shipments processes.
2. Logistic Service Provider Back Office	LSW module for Logistic Service Providers (LSPs), supporting services publishing, network design and interoperability between B2B platforms.	LSPs collaboration layer, enabling door-to-door optimized solutions design.
	CMPs guarantee LBS service catalogue/ Rules and constrains publication, ensuring interoperability with the business layer.	Provide contracts / rules for LBS publish their services / rules / constrains in order to guarantee interoperability with the business layer.
3. Logistic Service Provider Professional Frontend	LSW module for LSPs, supporting Sourcing, Planning, Booking, Execution, Completion and Monitoring operational processes.	Provides the LSPs with the means to interact with LSWs, namely solutions to manage request for quotations, bookings, control execution, complete services and monitoring operations.
4. Promotion of proprietary applications on LSW platform	LSW service supporting the promotion of proprietary applications, compliant with LSW platform.	Promote and advertise catalogue of LSW compliant applications.

Products / Services	Description	Objectives / Mission
5. Certification / Accreditation services	Services for LSPs' processes certification ensuring interoperability. LSPs accreditation in order to guarantee liability of operations.	Guarantee LSPs processes interoperability and accreditation, compliant with LSW processes.
6. Carbon footprint design and guidelines management	Service for definition and implementation of rules and guidelines for carbon footprint calculation, associated to each service type.	Define standards and benchmarks for carbon footprint calculation.
7. Carbon footprint consulting services	Consulting services for LSPs, supporting company sustainability assessment in order to calculate services carbon footprint.	Provide LSPs sustainability assessment report for carbon footprint calculation and certification.
8. Carbon footprint certification services	Service for LSPs carbon footprint certification.	Guarantee transparency and reliability for LSPs carbon footprint calculation.
9. EcoNet and message exchange Services	The ECoNet concept provides a standard and modular platform for collaboration and cooperation between organizations, It allows for the creation and participation in collaborative contexts of sub-networks that belong to the global collaborative network.	ECoNet provides a flexible collaboration and cooperation platform for organizations, capable to serve different kinds of business areas, with the necessary communication, security and coordination mechanisms.
10. EAP (Enterprise Access Points)	Single connections point for applications, able to relay information to other access points. It can be implemented in-house if data security for privacy is a concern. This is a decision comparable to use an external e-	Provide solutions for Logistic Service Clients and Providers to comply with common framework messages, in a format that is simple and cheap to adopt.

Products / Services	Description	Objectives / Mission
	mail provider or implement the server in-house. Actors declare support for profiles, ensuring interoperability at the semantic level	
11. Consulting and IT services for mapping proprietary/legacy applications to LSW services	Consulting and IT services to implement interoperability between proprietary/legacy systems and LSW.	Guarantee interoperability between proprietary/legacy systems and LSW.
12. Routing services	Routing mechanisms services that operates in services catalogues, complaint with LSW, enabling services combination and optimization.	Improve LSW capability to search optimized multi-modal solutions, based on a service catalogue.
13. Mapping services	Mapping services used to represent routing solutions in a geographic framework.	Allow Logistic Service Clients to visualize and interact with routing solutions presented by the system, in a location-based service.
14. Services Catalogue	Interoperable logistic service catalogue, containing LSP simple services and Logistic Integrators service networks.	Improve LSW service offerings in order to enable door-to-door solutions.
15. Mobile applications for Planning, Booking, Execution management, Completion	Simple APPs, for mobile devices, supporting decentralized activities, namely: Planning, Booking, Execution management and Completion.	Provide a cheap solution for real time and decentralized processes implementation.
16. Other commercial APPs	Simple APPs, compliant with LSW, supporting specific functionalities or processes.	Processes/Activities automation/optimization compliant with LSW.

INTELLIGENT FREIGHT CARS, NEW HANDLING MACHINERY AND PROCESSES

The use of intelligent freight cars will enable better use of existing capacity due to the optimization of processes, the minimization of unproductive elements such as empty runs and reducing energy costs.

This is achieved by making freight cars intelligent and connecting them to the internet. Railcars are equipped with sensors that supply data such as the precise position of a railcar, temperature in the storage area, etc. The system collect, save and process the information, and communicate with each other within telecommunication networks.

In case of perishable products, this kind of solution would be interesting, as nowadays-refrigerated containers are not commonly found in multimodal railway transport for several reasons. One of them is the reluctance of the customers to lose the cargo due to the lack of prepared terminals and also the need for maintaining the cold chain conditions during transport. Thus, temperature sensors providing valuable information about storage conditions and cold chain warehouses in intermodal terminals, could give this market a chance in front of road transport.

The levels of automation at terminals will increase strongly. Terminals will use more and more automated and robotized equipment, such as automated cranes and Automated Guided Vehicles (AGV). Not only the physical activities will be automated, but also supporting activities, such as planning, scheduling, container identifications, seal recognition checks and container or cargo identification. This trend of automation has started in high wage countries (see for example the port of Rotterdam and Hamburg), but is spreading to middle wage countries as well. The automated terminals require fewer personnel to achieve high throughput than manual operated terminals. However, higher educated personnel are required because of the more complicated types of equipment and software that will be used for automation on terminals.

It should be taken into consideration that this type of innovation, requires specific terminal layouts.

Any case, it is expected that all these solutions will bring an improvement into the security, the reliability and the performance of the whole infrastructure, and therefore will be tested into the 8th Dimension performance tests under those guidelines.

2.2.2.3 New materials

Concrete is the most used man-made material. The production of concrete in the industrialized world annually amounts to 1.5-3 tonnes per capita. Concrete is used in the construction of buildings, bridges, dams, roads, tunnels – basically every contemporary construction contains concrete. Due to its mechanical properties, durability, variability and availability of resources, concrete represents the mostly widespread structural material for building construction.

Cement production is associated with large energy consumption and consequently with high CO_2 emissions. World cement production has increased 12 times in the second half of the last century; the cement industry produces at present about 5 - 7% of global man-made CO_2 emissions. Moreover, high concrete use is associated with high transport needs and demands on production and demolition processes within the entire life cycle. This all has significant impacts on the environment.

Current concrete developments, production technology and the development of concrete constructions during last twenty years have led to a quality shift of technical parameters and also of related environmental impacts. Due to mix optimization, new types of concrete have significantly better characteristics from the perspective of strength, mechanical resistance, durability and resistance to extreme loads. Concrete is gradually becoming a building material with a high potential for environmental impact reduction. Better knowledge is still needed about the technological processes and their impacts with respect to a wide variety of sustainability aspects within entire life cycle – from acquisition of materials, through production of concrete and concrete components, construction, use, up to demolition of the concrete structure and recycling.

The technical and technological qualities of concrete have a significant impact on many aspects of structure sustainability within the whole life cycle. The evaluation of complex quality considering all important and relevant aspects of sustainability (environmental, economic and social) requires a holistic approach. This could be achieved by applying an Integrated Life Cycle Assessment - ILCA.

