Increasing Capacity 4 Rail networks through enhanced infrastructure and optimised operations (CAPACITY4RAIL)

Final Publishable Summary Report (1 October 2013 to 30 September 2017)

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AUTHOR, COMPANY	Alvaro Andres (UIC) and Herman Bertrand (ARTTIC)
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PROJECT FINAL REPORT

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Name of the scientific representative of the project's co-ordinator, Title and Organisation:

PROJECT COORDINATOR: ÁLVARO ANDRÉS

ORGANISATION: UNION INTERNATIONALE DES CHEMINS DE FER (UIC)

Tel: +33 (0)1 44 49 20 86

Fax: +33 (0)1 44 49 20 69

E-mail: ANDRES@UIC.ORG

Project website address: www.capacity4rail.eu

Abbreviations Used in this Document

Abbreviation / acronym	Description
C4R	Capacity4Rail project
SP1	C4R-Subproject 1 “Infrastructure”
SP2	C4R-Subproject 2 "New concepts for Efficient Freight Systems"
SP3	C4R-Subproject 3 "Operation for enhanced capacity"
SP4	C4R-Subproject 4 "Operation for enhanced capacity"
SP5	C4R-Subproject 5 "System assessment and migration to 2030-2050"
SP6	C4R-Subproject 6 "Management, Dissemination, Training and Exploitation"
3MB	C4R-1st slab track concept, Multi Moulded Modular Slab Track
7FP	7th Framework Programme
AMS	Advance monitoring system
CER	Community of European Railway and Infrastructure Companies
DG RTD	Directorate general for research and innovation
DGs	Directorate general
EASME	Executive Agency for SMEs
EC	European Commission
ECM	Entity in charge of maintenance
EIM	European Infrastructure Managers
EoT	End of train (devices)
EP	Electronic pneumatic brake system
EPF	European Passengers' Federation
EPTTOLA	European Passenger Train and Traction Operating Lessors’ Association
ERA	European Union Agency for Railways (before, the European Railway Agency)
ERCEA	ERCEA
ERFA	European Rail Freight Association
ERRAC	European Rail Research Advisory Council
ERTMS	European Rail Traffic Management System
ESC	European Shippers' Council
ETCS	European Train Control System
EU	European Union
F&L	European Freight and Logistics Leaders Forum
FRE	Subsystem FRE-Freight System > Rolling Stock and Terminals
H2020	Horizon 2020, "The EU Framework Programme for Research and Innovation" 2014-2020
HS	High speed (line)
IM	Infrastructure Manager

Abbreviation / acronym	Description
INF	Subsystem INF-Infrastructure
IP	Integrating Project
IT	Information technology
ITU	Total Transit Time
KPI	Key performance indicator
LCC	Life cycle cost
LPWAN	Low power wide Area networks
L-Track	C4R-2nsd slab track concept, Ladder Track
OPE	Subsystem OPE-Operations
PoC	Proof of concept
R&D&I	Research, development and innovation
RAMS	Reliability, availability, maintainability and safety
RCF	Rolling contact fatigue
RFC	Rail freight corridors
REA	Research Executive Agency
RFID	Radio-frequency identification
RU	Railway Undertaking
S&C	Switches and crossings
S2R	Shift2Rail
SC	Societal challenges
SHM	Structural Health Monitoring
SME	Small and medium-sized enterprises
SRRIA	Strategic Rail Research and Innovation Agenda
TEN-T	EC Trans-European Transport Network
TEU	"Twenty-foot Equivalent Unit2
TiT	Tunnel-into-tunnel technology
TRL	Technology readiness level
UIC	International Union of Railways
UIP	International Union of Private Wagon Owners
UITP	International Union of Public Transport
UNIFE	The Association of the European Rail Industry
USP	Under sleeper pads
VHST	Very high speed track (/traffic/train)
WP	Work Package

1. Final Publishable Summary Report

Executive summary

High objectives and expectations are put on railway transport, to be able to take a full part and respond to the upcoming growing demand for both passenger mobility and freight traffic.

In 2011, the White Paper on European Transport reasserted how fundamental transport was for society, for the mobility of European citizens and for the growth and vitality of the European economy. The Paper assigned ambitious challenges to the transport system, in terms of development, durability and competitiveness.

Rail has a major role to face these challenges in this transport system of tomorrow. The railway system has to take a leap forward in competitiveness, and complete its change toward efficiency, sustainability, and integration. Therefore, efforts must be focused on increasing the attractiveness of Rail System.

The Capacity4Rail (C4R) project aims at bringing today's railway system to this future vision for 2030/2050. Five major criteria have been defined that describe the 2050 railway. The future railway system should be **affordable, adaptable, automated, resilient and high-capacity.**

With this vision, Capacity4Rail aims at offering an **affordable increase of capacity**, **availability** and **performance** to the railway system, by developing a **holistic view** on the railway as a system of interacting technical components driven by **customer demand.**

This plan is addressed by different ways:

- A more efficient use of existing resources, by optimizing **operating strategies**, enhancing traffic planning, improving transshipment procedures and improving automation and operational procedures to reduce the time needed to recover from traffic disruption (see SP3 **"Operation for enhanced capacity"**).
- A reduction of the non-operational capacity-consumers, through the **design** of resilient, reliable and low-maintenance **infrastructure** and **vehicles**, non-intrusive **inspection**, fast renewal and construction **processes** (see SP1 "Infrastructure", SP2 "New concepts for Efficient Freight Systems" and SP4 "Advanced Monitoring").
- An increase of the performance of existing resources, through significant improvements of wagons maneuverability and equipment to answer **freight customers'** needs for **higher reliability and performance** (see SP2 "New concepts for Efficient Freight Systems").

To this end, a coordinated approach was needed, in which combined progresses in **infrastructure, freight system, operation techniques and monitoring technologies** are defined and pushed further in a system vision. Besides, Capacity4Rail has defined a comprehensive **roadmap** to describe the necessary steps to develop and implement innovation and to progress from the current state-of-the-art to a shared global vision of the 2050 railway along realistic scenarios.

The Capacity4Rail project has been a continuation of and a contribution to the research and development effort of the European railway community, building on development of previous projects. The project builds on previous results and has deliver both technical demonstrations and system wide guidelines and recommendations that will be the basis for future research and investments.

In addition, the demonstration activities play a crucial role in Capacity4Rail as they enable the assessment of the innovations developed in the project, which will serve to identify room for improvement and will guide their further development.

CAPACITY4RAIL brings together a large range of major active stakeholders of all fields: railway operators; infrastructure managers; track systems suppliers; rolling stock manufacturers; wagon keepers; logistic providers; engineering companies; and research laboratories, all supported by universities on a firm scientific basis. The project has been developed by 46 partners from 13 countries.

Summary description of project context and objectives

In 2011, the White Paper on European Transport reasserted how fundamental transport was for society, for the mobility of European citizens and for the growth and vitality of the European economy.

The Paper assigned ambitious challenges to the transport system, in terms of development, durability and competitiveness.

Thanks to its recognized environmental and energy advantages, **rail has a major role to play** in this transport system of tomorrow but in order to succeed in this role and to fulfil what is expected from it, the **railway system has to take a leap forward in competitiveness**, break with some handicaps of past heritage and complete its change toward efficiency, sustainability, and integration.

In order to **make rail an attractive option to freight and passengers**, a coherent approach needs to be adopted. The research and development on operations and infrastructure needs to be done with a rational systems approach, looking at increasing the capacity and resilience of rail networks, whilst reducing the cost of maintenance and ultimately the costs to the end users. This can only be done if an overall framework for research is adopted and implemented in a systematic and system wide manner, with a buy in from all of the stakeholders in the process.

Following the White Paper, **CAPACITY4RAIL** proposed to bring a system vision of the railways looking towards 2030-2050, by developing new concepts in the fields of **infrastructure, freight, operation and monitoring,** towards an **affordable, adaptable, automated, resilient, and high-capacity** railway system through major step changes in infrastructure design, construction and maintenance (including advanced monitoring), operations management, incident recovering through real-time data management, freight operations with a particular focus on transshipment and improved specifications for rolling stock.

Affordable: for the customers and the investors, with limited capital and operational expenditures, minimised life cycle cost and lowest environmental impact.

Adaptable: the railway system will be able to cope with daily, monthly, yearly or seasonal variations of the demand, but will also have sufficient reactivity to adapt unplanned temporary modal shifts

Automated: for optimised performance and to help planners respond dynamically to planned and unplanned changes.

Resilient: able to recover not only from major disruptions, but also daily minor perturbations

High Capacity: a railway with virtually no constraints on operations, that can accommodate customer demand at any time and tolerate interventions with minimal impact.

This plan is addressed by different ways:

- A more efficient use of existing resources, by optimizing **operating strategies**, enhancing traffic planning, improving transshipment procedures and improving automation and operational procedures to reduce the time needed to recover from traffic disruption (see later SP3 “Operation for enhanced capacity”).
- A reduction of the non-operational capacity-consumers, through the **design** of resilient, reliable and low-maintenance **infrastructure** and **vehicles**, non-intrusive **inspection,** fast renewal and construction **processes** (see SP1 “Infrastructure”, SP2 “New concepts for Efficient Freight Systems” and SP4 “Advanced Monitoring”).
- An increase of the performance of existing resources, through significant improvements of wagons maneuverability and equipment to answer **freight customers’** needs for **higher reliability** and **performance** (see SP2 “New concepts for Efficient Freight Systems”).

In order to best address this approach, the project has been broken into the following six sub-projects:

- ✓ SP1: Infrastructure
- ✓ SP2: New concepts for efficient freight systems
- ✓ SP3: Operation for enhanced capacity
- ✓ SP4: Advanced monitoring
- ✓ SP5: System assessment and migration to 2030-2050
- ✓ SP6: Management, Dissemination, Training and Exploitation.

The Capacity4Rail project has been a continuation of and a contribution to the research and development effort of the European railway community, building on development of previous projects, as described below.

INFRASTRUCTURE

Releasing operational capacity from infrastructure through a higher reliability, a lower need for maintenance and an optimization of maintenance and monitoring procedures have already been a recurrent concern in past projects, which provided significant advances and concept developments.

CAPACITY4RAIL has taken advantage on these results and achievements, also considering that significant progress in terms of track availability for running trains and increased resilience will come only through achieving a major breakthrough and step change in the design of the track system.

The ‘Infrastructure’ sub-project has three research streams:

- Innovative slab track concepts developed with a global LCC and RAMS-driven design approach, in view of potential application for mixed traffic, but also for very high-speed, with the following distinctive features:
    - Affordability through cost savings in design and construction with prefabricated elements and modular construction techniques
    - Advanced maintainability through health monitoring of actual deterioration status and plug-in-place for sub-systems replacement
    - Low maintenance through embedded monitoring techniques (AMS, advanced monitoring systems).
- The performance of very high-speed track systems. The identified limiting factors and obstacles to very high-speed (above 350km/h) have been addressed, especially in the analysis of improved design methodology in terms of vehicle-track interaction and effect of track irregularities on bridges behaviour and settlement issues in transition areas.
- Switches and crossings are one of the most critical components in terms of reliability and maintenance needs. The main scope in C4R has been to investigate and propose innovative designs aiming towards improved railway turnouts (S&C) that reduces material deterioration (wear, plastic deformation, rolling contact fatigue) and failures.

FREIGHT

With regard to freight, CAPACITY4RAIL has analysed the still existing gaps and bottlenecks which undermine the modal shift of freight traffic to rail and proposes technical and operational solutions for attracting shippers and logistic operators towards a competitive and sustainable rail transport system.

Considering the most important concerns of shippers with regard to a competitive, frequent, reliable and highly reactive service with continuous flows of information on the transport progress, CAPACITY4RAIL has developed innovative concepts in view of a major evolution of the performance of both combined transport and industrial block trains.