One objective of WP8.1 is to define a methodology for the integrated life-cycle assessment of concrete structures taking into account the main essential aspects of sustainability such as: environmental aspects, economic aspects and social aspects

throughout the whole life of the concrete structure. This meant covering all technical quality issues, including safety, serviceability, durability, maintainability and repairability, which represent key issues in the design and construction of high quality concrete structures. The aim is to establish a basic methodology assist in the development of design and assessment tools focused on the sustainability of concrete structures within the whole life cycle.

Traditional approach

The traditional approach to designing structures (including concrete structures) has commonly focused on the required performance parameters (usually defined in corresponding standards), while maintaining an acceptable construction cost. The time interval usually applied for the assessment of the performance quality has been limited to the construction stage, or to a period of a few years after completion of construction during the guarantee period, or when visual signs of deterioration have been observed. Unfortunately, this approach is still applied in most construction practices.

New conceptual approach

By contrast, the new conceptual approach to the design of structures is an Integrated Life Cycle Design – ILCD – representing a multi-parametric design of structures with various structure definition levels (functional units: material, components, structure) and aimed at achieving optimum performance parameters as seen from a wide spectrum of sustainability criteria throughout the entire life cycle. Integrated life cycle assessment – ILCA represents a multi-parametric assessment of the structure within the whole life cycle considering all essential aspects of sustainability, such as environmental, economic and social aspects. This approach can be defined as Life Cycle Sustainability Assessment – LCSA.

The ILCD approach is based on the design of the material, component and structure with pre-defined performance – performance based design. The demands result from the anticipated performance of the material and component in a specific structure during the entire life cycle. This process requires the pre-determination of structure life cycle scenarios. In other words, the design should involve optimization of all components in all major phases of the life cycle: from cradle to grave – from the production of material and elements through construction, use and maintenance to the demolition of the structure or from cradle to cradle when considering also recycling or reuse of

components. The condition for achieving these performance parameters is integration of various design aspects and anticipated degradation and wear of these components. Consequently, all relevant and important criteria of sustainability should be considered, including economic, environmental and social ones.

Integrated optimization of structures is a process targeting a maximum level of sustainability throughout the reduction of negative environmental impacts, while maintaining the structure's serviceability and safety throughout its entire expected life. An owner-defined serviceability and reliability level should be achieved while keeping the cost and environmental impacts on a reasonable (minimum) level, and technical and social performance at a maximum feasible level.

Concepts about corrosion

Corrosion in reinforced concrete is today one of the main diseases in our buildings, especially in areas near the coast, with aggressive environments. Corrosive lesions at concrete infrastructure are difficult to repair and the prescription of an appropriate treatment becomes a complicated task.

The durability of reinforced concrete is the result of the protective action of concrete on the steel bars. This protection can be seen as double. On the one hand, the cover is a physical barrier against corrosion. On the other hand, the high alkalinity of the concrete develops over the steel bars a passivation layer that keeps unchanged indefinitely. Passivation means that the steel is coated with a transparent oxide layer that acts as a barrier preventing further oxidation.

The threat of corrosion starts once the passivating layer disappears, caused by carbonation and chloride attack.

Carbonation is that the alkali (or basic) compounds of the concrete react with carbon dioxide (CO_2) from the atmosphere, reducing the alkalinity of concrete. Decreasing alkalinity means a widespread depassivation of the steel bars.

Chloride attack is that the chloride ions have the ability to destroy at one point the passivation layer, causing “pitting” corrosion. Chlorides can be in the concrete for two reasons, either because they are added with components (additives, water, etc.) or because they penetrate through the pore network. The latter situation occurs in marine climates or areas where deicing salts are used. Likewise, the cracks of reinforced

concrete are a quick access to aggressive. Once the steel bars are corroded, they increase in volume, creating more cracks through which contaminants are entering.

Once unprotected steel bars, the factors that cause of corrosion are the simultaneous existence of moisture and oxygen. Moisture provides the aqueous medium in which the oxidation reaction occurs. The higher the humidity level, the lower the electric resistivity, that's to say, opposing the movement of electrons. Thus, if the pores contain very little moisture, the electrical resistance is very high and the corrosion process is very difficult. However, if the pores are fully saturated with water, but the resistivity is low, oxygen has to be dissolved in water to reach the steel bars. Under these conditions it is said that the process is controlled by the oxygen supply. Maximum rates occur when the moisture content is high but the pores are not saturated.

In this case, the electrical resistivity is low and the content of oxygen sufficient to cause corrosion.

Maintenance strategy

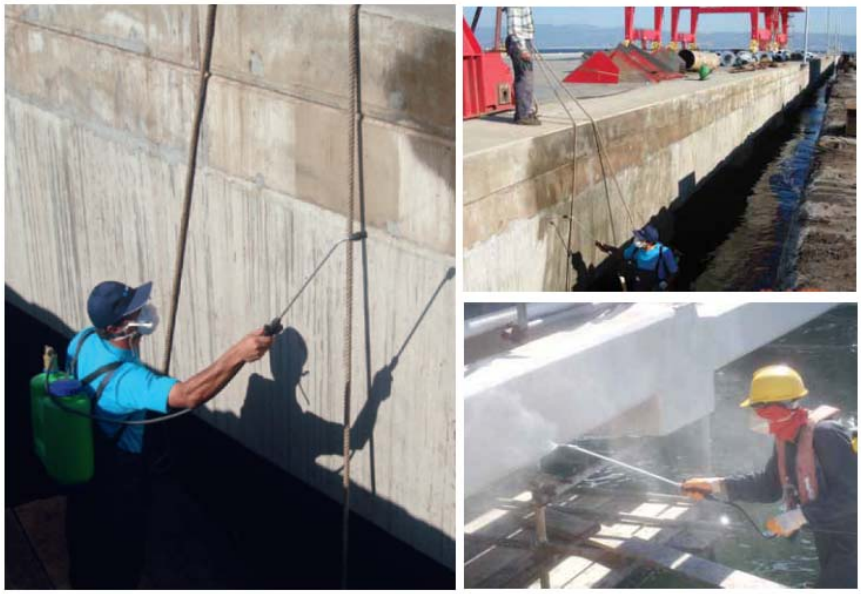
To achieve for example 100-year service life with depassivation of rebar as the limit state in a given situation makes it important to incorporate state-of-the-art durability technology into the project. The basic methodology in this respect is to define exposure conditions for a number of relevant exposure classes, and then use these classes as a basis for a strategy to be consistently incorporated in the design and specification. For each exposure class the relevant deterioration mechanisms must be defined, and the strategy must be developed accordingly.

A close dialogue should be established between the designer and the Owner in order to clarify the decision process in relation to risks and consequences for the different durability strategies set forward. One durability strategy could be to use stainless steel reinforcement for exposed areas on the structure. The concrete cover needs not to be as big as with black steel reinforcement and the crack width could be accepted wider as the stainless steel has a much higher threshold value for chloride induced corrosion. This however makes the structure less robust. On the other hand using cathodic protection will often mean that the construction costs are reduced, however a lifelong operation and maintenance has to be foreseen. Other strategies, surface coating, sacrificial reinforcement layer, epoxy coated rebar, etc., all have different pros and cons that need to be discussed with the Owner.

Corrosion inhibitors

MasterProtect 8000 CI BASF is used as migratory corrosion inhibitor, colorless low viscosity liquid silane based, besides organofunctional corrosion inhibitors. It is indicated for protection against initiated corrosion in reinforced concrete structures, as well as for preventing corrosion in the same type of structures.

Photo 1. Corrosion inhibitors application for repairing and protection of concrete structures



Effects on concrete	Effects on steel
Concrete waterproofing It is provided with hydrophobicity, both the concrete surface as the pore network. The product permeates the capillary pores of the concrete and adheres to its surface forming a chemical bond of great strength. The capillary network is not completely saturated, leaving enough space to allow the water vapor molecules go through; but not those of liquid water, since they are larger. **Lower humidity of concrete** The difference in size between the water molecule and the water vapor enables the	**Corrosion rate is reduced** The corrosion rate depends on the level of moisture in the concrete and on the access of oxygen to the depth of the reinforcements. A decrease in the access of water means a level of almost zero moisture, whereby the corrosion rate slows to values below 0,2µA/cm², limit beyond which it is considered that the reinforcements are in the passive condition, and therefore protected against corrosion. **Electrochemical reactions between the anode and cathode are blocked**

Effects on concrete	Effects on steel
concrete to be waterproof but breathable at the same time. By having hydrophobicity and prevent access of water from the outside, moisture in concrete is greatly reduced, which drastically reduces the corrosion of reinforcement steel bars. Increase in electrical resistance The electrical resistance of concrete is directly related to the concrete opposition exerted against corrosion and at the same time is inversely proportional to the moisture level in the capillary network. This occurs because the concrete, in the complete absence of moisture, lacks electrolyte (water), which functions as electrical conductor and, therefore, as the oxidizing agent. Therefore, the greater the amount of water, the easier the corrosion occurs. Waterproofing concrete and decreasing the humidity means an increase in the electrical resistance against corrosion. **Reduction in access of chlorides** Chlorides, dissolved in water, penetrate concrete. Preventing the access of water, the entry of chlorides is significantly reduced. **Avoid incipient anodes** When the concrete contaminated by chlorides is repaired using the traditional technique of patching, the problem of corrosion to adjacent areas can be transferred (mechanism called "incipient formation of anode"). Remove all chloride-contaminated concrete would be necessary and, even though, corrosion may still occur if the concrete is not sufficiently alkaline. The implementation of the migration inhibitor works electrochemically by preventing the flow corrosion current, drastically reducing the pore water. This prevents the formation of incipient anodes and is equally effective against corrosion by carbonation of the concrete. **Does not change the appearance of the concrete** It is a transparent product that retains the appearance of concrete.	Electrochemical reactions between the anode and cathode occur in aqueous media; the fact of reducing the access of water blocks these reactions. Furthermore, the material has high affinity with metal, being attracted by it and chemically joining to the oxide layer. For that reason, in addition to repelling chloride ions (Cl-), causing timely depassivation of steel, and inhibit corrosion of the damaged areas, the product protects steel passivation layer in those areas not affected by any pathology.

LCA of environmentally optimized floor structures

Waffle and ribbed reinforced concrete structures are widely used in building constructions. The structural advantages of the ribbed cross section are bidirectional – two-way span structure and lower self-weight. Waffle floor structures can reduce material consumption to 50% in comparison to full reinforced slab while keeping similar static parameters. Utilizing high performance concrete can save another 20%. The weight reduction of concrete floor structures is recently gaining importance with regards to increasing demands on construction materials savings and on further savings related to transportation. Reduced self weight of ribbed shape represents lower load and consequently lower reinforcement consumption of floor slab itself and lower load on supporting structures. Additional savings are in transportation cost. The motivation is based not only on economic but also on environmental advantages followed from sustainable development criteria.

Partial task of the research could be to verify the option of slender waffle and rib floor structures design with minimized upper deck thickness (up to 30 mm). The slab of this thickness cannot be effectively reinforced by conventional reinforcement and thus the possibility of high performance fibre concrete utilization was verified while maintaining structure reliability on high level.

Polypropylene Fiber Reinforced concrete (PFRC)

Fibre reinforced concrete (FRC) is a suitable material solution for many structural applications. Besides advantages in construction and cost, FRC provides structural benefits and superior durability properties compared to conventional, steel bar reinforced concrete (RC). The capacity of the fibres to reduce crack width and deflection is often more important than the increase in tensile strength of the concrete. Furthermore, the addition of fibres enables load carrying capacities after cracking and allows for stress redistribution, which makes the otherwise quasi-brittle behaviour of the concrete more ductile and the whole structure more robust. Several research investigations have shown that the durability of polypropylene fibre reinforced concrete (SFRC) under chloride exposure is superior to steel bar reinforced concrete (RC). Among others, it has been demonstrated that the chloride threshold of fibres in FRC is 5-10 times higher than that of rebars in RC (Dauberschmidt, 2006). Under

practical conditions, corrosion in SFRC is generally limited to fibres protruding from the surface or to the surface layer that may be affected by leaching or carbonation. Rust stains on the surface may occur, however chloride induced corrosion within a SFRC member is highly unlikely. Furthermore, even in the highly unlikely event of corrosion of internal fibres, spalling and cracking due to the formation of voluminous corrosion products (a common durability issue for RC) cannot take place for FRC, because the individual cross-sections of the fibres are limited.