Several technological step changes are considered in the project, including:

- Higher breaking performances allowing better maneuverability of freight trains for a better interleaving into mixed traffic

- Automatic coupling and decoupling of wagons, associated with RFID identification for industrialised operations in marshalling yards
- 'Intelligent' sensor-equipped wagons allowing faster break testing and continuous monitoring of the wagon condition

All these innovations supported by fundamental investigations on the vehicles design, structural stresses and wheel/brake shoe contact conditions.

Infrastructure design and operation procedures will inevitably account for these new characteristics of the freight traffic.

Economic assessments of the potential benefits have been carried out to ensure that such innovations are not only affordable but can also be efficiently inserted into the current practice.

OPERATIONS

The 'Operation' sub-project is building on the previous European on-going project results, aiming to achieve automated and resilient operations that will enhance capacity on the railways. These projects developed new improved timetabling and real-time traffic management techniques, as well as real-time information to traffic controllers and drivers in order to help maximise the available capacity on the European railway network, decrease delays and improve traffic fluidity.

CAPACITY4RAIL has taken the work further and develop what will be decision support systems into automated systems. This will enable the future controllers of the railway to focus on fulfilling the challenges of, for example, running 'on demand' train variations in resource allocation and collaborative working within and between countries, an improved efficiency of transshipment at nodes, while the systems take care of routine operations and recovery from small or even medium perturbations.

In addition to these developments for a higher level of automation, the 'Operation' part of CAPACITY4RAIL has specified guidelines for emergency and requirements for incident management plans to handle large incidents including those caused by extreme weather.

ADVANCED MONITORING

Previous European activities aimed at squeezing extra capacity by reducing the time available for infrastructure maintenance operations and planning.

This requires a high level of quality monitoring information in order to have a continuous knowledge of the system condition to carry out the right maintenance at the right time, meaning that monitoring strategies have to be optimised to obtain relevant information when needed that can be cross-correlated with other sources.

Moreover, the monitoring process itself needs to be non-intrusive, i.e. with no impact on operations, and maintenance free.

Monitoring systems currently in use on railways are often designed to proceed with measurements at one time and/or at one specific location.

But outside the railway industry, advanced monitoring technologies are already in use, including low-cost, miniaturised, low-power consuming autonomous sensors, associated with wireless data transmission facilities.

Learning from other industries, CAPACITY4RAIL has investigated ways to implement such components into both future and existing infrastructure, and to develop associated strategies for a non-intrusive and highly automated monitoring.

THE SYSTEM ASSESSMENT AND MIGRATION TO 2030/2050

The work in CAPACITY4RAIL has been designed in such a way to guarantee the greatest interaction between the working groups and ensure results that are relative to the research community and will be deployed in the field.

Whilst the first four SPs will take a top-down approach to the research, by examining the state-of-the-art and working on the key elements that will move the technologies forward, SP5, 'System assessment and migration', takes a bottom-up approach and first looks at the boundaries and requirements that exist within the rail system and defines the constraints to the overall system approach. SP5 has been a horizontally oriented sub-project and cuts across the technical work streams of the other technical sub-projects.

The general objectives of SP5 have been,

- To define the scenarios and migration paths from existing railway system to the future one, considering the innovations and technologies identified/validated in the project.
- To assess the technologies and scenarios and their ranking, through two complementary methodologies: a Cost-Benefit Analysis (CBA), supplemented by a Multi-Criteria Analysis (MCA) that help take into account non-economic aspects that are usually not captured in a CBA.
- To perform the demonstration activities - on operated railway infrastructures or in specific laboratories with real-scale test facilities- for the assessment of the innovations and the most promising designs developed in the project:
    - Modular integrated design of new concepts for infrastructures (2 slab-track innovative designs)
    - Switches & crossings for future railways
    - Monitoring Technologies and sensors, including AMS Advance Monitoring Systems integrated in the new concepts for infrastructure
- To review/update the vision of the railway/system 2030/2050 based on the progress achieved in the project
- To provide recommendations for further actions presented as a collection of prioritized set of demonstration actions, cooperative research activities and required developments to be undertaken at the European scale in order to progress toward the Vision for Rail, within research and development initiatives of Horizon 2020 and further.

THE CONTEXT AND THE C4R CONSORTIUM

CAPACITY4RAIL brings together a large range of major active stakeholders of all fields: railway operators; infrastructure managers; track systems suppliers; rolling stock manufacturers; wagon keepers; logistic providers; engineering companies; and research laboratories, all supported by universities on a firm scientific basis. The project has been developed by 46 partners from 13 countries.

This ensures a deep integration in the railway industry, a full awareness of the customer’s needs and of the system constraints and abilities, as well as an intimate connection to past and on-going research and to future research initiatives.

Description of the main S&T results / foregrounds

INFRASTRUCTURE AND ADVANCED MONITORING

Key issues and objectives

The overall scope objective of C4R was to increase capacity, availability and performance of the railway system through major step changes in the infrastructure design, renewal and maintenance, including advanced monitoring.

C4R has focused on:

- Developing new concepts for the railway track of the future by low maintenance and modular designs of slab tracks
- Understanding and solving the current obstacles to very high-speed traffic in track components and analyzing the dynamic solicitations for bridges structural design and innovation for transition zones
- Investigating the failure modes and developing breakthrough innovative concepts to improve the reliability of switches and crossings.
- Establishing a systematic and documented approach for infrastructure upgrading in order to meet the new demands on freight operations.
- Developing new concepts for railway structural and operational monitoring combined with automated maintenance forecasts and a prediction of the structural lifetime. The work has been directed toward the use of innovative simple and cheap sensors and a migration to intelligent components with in-built monitoring for new tracks structures and for existing ones.

Results

Plain Track -Slab Track

Two new slab track concepts have been designed, developed and prototyped, with the following particular distinct features:

- Cost and RAMS oriented design.
- Modular design in order to enable “Plug&Play” for rapid construction or maintenance.

The two concepts are, the **“Multi-Moulded Modular Blocks (3MB)”** and the **“Ladder Track (L-Track)”**

The **3MB modular slab track** is composed of prefabricated elements that are partially assembled before the transport to the construction site. This characteristic is also an advantage in the need of replacing any elements that has been damaged or broken.

On track site, the modules are laid over a concrete layer previously constructed. The fastening systems and the rails will be assembled over the blocks by following a Top-down construction procedure.

Main advantages of the concept:

- The system allows a certain flexibility if any geometry or alignment correction in the modules has to be done There is no need to have a precise subgrade layer levelling and as a result a precise positioning of the slab because final track alignment is achieved by top-down adjustment.
- Design is completely modular thanks to standard elements. There are two stiffness levels: Fasteners and under block pad.
- Realignment of the tracks because of soil settling is easy to achieve.
- Every single element can be repaired separately.
- Block replacing is easy to achieve
- Heavy machines are not required to repair or to change an element except for the slab panel.
- The elastic pad situated between the block and the module means an additional elastic layer that reduces the vibration emission.

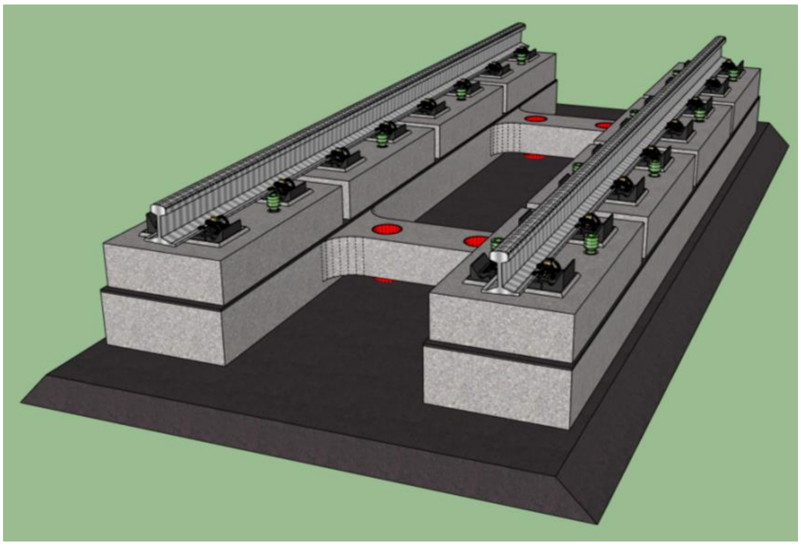

Figure 1: 3MB, final design general view

The "L-Track" slab track system is a reinforced concrete precast slab made of 2 longitudinal beams supporting rails and 2 transversal beams connecting them. As with the "3MB" concept it is designed for both mixed traffic and high-speed traffic. Rails are continuously supported. A mortar is poured between the slab and the asphalt layer to achieve final track geometry.

The LT is composed of one module. The rail seats on the module on a continuous way and it is fastened discretely with a direct system to the module. The system simplicity reduces the number of critical points and defects. The continuous rail support will extend the life in service of the rail and reduces the maintenance works associated.

Main advantages of the concept:

- There is no need to have a precise subgrade layer levelling and as a result a precise positioning of the slab because final track alignment is achieved by top-down adjustment.
- Design is completely modular thanks to standard elements.
- Slab is easy to make thanks to its simple design.
- Every single element can be repaired separately.
- Heavy machines are not required to repair or to change an element except for the slab panel.

Both typologies of slab-track concepts developed in C4R include an innovative monitoring system specially implemented for its design and special features. Data from the monitoring could be used in order to optimize the maintenance tasks what meaning a cost reductions and improvements in the level serviceability of the infrastructure. See 0.

The 3MB system has been tested and prototyped in the CEDEX track-box, where a specific real-scale track is available for testing a large range of track configurations. The tests and the subsequent analysis of the results show that the developed systems are compatible with current European rail regulations and provide additional features and advantages of significant value.

Furthermore, the developed concepts have been deemed worthy of intellectual protection by their IPR owners, a fact that speaks high volumes of the great potential of the envisioned solutions and has substantiated in formal patent applications to the World Intellectual Property Organization under the Patent Cooperation Treaty.

However, to this date the business case and cost estimation for production, logistics, installation and maintenance remain in very early, approximate and qualitative stages of definition, and require more extensive work to be considered mature.

It is the firm intention of the collaborating partners to pursue the optimization, further development and industrialisation of the production and installation procedures, with the objective of achieving fully developed, marketable and competitive versions of the two novel slab track concepts.

See the deliverables,

D11.3 Design requirements, concepts and prototype test results (Final)

D55.4 Report from Laboratory demonstrations

VHST Very High-Speed Track

The objectives of the project in this area have been:

- to analyse the impact of the pass-by of Very High-Speed Trains (VHST) in the current railway track sections, and
- to identify changes that are necessary to implement in the railway track design in order to improve dynamic performance under VHST circulation.

A numerical train/track FEM finite-element-method model, focused on estimations of track response to very high speed trains circulation. Some of tests performed in CEDEX Track Box (CTB) on ballasted tracks subjected to the pass-by of trains were selected. The results obtained were used to calibrate and validate the numerical models developed.

Two in-situ test campaigns were performed to analyse the track dynamic behaviour and to create a data base of the vibrations measured in a real track produced by passing-by of different trains travelling at high speeds (around 300 km/h). This data base will be used as a source to validate the test results obtained in CEDEX Track Box (CTB).

The model has served,

- To evaluate the predicted dynamic response of different track design cases (having the CTB reference case as basis) when equipped with **different combinations of railpads and undersleeper pads (USPs),** including the study of the impact of increasing train speed
- **To optimize the track design** (several specific combinations of railpad and USP stiffness) to improve dynamic performance at very high speeds (up to 400 km/h).

The objective of the track design optimization process performed with the FEM model was placed on identifying track solutions that would minimize both peak ballast accelerations and displacements, maintaining acceptable sleepers vibrations and desirable global track vertical stiffness. After some optimization procedures, analysis came up finally with some track design solutions to be further evaluated consisting of variants of the reference track model (CTB) equipped with combinations of rail pads and USPs having different stiffness, as following:

- Rail pad stiffness: 40, 60, 80, 100 kN/mm
- USP stiffness: 40, 60, 80, 100 kN/mm
- Train speed: 300, 320, 330, 350, 360, 380, 400 km/h.

Afterwards, from results obtained, four track design solutions were selected.

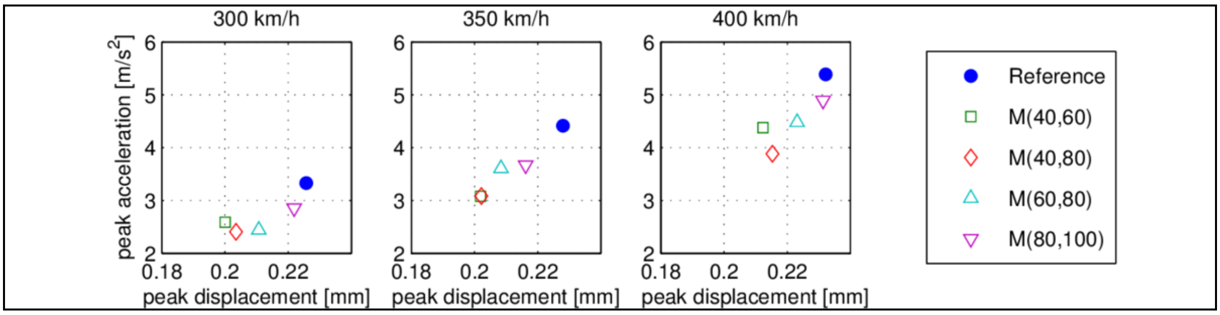

Figure 2: Track design optimization: peak response values of selected track variants.

The introduction of USPs results in a significant reduction in peak vertical displacement and acceleration levels within the track supporting layers, ballast layer included, for all the track design solutions tested.

However, it must be highlighted that these improvements are accompanied by increases in peak vertical displacement and acceleration levels on track components supported by the USPs, as the rails and the sleepers.

Notwithstanding, the results also suggest that incorporating stiffer USPs may reduce peak acceleration levels within the ballast layer while preserving peak sleeper acceleration levels.

See *D12.1 Innovative designs and methods for VHST (Intermediate)*

S&C Switches and crossings

The main scope in C4R has been to investigate and propose innovative designs aiming towards improved railway turnouts (S&C) that reduces material deterioration (wear, plastic deformation, rolling contact fatigue) and failures.

Based on numerical simulations of dynamic vehicle-track interaction using validated models and software, it has been demonstrated how rail and track degradation can be reduced by optimization of geometry and stiffness properties of the turnout, leading to reduced Life Cycle Cost (LCC).

The adopted approach incorporates studies of short-term design measures for improving current S&Cs, a medium-term strategy where improved solutions are incorporated in an existing railway system and a long-term vision where radically innovative solutions can be introduced without a need for compromising with existing structures.

The investigated **short-term** solutions for minimizing loads and rail profile degradation in the switch panel include selection of,

- rail profile and rail inclination,
- rail grade, and
- friction management.

The calculations have shown that a design with inclined rails (1:30) is superior to the case with vertical rails. The selection of rail grade R350HT instead of R260 leads to an expected reduction in wear.

The predicted influences of rail grade and friction management on RCF are uncertain due to the wide range of factors influencing RCF initiation.

It has been shown that both wear and RCF are reduced significantly by maintaining a low friction coefficient in the wheel-rail contact. In particular, situations with dry wheel-rail contact (high friction) should be avoided as these lead to very high RCF damage impact.

The investigated **medium-term** solutions have focused on improving the performance of the crossing panel. These solutions have included:

- geometry optimization of the crossing to minimize impact loads and reduce the steering force damage in the contact areas.
- dynamic load mitigation (ballast protection) through rail pad stiffness optimization and the use of under sleeper pads (USP) or connecting elements between sleepers, and
- novel materials in crossing nose and wing rails to resist fatigue, wear and plastic deformation.

The investigation in **crossing geometry** has highlighted key differences in current design practice and machining tools used for “half” and “full” cant (UK terminology; 1/40 and 1/20 respectively) geometries, leading to quantifiably different damage behaviour. The interaction between wheel shape and the crossing wing geometry is a determining factor in the level for vertical impact force, lateral dynamics and resulting rail damage. The crossing with a higher inclined wing rail showed better performance across all wheels simulated. The peculiar behaviour of hollow wheels has been quantified and shown to be more reactive to one of the crossing types. High conicity wheels are also potentially leading to higher dynamic impact. All this needs to be considered in the design process. On that basis, the proposed methodology can enable a fast and effective optimization process of the crossing wing rail geometry minimising vertical impact loads, wear and RCF on both wing rail and crossing vee.

A methodology has also been proposed for the optimization of **rail pad stiffness** in crossing panel, showing that low stiffness rail pads (ca 80 kN/mm) provide a suitable mitigation for ballast pressure, sleeper acceleration and minimizing contact forces, while maintaining acceptable bending stresses of rail components. An investigation into the role of under sleeper pads (USP) in mitigating vertical dynamics loads has been presented, highlighting the importance of careful selection of USP properties, so that the system response is fully understood while designing or upgrading an S&C. An investigation in linking sleepers together in the areas of load transfer of a crossing panel has shown some benefits in protecting the ballast layer while making the panel behave more like a slab.

Next generation of S&C, **long-term** solutions, are based on a whole-system approach including enhanced design, materials and components and incorporation of modern mechatronics for improved system kinematics and control.

Operation of S&Cs in extreme weather conditions is a challenge to railway administrations. Common problems occurring due to situations with strong winds at low temperatures and heavy snow fall, as well as at high temperatures and due to heavy rain fall and flooding has been analyzed.

Innovative designs and operational practices to ensure resilience to extreme weather conditions have been suggested.

As part of the demonstration activities, the following innovative S&C concepts has been tested:

- New crossing material: installation of bainitic crossing
- Battery driven wireless sensors for S&C: installation of wireless, battery based accelerometer sensor for dynamic measurements
- Material testing for wear and RCF resistance under realistic wheel-rail contact conditions
- Laser profile measurement equipment for crossing
- Controlling switch heating by weather prognosis
- Development of decision tool for S&C maintenance based on track geometry

See the deliverables,

D13.2 Innovative concepts and designs for resilient S&Cs (intermediate)

D13.3 Innovative concepts and designs for resilient S&Cs (Final)

D55.4 Report from Laboratory demonstrations

D55.4 Report from on-track demonstrations

Platform - Structural design requirements for VHST

C4R also intended to analyze the impact in VHST in terms of severity of dynamic solicitations for structural design and to identify bridge design requirements under these conditions of traffic, apart from upgraded freight services categories, as seen in next paragraphs.

The dynamic response of railway bridges on high-speed lines is limited by a set of serviceability criteria (e.g. the vertical deck acceleration) which may sometimes be over conservative. More accurate design limits may result in the use of slender bridges and enabling upgrading of more existing bridges to higher speeds, with a required safety limit.

Increased understanding of the real dynamic manner of action by experimental testing can hopefully result in more accurate predictions of the dynamic response and model updating and hence less need for safety margins in the models.

The main scope in C4R was to investigate, both numerically and experimentally, the dynamic behaviour and requirements for load bearing structures intended for very high-speed trains (e.g. for speeds up to 480 km/h) focusing on common types of railway bridges.

See *D12.2 Innovative designs and methods for VHST (Final)*

Upgrading of infrastructure

Nowadays, new railway lines are constructed for high-speed operations. Almost none new railway lines are constructed specifically for freight traffic, but many existing lines are transformed towards more freight and regional traffic. Freight operators often propose enhanced operations (see **Error! Reference source not found.** Rolling Stock and Terminals) but they cannot be attained if there are infrastructure limitations.

To achieve this, it is important that the upgrading is carried out in a systematic manner with a clear vision of the desired transport concept, and that state-of-the-art knowledge is employed.

The scope of C4R was to build an exhaustive and extensive Best Praxis Compilation founded on recent research and development projects to provide the infrastructure managers, contractors and regulatory bodies the tools to upgrade of infrastructure to answer the future operational needs.

See, *D11.5 Upgrading of infrastructure in order to meet new operation and market demands (Final).*

The techniques for the assessment of substructure conditions to identify the potential need of improvement have been analyzed including the interpretation and comparison of the results.

Existing methods for subgrade improvement have been examined. The selection of a proper method for the situation at hand includes factors such as the allowance of traffic during the repair, the type of soil suitable for the technique, the effectiveness in increasing each stability/strength aspect and the experience of the use of this particular technique. Besides, methods for reducing ground borne vibrations have been investigated.

The influence of the future operational demands (longer trains and increased train weights and consequently increased axle loads, loads per unit length or increased loading gauges) in bridges, culverts, retaining walls and tunnels have been explored.

For different kinds of bridges, specific areas for upgrading/repair are indicated. Examples are also given on methods to use. These include refined calculations, increased cross sections of the bridge structure, change of system for static load distribution, external pre-stressing and the use of externally bonded fibre reinforced polymers.

For tunnels, different cross sections and typical loading gauges are presented, as well as possibilities for working in tunnels with rail services in operation.

For culverts different types of damage and malfunctions are described and examples are given on measures that can be taken. For retaining walls, examples are given on how they can be constructed.

Consequences of upgraded operational conditions are investigated. Many upgrading scenarios tend to increase the track deterioration and that this deterioration needs to be addressed and mitigated. An overview of different deterioration phenomena and descriptions of potential consequences of different types of upgrading are presented in track and switches & crossings are presented.

A two-level approach to successively refined investigations is then outlined and exemplified. An Experience based methods and a Prediction based analyses. In this second level, the consequences of upgraded conditions in terms of increased deterioration are predicted in advance. This allows for a proactive approach where mitigating solutions may be used and their efficiency estimated through simulations. An outline of potential analyses that to varying degrees of detail predict the influence of different track components have ben outlined.

See D11.5 *Upgrading of infrastructure in order to meet new operation and market demands (Final)*

Advanced Monitoring

Condition monitoring and condition-based maintenance of railway systems is increasingly important to infrastructure managers as part of the process of operating efficient and cost-effective railways.

Condition monitoring systems monitor the immediate state and general degradation of assets and faulty or degraded infrastructure elements can lead to inefficient operation, or even failures and thus downtime or even damage to the track and/or trains.

In C4R numerous technologies have been considered for their suitability for application as part of a condition monitoring system, either for current railway elements (i.e. retrofitting) or to be built-in to new elements during production or installation (as it has been proved in the new slab track concepts have been designed, developed and prototyped.

The technologies and systems being considered need to be low cost and low power, while maintaining high levels of robustness. The successful use of such equipment may lead to the development of prognostic systems which would in turn allow more efficient maintenance scheduling.

Monitoring strategies

The first purpose in C4R has been to provide an overview of possibilities and challenges in the infrastructure inspection.

C4R aimed at providing an overall approach in enhancing a holistic strategy for monitoring and inspection techniques. This strategy provides support in identifying, evaluating and ranking key operational parameters, identify cause–effect relationship and select methods for interpreting collected data. In addition, it establishes the inputs for deciding feasibility of monitoring, defining placement strategies and evaluating costs and benefits of an enhanced monitoring.

Different areas of monitoring and inspections have been investigated and evaluated.