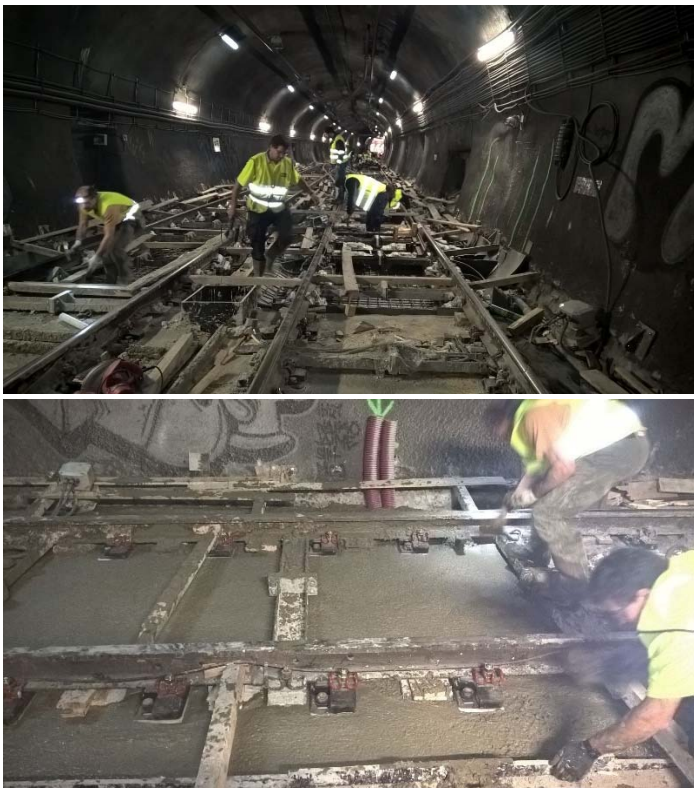
Polypropylene fibers is a beneficial material solution for projects located especially in the aggressive environment characterised by extreme high concentrations of chlorides and sulphates in the soil, sea and groundwater. Corrosion of polypropylene fibres can be safely excluded for the entire cross section made of FRC, even if exposed to the high chloride concentration (Cl). Consequently, the durability design is determined by the risk of sulphate attack of the concrete itself and the corrosion risk of additional splitting rebar reinforcement if used. Corrosion of fibres is foremost an aesthetic problem, but it neither interferes with the durability nor with the structural performance of an uncracked FRC member. Due to the fact that steel fibres do not require a concrete cover, they help to prevent local damage like wear, spalling at edges and chipping of corners, which is advantageous. FRC is further characterised by low production costs, which is particularly relevant for slabs or pavements. The potential of adopting Polypropylene fibre reinforcement will definitely gain more momentum in the future, not only pavements, slabs or tunnels, but also for bridges or structural parts of bridges.

The use of Polypropylene fibre reinforcement looks promising in case of FRC reinforced bridge deck overlays and edge beams. In Nordic countries such as Sweden and Norway there is a long tradition for using fibres for overlays on bridges. FRC overlays can potentially replace the traditionally used bridge insulation protecting the structural concrete and reinforcement. Moreover, FRC overlays are expected to be more durable and tough for wear from traffic. Thus, FRC overlays are expected to be much more cost effective than the traditional bridge insulation which needs replacement after 20-30 years depending on the

amount of traffic. Similar enhanced durability is expected for edge beams of bridges or other bridge barrier systems (which are in Nordic countries often prone to heavy reinforcement corrosion due to the use of de-icing salt during wintertime) if the traditional steel reinforcement can be partly or fully replaced by Polypropylene fibre reinforcement. Other possible areas where steel fibres may be used are bridge columns and pre-stressed elements where the conventional steel reinforcement is replaced by Polypropylene fibres.

Photo 2. Fiber distribution in fresh fiber reinforced concrete

Photo 3. Recent applications of polymeric fiber reinforced concrete in Madrid underground



Flooring

Mastertop cementitious coatings – economical hard cementitious toppings and dry shake floors that are based on sand, special cements, color pigments and hard aggregates. They feature extremely high mechanical resistance and therefore are well suited for factories and warehouses, giving outstanding cost-effective solutions for new build projects.

Mastertop epoxy coatings – commonly used in factories and warehouses because of their aesthetics, ease of cleaning, mechanical strength and resistance to corrosive liquids such as chemicals, oil, salt and diluted acids.

Mastertop polyurethane coatings – seamless flooring systems that are crack and scratch resistant, UV resistant, exceptionally tough, attractive and pleasant to walk on, sustainable and very durable. Typically used in environments such as public spaces, retail, commercial, education and healthcare sectors.

Ucrete industrial flooring – advanced polyurethane flooring technology for harsh environments. Demonstrates extraordinarily high resistance to mechanical, chemical and thermal stress, retaining its integrity at temperatures of up to 130°C. Has been proven for more than 40 years to meet the most stringent hygiene and cleanliness requirements. Ucrete is widely used in the food and beverage, chemical and pharmaceutical industries to provide long-lasting flooring solutions in aggressive environments.

Waterproofing Solutions

One of the most critical challenges facing concrete structures today is moisture penetration. Interior or exterior, above or below grade, unprotected structures suffer from water-induced damage, including deterioration and corrosion caused by alkalis, salts, acids and mold. Liquid-applied high performance membranes and cementitious coatings offer long-lasting protection against the most damaging conditions.

2.2.2.4 New track maintenance processes

Based on several of projects, VIAS has developed new efficient and technologically advanced solutions to carry out maintenance of the rail network. Therefore, these new processes and expertise will be included into the proposal as potential improvements inside the 7thD.

The OPTIRAIL project, in which VIAS participated, has developed a comprehensive framework, based on Fuzzy and Computational Intelligent techniques, to manage all the elements that are relevant for track maintenance, predicting future conservations needs with optimal allocations of resources.

This model was developed based on the know-how of the organizations involved in the project. This know-how was extracted from expert knowledge and data on ICT systems.

All of this allows for a better understanding of complex infrastructure behavior, extending consequently, the lifecycle and durability of networks and reducing the environmental impact.

OPTIRAIL ensures a more effective planning of the management and activities of infrastructure maintenance based on expert knowledge accumulated over years of experience and to the information stored in the monitoring and maintenance management systems.

<u>Tool and conceptual design</u>

Nowadays, railway maintenance involves many different tasks based on the information and knowledge collected from a wide range of heterogeneous sources, affecting the way each railway contractor or administrator deals with maintenance. The issue regarding to the railway maintenance is based on three layers from the point of view of OPTIRAIL:

- ✓ Physical layer
  - Physical parts of architecture: sensors and railway sections
- ✓ Logical/data layer
  - Includes data storage and acquisition/processing software
  - Business/domain logic: OPTIRAIL Layer
  - Information processed in order to reach project goals

- SOA (Services Oriented Architecture) based client-server architecture

Three level architecture:

- Level A: Data & Knowledge acquisition from ICT and Data storage
- Level B: Business logic, implemented based knowledge models
- Level C: User Interface, devoted to interaction Human-Machine

This conception is an open conception permitting new cases, models, monitoring systems, etc.

To acquire this diversity, the design of OPTIRAIL framework is based on an Open concept of Services Oriented Architecture (SOA) and is defined and implemented to reach the final goal: support railway maintenance decision making based on knowledge. This proposed framework is arranged on the three mentioned levels or layers: Physical, Logical and Business layers, embracing from data collection, processing and modelling, to decision making and interface with users.

Several quality qualifiers (such as safety index, degradation index and OPTIRAIL index) have been considered to supervise the track conditions along cross-border railways corridors. Their implementation can aid to make a simpler, easier and more collaborative domain in which railways corridors are managed and categorized by common standards and qualifiers, allowing stakeholders to develop their business not only in their local and national markets but international ones, improving the capabilities of European companies to interact in global markets.