See the deliverables, *D41.2 Monitoring-based deterioration prediction* and *D41.3 Strategies for data collection and analysis*

Requirements for next generation monitoring and inspection techniques

In a second phase, C4R has focused on:

- the identification of current of near-future technologies that may be suitable for adoption within the railway industry and
- how they should be evaluated in order to assess their appropriateness for use within the rail sector.

Sensing technologies

A range of **sensing technologies** and their applicability to the railway domain have been explored, and sensor and architecture identification and evaluation techniques have been demonstrated.

The technologies considered have not been constrained to any particular target measurement or physical mechanism and have spanned a range of classifications including computer vision applications, gyroscopes, geophones, accelerometers, strain gauges, magnetometers, environmental sensors (for precipitation, humidity, wind speed), fibre optic, acoustic sensors and current sensors.

The technologies identified and evaluated are either:

- currently available in rail but with scope for improvement
- available in other industries and suitable for adoption within rail; or
- near-horizon technologies being adopted that may be suitable for railway applications.

Once technologies, or combinations of technologies, were identified they were then passed through the **technology evaluation framework** developed.

The interactions between these system components and how they may be considered in isolation and together when designing monitoring systems has also been analyzed.

The systems described go beyond basic measurement technologies to consider. To this end, the evaluation frameworks and assessments have been extended to include:

- the **processing** fabric / architecture used, and to some extent the type of processing applied: e.g. the use of fully integrated systems with microcontrollers for processing and transceivers for wireless communication
- the solutions available for **providing power** to any measurement systems: energy harvesting and storage systems.
- the communications requirements and solutions for different measurement and **monitoring architectures**: wireless and wired communication methods have been analyzed.

Demonstration of innovative monitoring concepts

Following the described methodology for the identification of current technologies and the evaluation of their appropriateness for use within the rail as innovative monitoring systems, C4R has demonstrate how the use of a vibration sensing technology and low power computing systems have an appropriate applicability in monitoring rail movements in the track.

The key points for the design of this system were: low power, energy harvesting, low cost, wireless and easy to install. The selected sensors were assessed through laboratory and field tests.

In track, two sites were selected,

- Transition to a tunnel, HS1 High Speed “One” line, UK

During preliminary tests three wired accelerometers were used to determine the minimum requirement of a low power acceleration monitoring system. They monitored the vertical vibration of a number of sleepers.

- Transition onto a bridge, HS High Speed line, Alcácer do Sal, Portugal

In a second phase, two systems were developed to measure sleeper deflection on a high-speed railway line in the Alcácer do Sal region in Portugal. The site chosen was at the transition onto a railway bridge which crosses the River Sado. The two systems both demonstrate different methods of providing wireless measurement nodes fixed to the track.

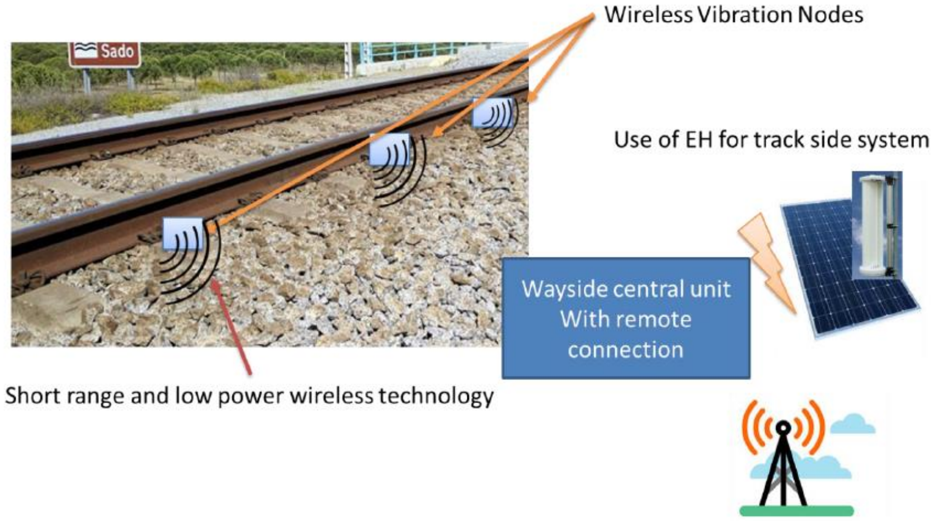

Figure 3: DEMO on monitoring techniques. Trackside system architecture.

Wireless technology to measure sleeper deflection on a high speed line.

A number of wireless and wired standards and technologies have been deployed. Wired standards were used for internal electronic systems and short distance communications, and short and long range wireless systems were successfully implemented.

See the deliverables,

D42.2 Recommendations and guidelines for next generation monitoring and inspection

D42.3 Report on demonstration of innovative monitoring concepts

Integration of AMS-Advanced monitoring systems in new concepts of infrastructure

A monitoring system has been designed for being easily **integrated into the new infrastructure concepts developed in C4R, the innovative slab-track systems.**

The sensor and communication technologies has been selected taking into account the findings defined in the previous points, “Monitoring strategies” and “Requirements for next generation monitoring and inspection techniques”.

A comparative analysis of the different current technologies in communications in the railway industry have been carried out.

The Passive RFID technology have been identified as the most promising one, given its low-cost, low power consumption and the maturity level of this technology. The research has been focused on the innovative application to structural health monitoring with the accomplishment of the requirements stated for precast concrete slab track.

Strain gauges have been integrated in the Passive RFID monitoring system. They provide relevant information in relation to the infrastructure condition. Some developments were performed to increase the sensibility in the voltage measurements in order to detect small changes in gauge resistance. Temperature and moisture sensors can be also easily integrated in the AMS.

Sensors tags have been embedded in the concrete, solving the geometric and physical interference. The electromagnetic interferences have been also investigated, supported by in-field measurements, and the RFID communication has proven to be compatible with the railway electromagnetic field.

A procedure for the installation of the AMS have been drafted.

The results from the tests performed on the devised monitoring system open the door to several intriguing and potent possibilities for the monitoring of slab tracks via RFID tags.

For instance, on-board RFID readers could be used to recover live data on the structural health and dynamic response of the different elements in the track, with little to no added cost, and saving significant amount of work, possession time and labour costs currently being spent in inspection and monitoring.

Figure 4: Location of the monitoring system in the 3MB prototype

Likewise, more advanced RFID systems (e.g. active tags) could be used to implement continuous monitoring and complex data gathering systems, powered wirelessly by the RFID antennas, with the data recovery and transport issues being solved without the need of additional systems.

In that context, the following steps in the development of structural health monitoring for the new slab track systems would be:

- To devise an optimized COTS-sensor deployment for both systems, so that the recovered data can be turned to useful information with minimal post-processing
- To map the dynamic behaviour of the track systems under several partial component failure conditions, so that imminent non-critical failure or malfunction of a component may be detected and predicted by a monitoring system based on accelerometers
- To extend the principles of the developed monitoring philosophy to other track systems and elements, where applicable

See the deliverables, *D43.1 Guidelines for installation and maintenance of sensors in new infrastructure* and *D43.2 Demonstration of new monitoring techniques*

Migration of innovative technologies to existing structures

The current monitoring systems can be expensive and be used for a single location and a specific case. To cover different locations cables for energy and data are need and it became a limitation for the maintainer services, especially in rail area. To implement innovative monitoring technologies into existing networks, investment has to be low. Therefore, these retro-fit solutions have to be developed with the focus on low-current sensor, low-current and wireless data transmission and using energy harvesting for power supply.

C4R has worked in demonstrate the application of retro-fit kits in existing structures, in order to monitor the risk of track buckling on a railway bridge (zone 1), the structural health of a long span railway bridge (zone 1) and, the track condition at a railway transition zone (zone 2)

The demonstration activities were carried out in the the Alcácer do Sal railway bridge which is part of the new Alcácer railway line, that connects Lisbon to the Algarve in Portugal. The structure is designed for passenger trains with speeds of up to 250 km/h and freight trains with a maximum axle load of 25 tonnes. Two locations, zones 1 and 2, were selected. In each of these locations, it was implemented a long-term monitoring system compose by a local main station and two nodes (zone 1) and one node (zone 2).

- Risk of track buckling

On a continuous welded rail track, where the expansion of the rails is hardly possible, high compressive stresses occur when there is a significant temperature increase. These compressive stresses may result in track buckling that can be prevented by monitoring the rail temperature and longitudinal strain.

In this way, one sensor node was mounted on the rail. This sensor node includes two weldable strain gages, one temperature sensor (RTD), an energy harvesting module, a ADCs module, a microcontroller and wireless transceiver module, a solar panel and a battery.

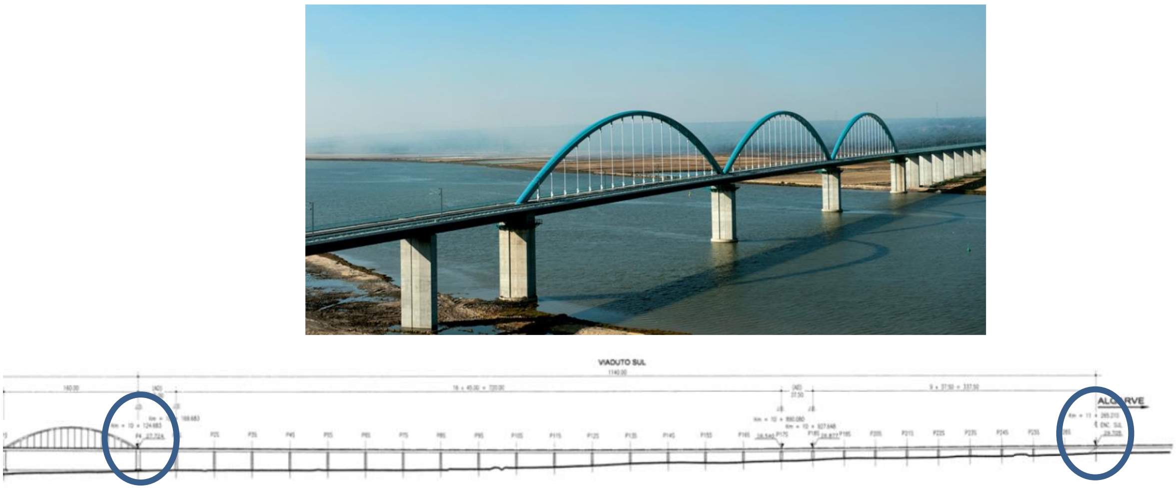

Figure 5: General view of the railway bridge of Alcácer do Sal and location of the north-zone1 (left) and south-zone 2 (right) monitoring zones

- Structural health monitoring of railway bridges

The Structural Health Monitoring of a long span railway bridge is important to prevent the failure of critical components of the bridge due to for example fatigue crack propagation. A similar node with the same configuration was installed.

- Track condition monitoring at railway transition zones

The variation in the subsoil stiffness when changing from one structure to another produce greater stress on the infrastructure. These differences along with the uneven settlement might increase the dynamic loads on the railway components and put in risk the traffic safety.

To study these settlements a several measurements can be taken as sleeper accelerations, rail-sleeper relative displacements, rail and sleeper vertical displacements, wheel loads and rail seat loads. Short term monitoring with this measurement was already conducted in the transition of Zone 2. This location was adopted to install the new long-term monitoring system for transition zones. A sensor node was installed in a sleeper in the end of the transition zone to measure the accelerations.

The sensor node includes an energy harvesting module, a wireless Power transceiver module, a microcontroller and wireless transceiver, a MEMS accelerometer, a battery and a solar panel.

The results and operation tests of the two devised long-term monitoring systems were shown to have **potential** for the application in the concept demonstrator's cases and also for **other types of applications**.