<u>Development of Fuzzy and Computational Intelligence based models for maintenance management</u>

Several data and knowledge based models were developed in OPTIRAIL, based on different CI approaches such as: Fuzzy rule-based systems, neural networks, random forests, support vector machines, evolutionary algorithms, and other methods, to enable a better maintenance tasks and planning.

On the one hand, deterioration models together with maintenance operation effect models make it possible to model the behavior of the track and to predict future quality measurements, across different scenarios of possible intervention.

On the another hand, a multi-objective optimization framework then allows us to use this knowledge to find maintenance plans optimized for specified objectives, such as minimizing intervention cost and maximizing capacity, at the same time, while guaranteeing safety.

OPTIRAIL improvements in INTERMODEL project

The accuracy of the derived models has a clear dependency on the quality and availability of data. The overall system and methodology of OPTIRAIL have been validated. The effectiveness of the systems for the case studies can be greatly enhanced by using larger datasets. This is a key requirement to have good models and thus make effective maintenance decisions. In addition, the open and adaptive architecture of the OPTIRAIL framework allows it for performance improvement along the time, with a continued learning process.

In order to reach a single European market, common practices should be defined, as a common interpretation. There is a need for using the same language along the corridors, and artificial intelligence could be the key to develop standard practices and procedures.

In order to implement or use OPTIRAIL in INTERMODEL project will be necessary to know what data is available from each case study scenarios and what tools are being used to managed it.

***Data refers to**:*

- A total description of the track, from substructure to superstructure.
    - Materials: type of rails, sleepers, fastenings and definition of cross section;
    - Age of materials.
- Operational information of the track: number of trains, tons per axe, etc.
    - Capacity and availability of the track.
    - Cost for delays.
- Available information related to maintenance operations:
    - Inspections: geometrical, dynamic, sonic, etc.
    - Traffic thresholds, the quality index, etc.

- Work orders (tamping, renewal, etc.)
- Cost.

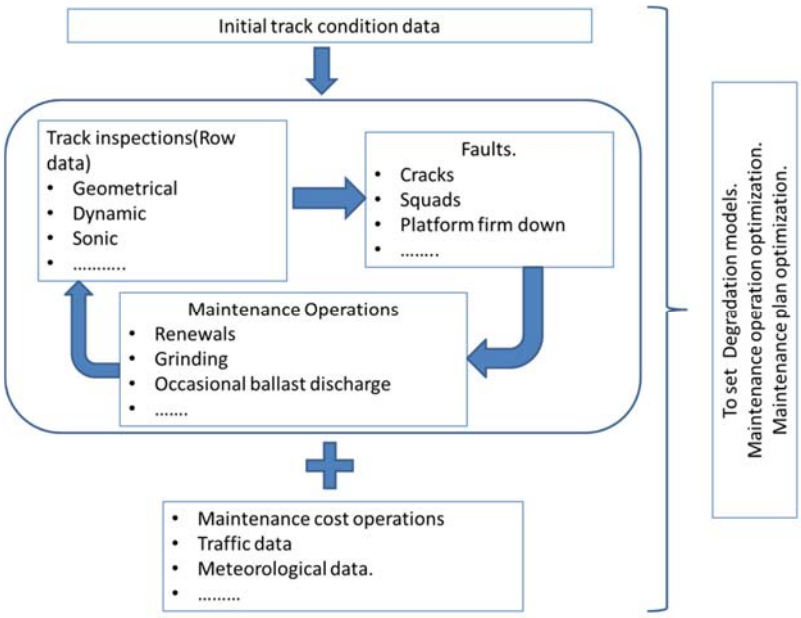
The models developed by OPTIRAIL project are based on the geometrical data, and after a detailed study of the methodologies used in different countries, it was decided to propose a minimum set of measurements as the basis and foundations of the decision-making tool for maintenance. This minimum set of parameters is composed by those defined in the European standard EN 13848- 1:2003 +A1:2008. These are listed below:

- Track gauge
- Longitudinal level
- Cross level
- Alignment
- Twist

The main reason for selecting these parameters is that the European standard is accepted by every country in the European Union. However, it is mandatory to highlight that although the meanings of these measurements are the same along the corridors, the way of storing the data is not the same for the different railway administrators. In that sense OPTIRAIL treats the data into a common template.

Regarding the necessary data to build the models, it is very important to have the row data. Most common data is just to store or use for a maintenance operation/decision. Row data allows knowing what the real evolution of the track is, so therefore the accuracy of the model is better.

Figure 3. Summary of desired data in order to make a prediction.



Innovations developed within OPTIRAIL project

The most important innovation carried out in OPTIRAIL is a new maintenance model, based on Computational Intelligence techniques. This system builds models for railway infrastructure and elements upon which the deterioration of the assets is predictive. With a knowledge base extracted from experts, and the deterioration models an optimal maintenance schedule is produced.

As abovementioned, the accuracy of derived models has a clear dependency on the quality and availability of data, which is a key requirement to have appropriate models and thus make effective maintenance decisions.

Other issue that OPTIRAIL tries to solve is the cross boarder coordination. For this purpose, the consortium propose a conceptual solution after the approval of several European Railway administrators. However, the consortium realized that it was not feasible to develop and implement a real solution, but just a conceptual one.

Under this perspective, OPTIRAIL proposed to develop a quality index standardization that could be used in cross-border operations based on the following three values:

Safety index: percentage of maintenance sections where geometric parameters exceed safety thresholds. These safety thresholds are the ones defined by the European standard as immediate action limits.

Degradation index: percentage of maintenance sections where geometric parameters exceed alarm thresholds. These alarm thresholds are the ones defined by the European standard as alarm limits.

OPTIRAIL index (OI): is the predicted time in which any of the geometrical parameters will overpass its security threshold in the analysed section of the track.

In order to apply the OPTIRAIL index defined, a conceptual scenario was created as a sector where some of its attribute values do not change along it. A track sector can be assigned to different scenarios along time because its property values change over the time.

The OI is computed by the OPTIRAIL prediction model and the OI is used by all operators in all circumstances, including cross-border freight corridors.

The OPTIRAIL optimization will be applied to a set of scenarios defined by the maintainer. The algorithm will take into account all the available information and data for those scenarios, their predictive models and the optimization criteria.

<u>Restrictions to consider</u>

The right properties of the models developed in OPTIRAIL project belongs to OPTIRAIL Consortium, so it is unfeasible to take them into consideration for the pilot terminals according to the consortium agreement nº 314031.

However, VIAS will define different maintenance tasks to be carried out in the line that will be integrated in the Integrated Planning Environment developed within INTERMODEL EU project (performance, costs, equipment and materials...). In this way, these work orders or maintenance tasks guidelines will be taken into account not only in the 7thD but in the operational simulation of terminals.