The energy harvesting modules developed demonstrates to be efficient and guarantee the power to the sensors, microcontroller and wireless data communication. For static monitoring systems (case of zone 1) the use of only one solar panel was sufficient. For dynamic monitoring systems (case of zone 2) the use of wireless power transmission technology possibly the necessary energy. In both cases, the energy harvest module has the ability to collect energy from other sources simultaneously. The acquisition and wireless communication modules demonstrate to collect correctly the data from sensors and the data communication from the nodes to the receiver location (main station) was stable.

These monitoring systems have the **potential to be implemented in several applications.** Examples of future applications are the condition monitoring of pantograph-catenary interaction. Weighing in motion and wheel defect detection systems and bogie condition monitoring on freight trains.

See the deliverables,

D44.1 Recommendations for monitoring of critical components in the railway, D44.2 Marketable retro-fit kits for selected applications and *D44.3 Recommendation for an Open-Source and Open-Interface for railway advanced monitoring applications*

NEW CONCEPTS FOR EFFICIENT FREIGHT SYSTEMS

Key objectives

The objectives and actions were centred on the following aspects:

- Proposal for a new conceptual design approach of a modern fully integrated rail freight system to meet the requirements for the above-mentioned scenarios 2030/2050, established in the EC White Paper, for the wagons to enhance its capacity, as well as the conceptual design on general rail freight vehicles, and complete trains, for a catalogue on rail freight systems for scenarios now, in 2020, 2030 and 2050 to contribute to the Commission's goals
- Prepare clear specifications for fully integrated rail freight systems for seamless logistics and networks, working towards more developed standards and technical specs
- Proposal of a rail freight system development to be implemented, covering the GAP analysis for joint vehicles, intermodal systems and operation principles
- Assess the potential of rail freight systems of the future for market up-take, adopting existing and expected future customer requirements for different goods segments

Results *Freight vehicles*

Multiple innovations on the wagons, with simultaneously introduction of new modernized wagons components, with novel sensors and monitoring, should ensure allowance of the freight trains easily to blend with passenger train traffic.

In case of freight vehicles, the related measures affect both wagons and complete train configurations in terms of length, speed, performance, central/automatic couplers, EP/electronic braking, electrification, automation and weight. Influencing operations, also wagon shunting is considered as an issue.

The design of the novel rail freight vehicles for the future, has been dealing with wagon design to enhance its carrying capacity, along with complete configuration of freight vehicles with locos, the braking system to increase safety, train length and failure detection in order to enable more reliable paths for rail freight on the network. The keys for such development have been:

- Heavier and longer trains which utilize the full potential of modern locomotives
- More efficient wagons by higher axle load and wider gauge and better length-utilization
- Improved train performance with electro-pneumatic brakes and automatic couplers

Wagons

Concerning wagons, an important question is whether development will be incremental, as it has been so far, or if it is possible to make a system change. Incremental change means successively higher axle loads, wider gauge, better length-utilization in a given train length, higher payload and less tare weight per wagon, more silent brake-blocks, end of train (EoT) devices and some electronic sensors.

A system change will include electro-pneumatic brakes, disc-brakes, full electronic control of the wagons and load and automatic central couplers. The automatic couplers are the most critical component, but important not only because it will make shunting and marshalling safer and cheaper but also because it will make it possible to operate longer trains without problems and introduce electronic braking systems and control and to feed the train with electricity.

Changes involve also trailer railway transport. Solutions where trailers do not need to be lifted to wagons but can be rolled on and off along a ramp can thus widen the market considerably. They also mean that simple terminals only need to be dimensioned for the trucks' axle load.

Locomotives

Modern locomotives have a tractive power of 5-6 MW capable of hauling 2,000-2,500 tonne trains of up to 1,000m in length. Not only the tractive power but also the locomotives' axle load is critical for optimal traction. To increase the axle load from normally around 20 tonnes to 22.5 or for heavy haul, 25-30 tonnes is a possibility to operate heavier trains combined with track-friendly bogies.

Today, most rail operators use electric locos for long haul and diesel locos for feeder transport and terminal shunting. But once duo-locos have now been introduced into markets, equipped with both normal electric traction and diesel traction, either for shunting or for line haul, they can be used to shunt the wagons itself at a marshalling yard or stop at an un-electrified siding at an industry, and change wagons directly.

The operators thus need only one loco instead of two and it will also make it possible to introduce new operation principles and change wagons along the line. It will also decrease vulnerability in case of current interruptions. In the long term, it will also make it possible to avoid catenaries at marshalling yards and sidings, which will save money for the IM.

Train Configurations

While the improvement of capacity for passenger trains will mean the use of double-deckers and duo-locos, to increase the capacity of the rail system, will mean for freight the use of trains and vehicles with higher capacity: longer trains, higher and wider gauge, with higher axle load and metre load.

With the measures listed above, combined with adaptation of freight corridors for long and heavy freight trains, supposing, upgrade of infrastructure, signalling system (with shorter block lengths) operation and monitoring systems, the longer and heavier trains will make it possible to roughly double the capacity for freight trains without building new railways and in the long term with ERTMS level 3 even more.

Finally, a catalogue has been produced to integrate all developments, and amongst them consolidate the rolling stock design, after analysis of the potential market up-take of the new designs for rail freight systems. The catalogue focusses on rail freight system designs and technological innovations in six key areas which were: freight, modal shift from road to rail, EU-wide high-speed rail network, multimodal TEN-T core network, long-term comprehensive network, traffic management systems in all modes, and multimodal transport information

The catalogue also has been specified for

- Monitoring of vehicles, sensor for performance and hazards, positioning of goods
- Smart implementation and utilization of the high capacity freight trains in the Automated Decision Support Systems
- Vehicle 2 Infrastructure (V2I) communication; for maximizing speed, performance and overall capacity
- Relation to Infrastructure Managers and Train operations from Railway Undertakings

Results of this catalogue have been submitted to a comprehensive industry survey, and were assessed with the aim to understand levels of industry receptivity and acceptance in relation to performance and operational and technological characteristics of the new system designs, focusing on rail freight system designs and technological innovations in the six key areas that were already identified.

Terminals

New conceptual designs have been developed in C4R to make new or adapted, time and cost-efficient terminals, based on transshipment technologies and interchanges of the future (rail yards, intermodal terminals, shunting facilities, rail-sea ports, etc.), to upgrade the field of co-modal transshipments and terminals, in the following points:

- Operations: Wagon shunting, intelligence for vehicles in terminals, terminal operation
- Facilities: Marshalling yards, terminals

Also for intermodal transshipments, in terminals it has been considered that is generally an advantage to introduce liner trains. So, if terminals are located on an electrified side track where the train can drive straight in and out onto the line again, there is no need for a diesel loco to be switched in.

This in turn requires a horizontal transfer technology to be implemented in terminals that can function under the overhead contact wires. The train must be able to be loaded and unloaded during a stop of 15-30 minutes. This also obviates the need to park wagons. The terminals can also be made more compact and require less space. This will reduce the costs which is critical for intermodal.

An identification has been performed of a set of Key Performance Indicators (KPI's) by terminal typology capable to represent the operational modes of the terminal and the assessment of future terminal performances including the effects of innovative technologies and operational measures.

Also, appropriate innovations have been identified to be included in the future consolidated scenarios (2030/2050) for each terminal typology and case study and the innovations suitable to increase the global efficiency of logistic chains.

This work was finally transferred to the catalogue of Rail Freight Systems of the Future, to study and design new concepts for network-based services for fully integrated rail freight systems to meet requirements of 2030/2050, in particular to terminal configurations and functions, with their technical and operational aspects. Current state of the art is identified for each and the changes necessary to achieve the EC goals are defined in the short, medium and long term.

The approaches, the majority of which were for full automation of facilities like the terminals and marshalling yards, were traying to help planners to understand and prioritise system capabilities and decide on optimal strategies to: increase overall system capability of the facilities; respond dynamically to planned and unplanned changes; and support real-time punctuality management. These strategies will take into account the requirements for high speed freight operations.

Operations of railway freight terminals

The case studies for operations were performed on various terminal typologies: Rail to Road, Rail to Sea and Rail to Rail were examined to see their actual situation and their evolution on functional and operational terms and business cases. All case studies are located along TEN-T multimodal corridors.

In particular, for the type Rail to Road, the Duss terminal in Riem (Munich) is on the crossing of Scandinavian - Mediterranean and Rheine- Danube corridors, while the NV Combinant terminal, IFB Zomerweg, HTA-Hupac, all in Antwerp, are located on the North Sea - Baltic and North Sea – Mediterranean corridors.

For Rail to Sea, the terminal Noatum Prince Felipe in Valencia is on the Mediterranean corridor. Finally, for the Rail to Rail the marshalling yard of Hallsberg is located on the corridor Scandinavian - Mediterranean.

The activities performed, provided a large set of results concerning typical terminal operation in the present situation and in selected future scenarios which provide original results, particularly concerning:

- Achievable operational standards of intermodal and wagonload terminals
- Financial results concerning the business case of intermodal and wagonload terminals,
- Economic results from a societal viewpoint, which are useful to pilot future European actions in the freight transport and rail systems fields

Key innovations were identified for the three typologies of terminal that have been evaluated in the carried-out cases studies, with a progressive implementation in time.

For Road-Rail and Sea-Rail intermodal terminals, both innovative operational measures and technologies were included in the scenarios, on innovations.

Therefore, each scenario represents a different temporal step of the application of these innovations. For marshalling yards, only innovative technologies only were included. This elaboration produced, for each typology of terminal, two different scenarios, with innovative operational measures and technologies for each of the three typologies.

Co-modal transshipment and interchange/logistics

After the terminal scenarios were clear, Key Performance Indicators (KPI's) were selected.

The selection for KPI's in inland interchanges (Rail-Road terminals) was:

Terminals Type	Analytical methods	Simulation model
Rail-Road	Total Transit Time (ITU) Total Transit Time (vehicle)	Equipment Performance System utilization rate
Rail-Rail	Maximum flow through the yard Mean number of wagons in the yard at the same time	Average wagon transit time Tracks utilization rate
Rail-Sea	Total Transit Time (ITU) Total Transit Time (vehicle)	Equipment Performance System utilization rate

The assessment in terms of positive/negative effects measured with the KPI's, was completed with the business case from the Business as Usual, to the different scenarios with a traffic estimation, calculation CAPEX and OPEX and the necessary assumptions on social benefits (Time saving of 1.0÷1.7 Euro / t h, external costs reduction due to road to rail modal split [2] 30.8÷40.2 Euro / kt km), and other further assumptions (Technical life of new infrastructure of 30 years, % of other costs on average EU28 labour costs [Eurostat, 2014] 24.43, % taxes and VAT on average EU28 cost of electricity [Eurostat, 2014] 25.00, and finally average EU yearly inflation % rate 1999-2015 [Eurostat, 2015] 1.73.

Total performance increased/Technical

For freight vehicles and trains, technical advances proposed for each scenario can be found summarized on today´s common standard, incremental change (2030) and system change (2050).

Two targets in the EU white paper at 2011 were 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and to triple the length of the existing high-speed rail network by 2030. For high speed rail the target seems to be achievable. The actual development of freight is not in line with the target and at present there are no indications that it will be fulfilled.