2.2.2.5 Integrating modes of transport and consolidating transport volumes

Consolidating transport volumes and consequently, reducing traffic levels, is one of the solutions to be able to offer individualized products and respond as well as possible to customer requirements.

In order to expand services offered and reducing costs, logistics companies tend to cooperate between them and consolidate transport volumes at the same time than integrate different modes of transport.

This allows transporting goods in a more environmentally friendly way and makes better use of capacity.

3. Improvements foreseen for real pilot terminals

3.1. Port of La Spezia

The Port of La Spezia is one of the most important container terminal in the whole Mediterranean Sea. It is a core port on the European corridor TEN-T Scandinavian – Mediterranean. The Ligurian terminal is the third Italian port for container handling overall, with over 1,3 million TEUs/year, and it is at the first place by percentage of containers transhipped by railway million to and from the port, thanks to an overall share that is about 30% of the total.

La Spezia main challenges in the short and mid-term are the new railway terminal design and the extension and improvement of the Corridor Management Platform (CMP), which was initially developed through the WiderMOS European project, previously mentioned.

New railway terminal design

The growth of the entire container terminal makes a new project necessary in the short term. The goal of increasing the traffic to 2,3 million TEUs/year for the entire port area, and the increase up to the 50% of the total volume of containers carried by train could only be achieved with the construction of a new port terminal and a new rail area with higher capacity and higher efficiency than the current one, that works now almost at its maximum capacity.

The project will provide new 9 tracks, at least 570 m long, dedicated to the arrivals and departures of trains coming from/going to the national railway, and a new layout of the maritime train station, which will be simplified in comparison with the as-is situation. In addition, the 10th track will be used by shunting locomotives.

Within the container terminal, a new train buffer for loading/unloading containers on cars will be built. Five tracks 550 m long are designed. In addition, a unique rail traffic control center located in the building of the maritime train station will be built. The control center will manage the movement of trains and shunting operations from the port area to the national railway link. In this sense, a 'synchromodal shunting software tool' will be developed in order to support the shunting operation in the Port of La Spezia and in the linked inland terminals, able to help operative departments of the shunting companies to a real time control of the shunting operations in the railway area.

Actually shunting operators are not able to know/check in real-time the trains arriving and departing from the railway-station and also view/edit remotely their track position. The receiving and delivery of goods at maritime terminal by rail is generated through maritime railway stations, where tracks can be found dedicated to temporary waiting/idle before the shunting operation from/to terminal and railways network.

At this moment, a dedicated company is managing the following activities:

1. Taking delivery of trains at Inbound/Outbound railways station;
2. Providing shunting from/to maritime terminal and railways stations or between stations; and
3. Managing receiving and delivery plan of trains to/from terminals, according to the arrival and departure timetable of trains.

Activities are currently performed with tools that already allow reaching high performances and efficiency in the rail traffic operations. However, they could be improved, with the further digitalization of procedures applied. In particular, the rail checker manually records the positioning of trains on the tracks at station. The information is transferred to the control room by phone calls or handwritten paper. Therefore, the control room has no real-time information on the real situation of tracks occupancy and shunting continuously performed, with limitation on improved planning.

Thanks to the 'synchromodal tool' and to a specific monitoring screen, the operators will have an overall real time view of the rail cars being placed in the shunting area and on the internal rail tracks. The software will work as a decision making tool that helps to decide if shifting the total train or even a group of cars from a track to another and communicate this instruction by means of simple steps. The shunting operators, working on the shunting area, will receive a real time signal of alert on their tablets and, then, they will execute the requested operation, giving a feedback to the operative room. Moreover, the system will give the possibility of monitoring live status of track occupation. A continuous improved planning process will be available; therefore, the overall capacity of the railway station will be increased. The software platform would also facilitate the dispatch of train documents.

The BIM model of the terminal provided by INTERMODEL EU project will be integrated within the 'synchromodal tool'. Indeed, the two actions will obtain some important results: reduced dwell time in the yards, improved connection performance,

improvement in on-time train departures, improved train/car velocity and better coordination of the arrivals/departures with the scheduled trains on the railway.

Extension and improvement of the CMP

Both within the national and the international contexts, several stakeholders involved in the supply chain have implemented different informative and administrative data sets and standards. Moreover, the transport and logistic industry is still highly based on paper – based exchanges and these facts make the entire bureaucratic process complex and ineffective, where hardly the computer systems are integrated with paper ones.

Meanwhile even more logistic operators, such as port and inland terminals, port authorities, transport operators, shipping companies, etc., are increasing their use of technologies for automating and digitalizing procedures, targeting to increase their performances. The Port of La Spezia has developed an innovative framework called Corridor Management Platform (CMP) according to the WiderMOS project abovementioned. The CMP is an information pipeline capable to make interoperable the information systems of the stakeholders involved in a national intermodal corridor by developing new functionalities and services in terms of exchange of railway information and exploiting innovative customs procedures.

Since the international part is not covered yet, the main goal of the extension of the Corridor Management Platform is to follow up the existing platforms with new pilot activities aimed at boosting the interconnection between international logistic actors by developing tools capable to make interoperable their systems. In addition, a specific focus will be placed on the integration of the Corridor Management Platform with international existing rail platforms.

A specific focus will be on cross border exchange of logistic information inside a set of pilots with some selected EU logistics actors in order to test a 'Cross Border logistic fast corridor information pipeline' model, in particular with Switzerland and Germany. A specific focus is also placed on the integration of the Corridor Management Platform with international existing rail platforms. The model will test a list of simplifications from the logistics point of view, with both Maritime and Inland aspects, allowing increasing security and visibility on goods along the supply chain.

The BIM model of the terminal provided by INTERMODEL project will be integrated within the 'Cross Border logistic fast corridor information pipeline'. Both inland and port terminal operators will benefit from having access to relevant information in advance, digitalizing administrative and operational procedures and increasing operational productivity. Productivity increases have many positive effects as they can generate: 1) Improved profit margins for the terminal operator, 2) Capacity to handle more traffic in a year in the same terminal and 3) Lower terminal handling charges for shippers.

3.2. Melzo inland terminal

Melzo inland terminal is a container and intermodal terminal with a large rail infrastructure, whose main objective in the short and mid-term is to enhance the overall terminal performance, thus improving handling and rail productivity.

The improvements that Melzo terminal expects to implement are the following:

- Conversion of F3 warehouse into temperature controlled warehouse in order to be able to cross-dock temperature controlled goods from maritime containers to intermodal swap bodies or regular trailers;
- Implementation of a third gantry crane in order to have a beack up equipment but also to increase the handling productivity and rail productivity and enhance the terminal performance in terms of handled number of train per week;
- Building 4 new shunting rail tracks in order to have a better buffer capacity in the shunting area;
- Building a second gate in/out in order to better serve the gantry crane area of the terminal avoiding trucks to run around the terminal to/from the gate to/from the gantry crane area.