Equipment	Common standard	Incremental change	System change
Wagons			
Running gear	Different	50% Track-friendly	All track-friendly
Brakes	Cast brakes	LL brakes	Disc brakes
Brake control	Pneumatic	Radio controlled EOT	Fully electronic
Couplers	Screw couplers	Automatic couplers on some trains	Automatic couplers on all trains
Max Speed	100 km/h	120 km/h	120-160 km/h
Max Axle load	22.5 tonnes	25 tonnes	30 tonnes
Floor height lowest	1,200 mm	1,000 mm	800 mm
IT-system	Way-side	Some in wagons	All radio controlled
Locomotives			
Tractive effort kN	300	350	400
Axle load	20 tonne	22,5 tonne	25 tonne
Propulsion	Electric	Some duo-locos	All duo-locos
Fuel	Diesel	LNG/Diesel	LNG/electric
Drivers	Always drivers	Some driverless	All driverless
Trains			
Train lengths in RFC	550-850 m	740-1050 m	1050-2100 m
Train weight	2,200 tonnes	4,400 tonnes	10,000 tonnes
Infrastructure			
Rail Freight Corridors	18,000km	25,000km	50,000km
Signalling systems	Different	ERTMS L2 in RFC	ERTMS L3 in RFC
Standard rail weight	UIC 60 kg/m	70 kg/m	70 kg/m
Speed. ordinary freight	100 km/h	100-120 km/h	120 km/h
Speed, fast freight	100 km/h	120-160 km/h	120-160 km/h
Traffic system			
Wagonload	Marshalling - feeder	Marshalling – feeder Some liner trains	Automatic marshalling Liner trains – duo-loco
Trainload		Remote controlled	All remote controlled
Intermodal	Endpoint-trains	Endpoint-trains Liner trains with stops at siding	Endpoint-trains Liner trains fully automated loading
High Speed Freight	National post trains	International post and parcel trains	International post and parcel train network
IT /monitoring systems			
	Some different	Standardized	Full control of all trains and consignments

The planned Rail Freight Corridors (RFC) are promising but there is no common plan to increase the standard in the RFC, which would be desirable. With the measures listed above, longer and heavier trains will make it possible to roughly double the capacity for freight trains without building new railways and in the long term with ERTMS level 3 even more.

Contributions from new conceptual design for wagons were estimated for each design and customer/goods orientation:

- For car transportation business, the introduction of the 6 axles/5 bodies wagons and the automated brake test (15% increase of asset rotation alone) with predictive maintenance (5%) and asset rotation impacts a capacity increase up to 30% could be reached in the best case (according to car lengths)
- For container transportation, the new 5 bodies wagon with the same various progress as for the car transportation enables to reach up to 20% capacity increase
- For 12-axle wagon for crane-able semi-trailers the capacity increase could be up to 17,5%

On the automatic couplers, and introduction of kits in locos and trains, some results (i.e. from Marathon project) for such trains offer a quick coupling of two standard trains thus enabling to maintain the departure frequency from different terminals and the economy on the trunk travel and a capacity to reach with the power of only one locomotive a siding in case of a breakdown. A significant increase of the network capacity (up to 40%), whatever signalling system is installed.

The EOT device with P brakes, for incremental change scenario, is easily adaptable on classical wagons at the end of the brake pipe, acting by detection of the first depression in the brake pipe, it opens the brake pipe at the end progressively, helping the end of the train to brake rapidly it reduces the longitudinal compression forces, reducing braking forces to 40% in 750m. train length, and 20% for 1000 m., and thus enables the train to be lengthened up to 1000 m. It informs also on the integrity of the train apart from reducing the stopping distance.

For a system change if high energy is needed on the wagon for the use EP brakes, the wire solution is almost compulsory with automatic couplers ensuring energy and bus of information continuity and command, providing also conditions of integrity and location of the train.

However, also a solution through wireless low power network on the wagon is recommended for the connection with the various devices incorporating IoT. For that case, it is recommended the use of Low power wide Area networks (LPWAN), to reduce drastically the costs and energy consumption but with latency, less accuracy of positioning and less data to be sent.

From the industry survey, participants were asked on these proposed new standards for freights in the different scenarios, and the alternatives for new conceptual designs on wagons/trains and on terminals and functions, to be chosen to implement it with five questions related to: gauge clearance, axle load, change to priority of path allocation, wagon innovations in freight wagons to accommodate modal shift, and finally, freight vehicle improvements still required.

- 60% thought ‘very’/‘moderately’ likely that axle load increase achieved EU wide by 2030.
    - On existing wagon designs, those chosen most frequently to facilitate modal shift were Special flat wagon with bogies, ordinary flat wagon with bogies and tank wagon
    - The three wagon improvements ranked by industry as most urgently required were lighter wagons, maintenance detectors and track friendly running gear

Current situation across EU concerning a high-speed network were analyzed including freight services identified as a focus towards 2030/2050. Remaining barriers to a high-speed network for freight services were examined, including rolling stock adaptation, service reliability and capacity constraints.

Even with this rolling stock improvement, the potential for a real high-speed network for freight services is still limited. The most important consequence of building high speed lines primarily for passenger traffic is that it will increase the capacity for freight and regional trains on the conventional network. Freight trains with higher speeds, in the range of 120-200 km/h, are possible and also used today for specific markets, mostly with classical high-performance freight wagons. It was concluded that:

- Future wagon designs to encourage modal shift and industry input regarding the wagon innovations (couplers, brakes, connectivity…) required most urgently.
- A better signalling system, shorter block lengths and in the long-term introduction of ERTMS level 3 as one of the most important needs complementary for the freight vehicles operational development for forecasts 2030/2050.
- Technological and operational innovations for various terminal typologies and industry viewpoint on the terminal innovations required most urgently.
- A review of traffic management systems and MTI including ERTMS deployment and innovations to streamline the flow of information within terminals.
- Main barriers to developing information and communication technologies and services are; a lack of training, the conservative attitude of incumbents and low profitability in the sector. To address this, these gaps must be addressed to achieve modal shift.
- Real-time monitoring systems including both on board and wayside mounted systems should be considered vital for rail freight services 2030/2050

- Automation of terminals and terminal functions seems to be the most efficient way to reduce costs and increase benefits in future terminals. There are many ideas but not so many systems ready for the market today, which means that strong effort must be carried out (e.g. in Shift2Rail program) to implement automated systems in real operation.
- Finally, introduction of IT-systems to get total control of the consignee from origin to destination, including terminal handling, is a prerequisite for any future rail development.
-

OPERATIONS FOR ENHANCED CAPACITY

Key issues and objectives

Railway operations strategies, that will increasingly use automation for optimized performance and enhanced capacity, have been developed within the framework of C4R, provided with road maps for technology to transform decision support systems, into automated systems that enable rail industry to meet the challenges of the future, such as high-speed and freight combined services on the same infrastructure, and greater levels of transshipment (co-modal) between railway system and others.

Focus for this functional subsystem was directed on the development planning tools, recommendations and a roadmap for more effective railway operations increasing levels of automation and optimising management of capacity and performance during both nominal and disrupted conditions. In detail, the aims were:

- Develop and test strategies for capacity planning and operation which are able to deal with
- problems of today's railway and that of the evolving railways of the future
- Creating a road map for the development of modelling and simulation tools, to ensure that in parallel to development of future concepts, the industry will have the ability to evaluate them. This will support strategic trade-off decisions as well as tactical real-time operational decisions, with proof of concept models developed
- Identify operational network constraints and develop operation improvements and logistic leverages, with specific implementation plans
- Use high level approaches to develop optimal strategies for specific network configurations that result in automatic approaches for resilient operations
- Smooth management of minor disturbances and large disruptions due to accidents or critical weather events, deriving joint requirements and testing for incident management plans ensuring the minimisation of effects on final customers
- Development of a data model that can be used to support autonomous data exchange and reasoning and satisfy requirements in the field of railway operations, as well as the requirements to support system wide decision making, including at multi-modal hubs/nodes

Results *Traffic management and capability*

C4R provides step-changes in the area of strategic, tactical and operational planning, outlining technological evolution of railway operations so to meet future challenges such as increased capacity (to address forecast of demand in 2030 and 2050), optimized management of emergencies, enhanced information sharing and greater levels of connection between rail and other transportation modes.

To increase the capacity of the rail system, it was clear the following measures can be taken regarding strict planning, and not exclusively dealing with traffic management:

- More efficient timetable planning; On double track: Bundling of trains with same average speed in timetable channels to harmonize speeds. Daylight faster freight trains an option.
- Use of trains/vehicles with higher capacity: For freight: Longer trains, higher and wider gauge, higher axle and metre load. For passengers: Double-decker and wide-body trains.
- Differentiation of track access charges to avoid peak hours and overloaded links.
- Better signalling system, shorter block lengths and in long term introduction of ERTMS L3.
- Adaptation of freight corridors for long and heavy freight trains.
- Investment in HSR to increase capacity for freight trains and regional trains on the conventional network and in some cases dedicated freight railways.

It was needed to:

- Make general approaches, the majority of which are fully automated, to help planners to understand and prioritise system capabilities and decide on optimal strategies for system capabilities and deciding on optimal strategies to: increase overall system capability; respond dynamically to planned and unplanned changes; and support real-time punctuality management, with strategies considering requirements from freight operations, established in the catalogue

- Develop new and innovative data processing methodologies and algorithms to enact and summarise raw measurements making data more practical for use in analysis tools, e.g.:
  - SysML incident management diagram against real-case disruption events occurred in several member countries, so that European infrastructure managers can avail of a schematic “reference European incident management process”
  - Assessing benefits of automation on current railway networks by applying advanced tools for improved real-time information to real-life operations. The example of a neural network-based tool for accurate prediction of train delays has been reported together with its application to a real-life instance on a portion of the Italian railway network.
- Create more relevant and effective data analysis tools to enable the processed data to be used in decision making; and new data visualisation and presentation tools to assist strategic and operational decision making, within them precisely:
  - Development and fine-tune the “Capability Trade-Offs” tool (within a capability matrix enwrapped) and apply it to a real railway corridor for a strategic evaluation of different innovations.
  - Development and verification of optimised strategies for disruption management against real-life case studies, and validation through extensive simulation experiments of the roadmap for increasing levels of automation in EU railways
  - Development, fine-tuning and application of the tool for optimised tactical-operational planning (the “CAIN-LiU” model) on a real railway corridor to assess the benefits that can be gained on capacity and performance when timetable designers and/or dispatchers are supported by such a tool, and that automated planning can bring on network capacity and performance
- Research, putting focus on data systems that are able to provide ubiquitous data on train position and condition, enabling automatic decision support systems and operations and planning staff to make better decisions;
- Identifying best strategies for increasing levels of automation in European railways so to achieve capacity and performance targets for 2030/2050. For this, a roadmap for automation level increase was validated via extensive simulation experiments to assess different combinations of technology deployment and understand best ways forward.
- Make Proof of concept (PoC) models that support the development of roadmaps for future modelling and simulation and operational strategies that provide a vision for future improvements in automated railway operations.

For each of the outputs, improvements were quantified through simulation or real-world demonstration of the project outcomes. The main focus was on developing a set of automated tools which can support decisions across the entire railway operational planning process from long-term to real-time management of traffic.

An analysis of EU best-practices to manage disruptions, identified critical activities to be improved, upgrading levels of automation. A roadmap to increase levels of automation in EU railway operations was provided, resulting in a set of recommendations to deploy an improved European traffic management system on handling of large disruptions, even if caused by extreme weather events.

A semantic web-based data architecture framework was developed to enable upgrade of automation levels by integrating infrastructure assets and railway operations, with traffic control centres, customers and other transportation modes to achieve a better performing intermodal system.

Capability trade off Traffic management and capability

At the strategic planning level, within C4R it has been developed the so-called **“Capability Trade-Offs”** decision support tool which quickly provides planners and/or investors with the innovation to the infrastructure and/or the operations which is able to meet future capacity targets while being the best trade-offs among the other main “whole system” high-level goals of the railway, such as: affordability, adaptability, resilience, robustness, and automation.

This software tool has been validated and applied to a real case study, namely the railway corridor between Peterborough and Doncaster on the East Coast Main Line in the UK. Results shows the effectiveness of such a tool in quickly indicating the best design alternative, as importantly as discarding not suitable alternatives, thereby saving costs and time.