4. Methodology for improvements/innovation selection

To accomplish the objectives of the present report, after a comprehensive analysis of relevant logistics trends, a questionnaire survey has been undertaken with relevant actors related to intermodal terminal and key experts within the Consortium in order to ascertain the relevance of different innovative solutions and improvements and views on own experience.

Stakeholder consultation and key experts within the Consortium is essential to choose the most appropriate innovations to be implemented in the pilot cases in order to:

- Enable stakeholders and key actors to provide input to the setting of the four pilot cases included in the project;
- Ensure that a relevant view of the current global trends in logistics is captured by the study to support the results of the decision-making tool to be used during the project-planning phase and thorough its life cycle.

The following objectives were defined for the stakeholder questionnaire:

- Identify technological and operative innovations to be implemented in intermodal terminals and the rail interconnection between them;
- Evaluate the importance of solutions proposed and perspectives about them;
- Know the opinion of different actors on new solutions included in the questionnaire;
- Identify new technologies/innovations that are being deployed that could be also implemented in the pilot cases.

Key tasks undertaken as part of the questionnaire survey include:

- Questionnaire design;
- Stakeholder list;
- Questionnaire distribution; and
- Data checking.

The methodology used for each of these tasks is detailed below:

Questionnaire design

After the comprehensive identification of global logistical trends, the structure of the questionnaire was defined. Mainly, it was based on addressing the objectives abovementioned.

The table below provides an outline of the questionnaire structure and the question topics within it. The full questionnaire can be found in Appendix I of the present report.

Table 5. Outline questionnaire structure

Sections	Question topics
New trends to be implemented in the next – years in your organization and importance (ranging from 1 – not important, to 5 – very important)	Digitization Internet of Things Intelligent traffic guidance systems Intelligent freight cars
	Integrating modes of transport and consolidating transport volumes
	Technology Modular container construction Alternative container design (bulk, cold chain) Automatic coupling Waste heat utilization Autonomous assistance systems Autonomous driving in rail transportation Alternative propulsion technologies
	Others
Experience with new solutions implemented, if any	
Recommendations	

Stakeholder list

Besides the experts in logistics within the Consortium, around 35 organizations related with logistics and transportation were sent the questionnaire. Among them are port authorities, logistics operators, intermodal terminals and railway operators.

The organizations contacted belong to five different EU Member States (France, Spain, Italy, Germany and Netherlands).

Questionnaire distribution

The survey was sent via e-mail to all Consortium partners and other stakeholders. The e-mail contained not only the questionnaire survey, but also information describing the context, scope and objectives of the consultation.

The key findings from the questionnaire are discussed in Section 5.

Data checking

Data received from the questionnaires was gathered and analysed with the goal of selecting the set of improvements to be implemented in the four pilot cases.

5. Selection of improvements and innovations

In this section, the findings from the activities previously described are outlined, providing the information needed to define the set of improvements and innovations that will be implemented in the pilot cases.

The table below gathers the answers received.

Table 6. Answers gathered from the questionnaire survey (1 – not important; 5 – high relevance)

INNOVATIVE SOLUTION	Northern ports		Northern intermodal terminals		Logistics operators		Southern ports		Southern terminals		Cargo handling equipment companies		Logistics consultants		Cartagena	
1. Digitization																
Internet of things	x	5	x	5	x	3	x	4	x	5	x	5	x	5	x	3
Intelligent traffic guidance systems	x	4			x	5		3	x	3	x	5	x	4	x	5
Intelligent freight cars	x	4	x	3	x	2		4	x	3	x	5		2	x	4
2. Integrating modes of transport and consolidating transport volumes	x	5	x	5	x	5	x	5					x	5	x	4
3. Technology																
Modular container construction		1			x	2	x	5	x	3	NA			4		1
Alternative container design (bulk, cold chain)		1			x	2	x	5	x	3	NA			4		1
Automatic coupling	x	3			x	3		4	x	4	NA			3	x	2
Waste heat utilization	x	2			x	3		3			x	3		3	x	1
Autonomous assistance systems	x	4	x	3	x	5		3			x	5		3	x	2
Autonomous driving in rail transportation		5			x	3		3	x	5	NA			3	x	3
Alternative propulsion technologies	x	3	x	3	x	4	x	5	x	5	NA		x	4		1
Electromobility																
Compressed Natural Gas (CNG)																
Liquified Natural Gas (LNG)																
Hybrid technology																
Hydrogen																
4. Others			x	3												

Higher relevance correspond to:

1. Integrating modes of transport and consolidating transport volumes
2. Internet of Things
3. Autonomous driving in rail transportation and intelligent traffic guidance systems
4. Autonomous assistance systems and alternative propulsion technologies (especially LNG)
5. Intelligent freight cars
6. Automatic coupling
7. Modular container construction and alternative container design
8. Waste heat utilization

Main pros, cons, and opinions about the relevance of different innovations and own experience are gathered in the following table:

Table 7. Main finding from the questionnaire survey

Digitization
Internet of things - The more data you get the better it is to find solutions for more efficient working; - Container RFID, electronic seals, port equipment and condition monitoring, for example, are key elements for the development of an 'intelligent' port; - Digitization affects the whole organization but also third parties. Intelligent traffic guidance systems - Navigation solutions, routes recommendations – efficient use of the infrastructure – standard among some logistics operators (integration of on board devices and transportation management systems – track and trace; web based booking of pick up and delivery spots; routing for drivers and lead time analyses) - Intelligent freight cars can be used in the mid-term; - Lack of legislative framework. Intelligent freight cars - Talking about AGV, northern ports are already searching for possibilities to optimize the internal shunting with more safety; - Lack of legislative framework.
Integrating modes of transport and consolidating transport volumes
- With more information given online, it is possible to get more and more attractive for the customers to get more volume in intermodal transport; - Volumes are consolidated based on optimal utilization of capacities as much as possible. Today mainly manual optimization by dispatchers with system support; - Success critical for the business (efficient utilization of capacities); - An extensive intermodal transportation network of rail, inland shipping, road, short sea and pipelines gives a port the best possible competitiveness in comparison with other terminals.
Technology
Modular container design - Innovative infrastructure-specific and resource-efficient solution, capable of providing optimal and adaptable responses to changes in conditions of the multimodal transport network; - It could be an important leverage for a future logistics model specially for temperature controlled cargo.

Alternative container design

- Standardization is key for high utilization; different types might need different handling which again increases complexity, thus, also costs;
- Modern ports have to be updated to the new needs of the international market, especially on the means of transport side (larger vessels, longer trains, etc.). An alternative design, which combine 'average' flow together with additional small 'over flow standard stack yard', reaches the optimum result.

Automatic coupling

- It could represent a potential increase in the terminal production mechanism.