Increase of Robustness in Traffic Management Systems

At the tactical and operational level C4R has also delivered a software tool (CAIN-LiU) for robustly increasing operational capacity of an existing timetable. This tool for integrated tactical-operational planning is indeed able to inset additional train paths in an already existing timetable, robustly, i.e.

minimising the impact on already existing services. The timetabling tool CAIN (developed at Oltis Group) has been dynamically integrated with the impact assessment tool developed at University of Linkoping (LiU), to identify optimised time slots where additional train path requests (from FOCs and/or TOCs) can be allocated while keeping standard levels of service punctuality.

In the medium-short time this tool can support timetable planners when e.g. allocating additional freight train paths in an already existing timetable. During real-time operations instead, dispatchers can be advised when managing emergencies where e.g. additional passenger train paths need to be operated to allow people evacuation via rail, in case other transport modes are shut down (e.g. like during explosion of the Islandic volcano Eyjafjallajökull in 2010 which caused closure of the air traffic).

The tool has been validated by means of an application to a real case study: the Swedish portion of the Scan-Med European railway corridor between Malmo and Hallsberg. Results shows that the solution proposed by the tool significantly outperforms in terms of delay minutes the decision which a human dispatcher would normally take when unsupported by any automatic tool.

A method for optimised allocation of time margins in the timetable has also been developed to return a rescheduled timetable which is robust against stochastic disturbances to operations. A Monte-Carlo experiment performed in simulation for the same railway corridor highlights that service punctuality is scarcely affected when optimally distributing timetable margins even when inserting an additional train path in an existing timetable.

Automation for Disruptions – Incident Management

C4R has tried to deal with traffic incidents by means of the use of SysML schemes European best-practices for disruption management in order to identify critical activities and opportunities for improvements by introducing higher levels of automation. A validation against real disruption cases has proved the developed SysML diagram as a valid reference schematic European disruption management process which can be usefully support infrastructure managers to improve their current incident management procedure.

A roadmap for increasing levels of automation in European railways has been outlined and validated by means of an extensive simulation experiment. The roadmap defines successive steps to increase Grades of Automation so to achieve capacity and performance targets in 2030 and 2050. A significant outcome is that only by increasing the Grade of Automation of a group of assets together is effective in improving railway capacity. Conversely upgrading the level of automation of a single asset does not necessarily produce evident benefits.

An instance of automation increase has been studied by applying in real-life an Extreme Machine Learning algorithm for predicting train delays. Outcomes of this application on a real railway section in Italy (between Milan and Genoa) showed that introducing this kind of automation can significantly improve the quality of dispatching decisions when managing real-time perturbations as well as the accuracy of information to customers.

Data exchange and data architecture

A semantic web-based architecture has been developed in C4R. This architecture is essential for enabling the increase of levels of automation in European railways, since it defines the communication interfaces among the different sensors/devices installed to monitor the condition of railway infrastructure assets as well as operating traffic. Dynamic real-time data communication between the infrastructure and the operation sides will provide more accurate information to both traffic controllers and passengers, with expected benefits on both level of service and quality of service, especially during disruption events. Three main storyboards have been identified to define a set of recommendations on the data format to use for any of the specific context of information usually available in the railway field and in the intermodal transportation system in general (e.g. RailML has been recommended for timetable data, Open Street Map for infrastructure data, etc.).

This semantic data architecture is called RaCoOn, based on ontologies allowing collection and merging of information contained in the data despite their provenance and format. Data can be shared not just across railway users but throughout the entire intermodal transportation platform, enabling an improved experience for passengers of the intermodal transport system. It can include crowdsourced data coming from social media to help sharing information on conditions of the intermodal transport system in particular in case of disturbances to the service (i.e. perturbations and/or disruptions).

Performance increase

The capability trade-off framework can support decision making by enabling assessment at a whole-system level, of the impact of an infrastructure/operational and/or technological change on the railway system.

The decision tool can support long-term investment decisions and strategic planning providing a quick identification of the innovations which are more beneficial from a “whole-system” perspective, and as importantly, ruling out the options that have limited potential to deliver future industry targets. The industrial uptake of such a tool will definitely lead towards substantial savings in time and costs within the long and often “not lean” design and evaluation process of railway infrastructure managers.

The key points of such a tool are: i) using a whole-system approach taking into account the capabilities of the railway system; ii) providing planners and investors with a quick and comparative graphical understanding of how given innovations are going to affect the current railway state in terms of the main high level railway goals: capacity, affordability, automation, adaptability and resilience; iii) automating the complex strategic investment planning process which often involves interactions between different representatives of the railway industry (e.g. infrastructure managers and train operating companies) so to reduce global costs and time.

With the CAIN-LiU application, it is shown effectively that support both timetable designers (in the medium term) and dispatchers (in the short term) is possible to help planning higher traffic volumes while optimally distributing timetable margins to achieve a robust schedule at the same time.

In the medium/short-term, this allows for example a more robust insertion of additional freight train paths in an already existing timetable, while minimising impacts on existing train services. In the short term, instead it is possible to robustly insert additional passenger train services in case of disruption or emergency where passengers might need to be evacuated via rail if other transportation modes (such as air or road transport) are shut down.

The automated system integrates tactical and operational planning and offers a web - train service database shared between the IM and TOCs/FOCs to facilitate and speed up amendment process to validate timetable changes (e.g. needed when cancelling/adding and/or rerouting train services).

The main objective for this application, once developed, was to assess the impact on punctuality of capacity enhancements provided by the integrated tactical-operational planning framework when applied to a real case study. The route selected for the case study was the 450 Km long Swedish portion between Malmö and Hallsberg of the Scandinavian-Mediterranean (SCAN-MED) European corridor, located in the southern part of Sweden (see figure) and represents the major freight link connecting the largest marshalling yard in Scandinavia to the continental part of Europe.

The objective of this application is to use the “CAIN-LiU integrated planning framework” to support dispatching decisions by suggesting an optimised time slot allocation for one extra freight train path which is requested to be added within an already existing timetable.

Two dispatching options were evaluated to identify the best allocation of this extra freight train path. They were evaluated regarding the impact that each option has on the overall service punctuality. in terms of mean and median of overall train delays (in minutes). On of the options, represented the best dispatching decision since it increases train delays by just 5.28% instead of 125.09%.

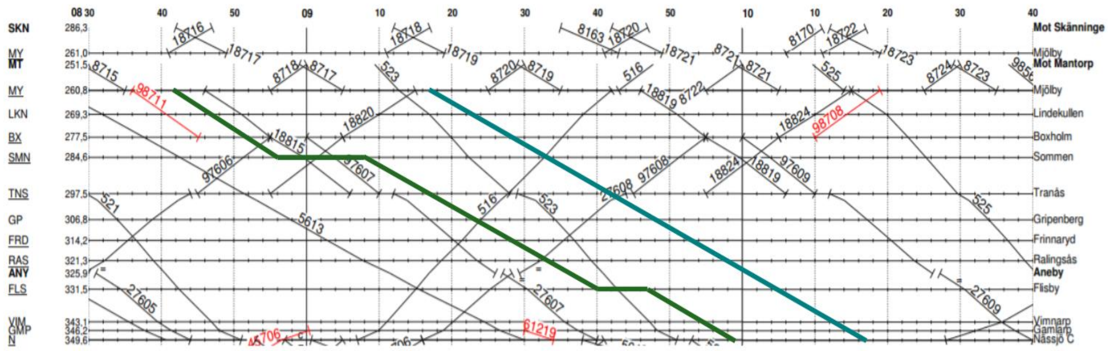

Figure 7 Graphical representation of Option 1 (green train path) and Option 2 (teal train path) for the insertion of an extra freight train path into an already existing timetable.

In order to increase the robustness of timetables produced with the support of the CAIN-LiU framework a method has been developed to optimally insert buffer times so to mitigate the impact of stochastic disturbances on service performance. The developed method bases on the indicator Robustness in Critical

Points (RCP) which has been proven in literature to improve recovery of train delays and prevent delay propagation at the same time.

The CAIN-LiU integrated planning framework also includes a web train schedule database which is shared among IMs, FOCs and TOCs. Such a system automates the timetable amendment process making it more flexible and fast in providing contingency plans in case of disruption or emergency.

The best practices currently used in several member countries to manage disruptions were described in formal scheme diagrams to identify potential criticalities in the management process which can be corrected by the introduction of several levels of automation. A roadmap for increasing levels of automation in European railways has been outlined and validated via simulation experiments.

Automatic tools for supporting operational planning/management and passenger information have been developed and instances of their applications to real railway networks have been reported to assess benefits that automation has on capacity, performance and especially on the interaction between IMs and RUs during complex decisional processes in case of disruptions or emergency.

SysML diagrams represent a "reference European schematic process for disruption management". Shortcomings of current European disruption management processes have also been highlighted by the SysML validation. Investigation of real-life disruption management procedures has led towards the formulation of recommendations for an improved European traffic management for handling disruptions. Main recommendations are reported as follows:

- Weather forecast models should be automatically integrated with the disruption management process so to prepare for extreme weather events, putting in operation strategies to mitigate and/or prevent effects on operations.
- Communication among stakeholders involved in the disruption management shall be supported by automatic systems for improved information sharing.
- Automatic decision support tools shall be made available to quickly provide stakeholders with optimised disruption management strategies that minimize the impact of the disruption on both service and customers.
- Automatic asset condition monitoring system shall be equipped for implementing a predictive maintenance strategy which increases network reliability.

A roadmap for increasing automation levels in European railways has been defined and validated by means of extensive simulation experiments. The roadmap first focused on defining grades of automation for each individual asset (i.e. separately for rolling stock, infrastructure, stations, etc.).

By combining the Grades of Automation defined for all the different types of railway assets, a global matrix of Grades of Automation (GoA) has been defined for the railways as a whole system.

Experiments showed that an incremental improvement of a single asset does not necessarily produce capacity enhancements. Instead, it is the automation increase of a group of assets which yields higher network capacity. A specific instance of automation increase has then been studied to assess the impacts that automation increase can actually have when applied to real-life operations.

That has been focused on the development of an Extreme Machine Learning algorithm for accurate train delay prediction which could support both passenger information and traffic controllers in the case of service perturbations. The algorithm developed uses a data-driven multivariate regression model which uses historical speed and position data of a given train journey to predict its future delay.

Applications to the railway section between Milan and Genoa in Italy has shown that the EML algorithm outperforms delay prediction currently made by IM by a factor 2 on average.

Another high-level aim was to develop a data architecture that is able to provide ubiquitous data for railway operations and supporting applications. enabling railways to harness and effectively use large and diverse sources of data to extract meaningful information and knowledge to support operational strategies.

A semantic web-based architecture has been developed This architecture is essential for enabling the increase of levels of automation in European railways, since it defines the communication interfaces among the different sensors/devices installed to monitor the condition of railway infrastructure assets as well as operating traffic. Dynamic real-time data communication between the infrastructure and the operation sides will provide more accurate information to both traffic controllers and passengers, with expected benefits on both level of service and quality of service, especially during disruption events. Three main storyboards have been identified to define a set of recommendations on the data format to use for any of the specific context of information usually available in the railway field and in the intermodal transportation system in general (e.g. RailML has been recommended for timetable data, Open Street Map for infrastructure data, etc.).

The semantic data architecture called RaCoOn, is based on ontologies allowing collection and merging of information contained in the data despite their provenance and format. This means that data can be shared not just across the railway users but throughout the entire intermodal transportation platform, enabling an improved experience for passengers of the intermodal transport system. The architecture can include crowdsourced data coming from social media to help sharing information on conditions of the intermodal transport system in particular in case of disturbances to the service (i.e. perturbations and/or disruptions).