Waste heat utilization

- Interesting to reduce costs and carbon emissions in terminals and other buildings.

Autonomous assistance systems (driver-assistance systems – safe and efficient transportation)

- Northern ports checking out the possibilities for AGV;
- Standard in new trucks for some logistics operators; in areas with older equipment or lack of required infrastructure not common (e.g. Eastern Europe, Middle East)
- Critical for track and trace, optimal routing, pro-active risk management; standard in new trucks; interfaces with transportation management systems of logistics providers and customers.

Autonomous driving in rail transportation

- Could represent a potential increase in the supply chain production mechanism.

Alternative propulsion technologies

- In some ports all internal trucks running with diesel. A possible alternative is the switch to electrified trucks (or AGV), but only when long distance guaranteed and the costs are feasible;
- Electromobility can be considered for local delivery of packages. Electro vehicles for short range; broader use if range increases; performance in cold areas still to be tested (reliability);
- Some experience with hybrid technology in delivery trucks;
- LNG for ships, cold ironing at berth, new technologies for powering reefer containers on trains. New technologies will enable new intermodal choices, with benefits on the environment and the cost of transportation;
- Can be a strategic aspect in the terminal development plan.

Others

- Automatic container warehouse for storage of empty 20'/40' boxes;
- Automatic trailer warehouse with the possibility to store trailers up to 7 high. Using the third dimension for storing non-stackable units;
- Automatic management of cranes by using laser technology. Studies are being carried out about applications possibilities in industrial sector.

Own experiences with new solutions
Pros - Electro vehicles are used for short range pick up and deliveries. Good experience; deployment can be enlarged systematically and quickly in all regions where applicable; - Digitization improves port efficiency; - New services create new businesses; - Just-in-time information to all operators; - More job opportunities; - Allows saving, respect for the environment and gives reliability; Cons - Innovations in rail sector are difficult because of legislation and bureaucracy. - New solutions are mostly very expensive and the ROI is badly calculable; - Implementation needs a lot of time and man power; - Getting subventions is very hard; - High risk as stability of some new technologies is unknown; - Electro vehicles are not yet in use for mid-long-range road transports; range and reliability are key for further deployment; - Social acceptance is not always easy (i.e. building new infrastructures); - Main bottleneck to the implementation of innovative solutions is the legislative framework; - Implementation can be difficult, especially for third parties;
Recommendations
- Container warehouses and trailer warehouses

According to the relevance given by partners and stakeholders to the different proposed innovations/improvements to take into account when designing intermodal terminals, Table 8 shows the technologies and solutions to be implemented in real and virtual pilot cases:

Table 8. Technologies and solutions proposed to be implemented in real and virtual pilot cases

Real pilot cases	Virtual pilot cases
La Spezia seaport terminal - New railway terminal design; - Extension and improvement of the CMP; - Improved maintenance scheduling (railway interconnection).	*Virtual pilot case 1* - Internet of things; - Alternative container design for bulk cargo/reefer container – multi-purpose terminal; - LNG; - LCA – new materials.
Melzo inland terminal - Conversion of F3 warehouse into temperature controlled warehouse; - Implementation of a third gantry crane; - Four new shunting rail tracks; - Second gate in/out; - Improved maintenance scheduling (railway interconnection).	*Virtual pilot case 2* - Internet of things; - Automated and robotized equipment (automated cranes and AGV); - LNG; - LCA - New materials.

6. Conclusions

The **objective** of this deliverable is to define a number of technological and operative innovations to be implemented into the four terminals defined and the rail interconnection between them.

The two steps followed in order to achieve this objective are:

1. Global logistics trends review
2. Questionnaire survey among stakeholders and Consortium partners

Several innovations have been reviewed and finally, some of them have been chosen according to the relevance given by stakeholders and partners. The innovations to be implemented are indicated in the table below:

Table 9. Proposed innovations to be implemented in the pilot terminal cases

Real pilot cases	Virtual pilot cases
La Spezia seaport terminal - New railway terminal design; - Extension and improvement of the CMP; - Improved maintenance scheduling (railway interconnection).	*Virtual pilot case 1* - Internet of things; - Alternative container design for bulk cargo/reefer container – multi-purpose terminal; - LNG; - LCA – new materials.
Melzo inland terminal - Conversion of F3 warehouse into temperature controlled warehouse; - Implementation of a third gantry crane; - Four new shunting rail tracks; - Second gate in/out; - Improved maintenance scheduling (railway interconnection).	*Virtual pilot case 2* - Internet of things; - Automated and robotized equipment (automated cranes and AGV); - LNG; - LCA - New materials.

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OPTIRAIL European project (http://www.optirail.eu/optirail/)

Appendix I

This appendix includes the questionnaire survey used during the consultation carried out among stakeholders and project partners.

WP3 – Subtask 3.2.1 Pilot innovations and improvements

Some of the tendencies in logistics already identified are as follows:

1. Digitization
    a. Internet of things for a more efficient use of resources
    b. Intelligent traffic guidance systems (navigation solutions, routes recommendations – efficient use of the infrastructure)
    c. Intelligent freight cars (optimization of processes)
2. Integrating modes of transport and consolidating transport volumes
3. Technology
    a. Modular container construction
    b. New container design
    c. Automatic coupling enabling rail freight cars to be joined together without manual work by operators
    d. Waste heat utilization (energy recovery in order to reduce the fuel consumption and emission of pollutants)
    e. Autonomous assistance systems (driver-assistance systems, more related to reduction of accidents – safe and efficient transportation)
    f. Autonomous driving in rail transportation
    g. Alternative propulsion technologies

        Electromobility (still being developed for its use in freight transportation)

        CNG – Compressed natural gas

        LNG – Liquified natural gas

        Hybrid technology

        Hydrogen

1. ***Do you plan to implement any of these new trends in your daily logistics operations in the next 5-10 years? Could you please evaluate the importance of each solution from your perspective and explain? (1 – not important; 5 – very important)***

Solution	YES/NO	Importance (1 to 5)
1. Digitization		
a. Internet of things *Evaluation:*		
b. Intelligent traffic guidance systems *Evaluation:*		
c. Intelligent freight cars *Evaluation:*		
2. Integrating modes of transport and consolidating transport volumes *Evaluation:*		
3. Technology		
a. Modular container construction *Evaluation:*		
b. Alternative container design (bulk, cold chain) *Evaluation:*		
c. Automatic coupling *Evaluation:*		
d. Waste heat utilization *Evaluation:*		
e. Autonomous assistance systems *Evaluation:*		
f. Autonomous driving in rail transportation *Evaluation:*		
g. Alternative propulsion technologies *Please, indicate the propulsion technology implemented*		

Evaluation:		
4. Others *Please, indicate the solution proposed*		

2. Which is your experience with new solutions? Indicate pros and cons

3. Would you recommend any other?