SYSTEM ASSESSMENT AND MIGRATION TO 2030/2050

SP5 has been the horizontally oriented sub-project, cutting across the technical work streams of the other sub-projects ensuring a whole-system approach.

The objectives of SP5 haven been:

- to set up the **assessment framework,**
- to describe the collective **"vision"** and scenarios,
- to coordinate the **demonstrations** activities in the different technical SPs,
- to conduct the global **assessment** of the project outputs to finally propose a roadmap for the future research work and implementation of the innovations to **ensure the migration** of the current railway system towards the targeted vision.

Refined Railway system 2030/2050, paving the way to an affordable, resilient, automated and adaptable railway

One of the first aims in C4R was to define comprehensive roadmaps to describe the necessary steps to develop and implement innovation and to progress from the current state-of-the-art to a shared global vision of the 2050 railway along realistic scenarios.

The roadmaps set the 2050 vision for an ***affordable, adaptable, resilient, automated*** and ***high capacity*** European railway. The starting point for each roadmap is the definition of one of the five aspects of the vision. For each of these criteria, a timeframe for subjects for research and development were setup, scheduling the successive steps of development, demonstration, legislation and implementation.

The roadmaps have been developed following a review of literature - including key documents such as the European *Commission's White Paper*. They include key metrics and published targets towards delivering the vision, as well as a list of broad-based research and development activities.

Regarding 2020/2030 and 2050 scenarios, the major challenges facing transport continue to be lack of capacity, increasing congestion, need to reduce environmental impact and address the mobility needs in a period of changing demographics and exponential growth in the introduction of new technologies. C4R has laid a very valuable foundation on which success can be built and a key element of the success of the C4R project will therefore lie in the handling of the outcomes and ensuring that the benefits of the research are realised. A brief description of the potential next steps needed to facilitate the realisation of benefits from the investment into the C4R project is provided. Some progress has been made in taking forward some of the results from C4R (e.g. SP2 work on freight) but more needs to be done. A main aspect of 'next steps' has been identified as the development of a proactive engagement strategy with internal and external stakeholders and ensuring that the momentum of progress is maintained

C4R research has made some important contributions towards meeting some of the challenges facing the railway industry in meeting the 2030/2050 targets. A detailed breakdown of the innovations and outputs (totalling 26) from C4R and brief descriptions are provided in the report. Detailed descriptions of each of the outputs are provided in the specific Task reports.

See the deliverables

D5.1.1 *Railway road map – paving the way to an affordable, resilient, automated and adaptable railway*
D5.6.1 *Refined Railway system 2030/2050*

Selected corridors for the assessment

In C4R the whole current railway system was presented as a network of railway corridors and supporting points (real sites) for carrying more comprehensive information gathering for locations for the assessment of the migration to the new C4R systems.

Real sites/corridors have been chosen in order to carry out the assessment of migration to the future rail system. Based on the availability of data and time constraints only two of the corridors initially agreed were taken forward for assessment. Therefore, the detailed baseline data was collected, and the scenarios refined.

On a selected corridor section, a baseline scenario is then defined by the available data about that route. This data should include the following: infrastructure characteristics, monitoring and maintenance strategy, track possession strategy, train characteristics, traffic scenario, traffic management principles and signalling system, incident and natural hazards, costs related to current infrastructure maintenance and operation costs, value of time and delays, environmental impact (Emissions of CO2) and the economic impact from emissions.

The detailed corridor analysis referred to following questions:

- Why this corridor has been selected
- What are the weak points, constraints, hazards ("hot spots")?
- Are there any sections where capacity constraints are now or will be in the near future?
- **How the C4R technologies/innovations can improve the situation** in terms of solving the capacity shortage (in short-term view 2020, mid-term 2030 and long-term view 2050)?
- What are the current investment plans under TEN-T, or national upgrades and the time frames of these?

The following corridors were initially selected for developing the scenarios:

- East Coast Mainline in the UK
- **Scandinavian-Mediterranean corridor (Malmö to Mjölby in Sweden)**
- North Sea- Mediterranean (Perpignan, Marseille, Metz, in France)
- North Sea – Mediterranean (Spanish section - French/Spanish border to Barcelona and Valencia)
- **Southern France, Montpellier-Perpignan.**

Migration scenarios and paths

Baseline scenario

C4R aimed to define the global and selected migration scenarios and paths, and to identify the steps to migrate from existing rail system to the one envisioned.

By defining the scenarios, a distinction between the generic scenarios (related to SP1-SP4 innovations) and the specific scenarios (related to the selected corridors) have been made.

The defined scenarios should refer to the C4R targets such as

- The fragility of some key component of the **infrastructure** system (especially in extreme weather conditions) such as switches may impact the efficiency of the whole system. The resilience of switches to any kind of known failure will be reinforced, as well as the ability of the operation system to recover from incidents (SP1)
- Intermodal integration within the global transport system will be improved through **enhanced transshipment of passengers and freight** (SP2)
- Capacity enhancements will also be achieved by higher speed freight vehicles, allowing an optimized interleaving of freight trains into mixed traffic, and **improved planning models for operation** (SP3)
- New concepts for low maintenance infrastructure, using standardized and “plug-and-play” concepts will be proposed. Non-intrusive **innovative monitoring techniques** or self-monitoring infrastructure will be investigated, allowing low or no impact (SP4)

The baseline scenario(s), taking selected corridors or sections with the relevant characteristics of the railway routes (boundary conditions, properties, future demands, capacity constraints etc.) serve as a base to compare the current situation (without innovations) with the future situation (with the innovations of C4R).

In addition, the C4R targets include increased capacity for future increases to freight and passenger traffic as well as for modal shift from road to rail. As a consequence, the C4R scenarios must also consider data from road, including: operational cost of road freight and passenger vehicles, utilisation of road vehicles, maximum loading of road vehicles, value of time/cost of delays for road freight and road passengers and environmental emissions and economic value of road vehicle emissions

The C4R scenarios

The role of scenarios in C4R is to both test the outputs and also demonstrate how C4R outputs will help deliver the 2050 vision of a higher capacity passenger and freight railways that can be delivered more efficiently than today's railways through improved reliability, affordability, resilience and automation.

A scenario is a potential 'combination of situations' that the future railway may be required to cope with, including the characteristics of railway routes (infrastructure, local climatic conditions and variations, operations, bottlenecks etc.) and particular combinations of overarching drivers.

It is also important to take into account scenarios for the future of road transport, if innovations in road freight, for example heavier loads and driverless vehicles reduce the costs of road freight this is expected to impact on the targets for modal shift from road to rail.

In this approach the scenarios are set up from the C4R innovations (SP1-SP4 innovations) and their key parameters related to the capacity enhancement. The scenarios are derived from the C4R innovations with the associated technical parameters/ properties contributing to Reliability, Availability and Capacity,

These are the innovations/technologies that have been developed by the SP's and the scenarios have been focussed on:

SP1: Design of resilient & reliable low maintenance infrastructure

- Modular integrated design of new concepts for infrastructure (new slab track)
- Switches & Crossings for future railways, enhanced resilience to failure

SP2: Improved specifications for rolling stock and trans-shipment procedures

- New freight wagons with higher axle loads (> 25T/axle), automatic coupling with electrical connection, lighter wagons, track friendly running gear etc.

SP3: Use of traffic management as an innovation, incident recovering by improved traffic planning and operating strategies

SP4: Integration of Advanced (or new) Monitoring Systems in the design & built-in process for easier to monitor infrastructure with low cost and low impact inspection.

With respect to each SP, the top targets and requirements of C4R have been determined. These top targets are based on the roadmap, defined KPI's of C4R project as well as on the EU White Paper scenarios. To compare the actual situation with the future situation (implies the use of the C4R innovations) it was necessary to identify the differences between the baseline (current situation, 2015), short-term view with 2030 and long-term view with 2050 for the definition of the top targets as well as the specific parameters.

The specific parameters (technical parameters), being relevant for the scenarios with respect for each SP, have been defined. the impact of the C4R innovations with the associated technical parameters on the five key aspects has been indicated qualitatively by each SP. In this regard, each SP had to answer how far his concerned innovation will contribute to the C4R project targets. The qualitative analysis has been carried out in order to determine the optimum benefit that the C4R innovations or their combinations may provide.

See the deliverables

D5.3.2 *Migration scenarios and paths*

D5.4.2&3 *Assessment of technologies, scenarios and impacts*

Assessment of technologies, scenarios and impacts

Results of the demonstrations indicate the technical feasibility of the innovations; these results are combined with the CBA assessments to provide final conclusions on the innovations proposed in the project.

Most of the demonstrations are not finished as planned in the DOW and not all necessary data are available or evaluated at the end of C4R. That means, a quantifiable assessment was not possible but the quantitative assessment and the idea behind the innovations are in line with the C4R targets.

Demonstrations were carried out in SP1 and SP4. Most of the innovations address the capacity of the railway system. The impact on this important requirement strongly depends on the local situation and the given bottle necks.

A **Cost-Benefit Analysis (CBA)** based on a tool developed in the project was performed for the two cases analysed. This methodology has been also supplemented by a Multi-Criteria Analysis (MCA) that help take into account non-economic aspects that are usually not captured in a CBA.

The first case study is built on **the Swedish sections of the Scandinavian-Mediterranean TEN-T Corridor**. Both rail and road corridor sections are modelled with input data about infrastructure, operation and traffic forecasts. The analysis is made through a set of Scenarios where the different sets of C4R Innovations, operational or market conditions changes are modelled.

The **first scenario** (Scenario 1) includes the implementation of all C4R innovations throughout the Swedish rail network, as well as increases in train length up to 1500 m.

Two scenarios (2 and 3) are built with a more limited implementation of infrastructure innovations, mainly slab track. The results show an improvement relative to Scenario 1, showing the advantages of a more selective approach.

A **Rail Positive Scenario** (4) assumes a **full migration to innovative freight wagons**, including automatic couplers and EP brakes, leading to further operating costs reductions and a small speed increase. This scenario has the most positive results of all that were tested.

In order to test how some of the expected innovations in road transportation would affect the profitability of the investment in the rail sector being tested, **Road Positive Scenarios** (5 and 6) were also tested. These assume an increase in road truck gross weight and reductions in operating costs.

A second case study was based on a more detailed analysis of a smaller corridor section in **southern France (Montpellier-Perpignan)** This corridor section has the further feature of being a bottleneck in the wider corridor it is inserted in.

A comparable set of scenarios was analysed for this corridor section showing overall positive results in terms of NPV, even for the ones with heavier investment. However, the relative changes between the different scenarios are not qualitatively different from the ones obtained in the first case study.

The results of the Montpellier-Perpignan case study in comparison with the Swedish one show how the kind of deep investment in infrastructure is more easily profitable in capacity constrained sections, even if this profitability hangs on an assumed increase in availability.

Main conclusions

Both case studies show how improvements in operation leading to longer, **higher capacity** trains can have very positive impacts with relatively modest investments.

Deep **infrastructure investments** may or may not be profitable, depending on the conditions of the corridor. What becomes apparent from the results of the analysis is that there is a much higher chance of large investments, such as upgrade to slab track, being profitable in capacity constrained sections. However, local boundary conditions, which have big impact on investment cost, complexity of upgrade and operational risks must be necessarily considered in decision making. It should, however, be noted that the biggest share of the benefit is generated by gains in availability leading to increased capacity.

The **introduction of innovative operational** concepts may have a very high profitability. These are rolling stock innovations, such as automatic couplers, EP brakes, often combined with modest infrastructure investment in siding extensions to allow for longer and heavier trains.

In both studies the preceding issues, the main benefits generating mechanism is the modal transfer from road to rail that is allowed by the increased carrying capacity. Benefits in other categories are usually small in comparison. Still, some of the analysed scenarios show that improvements in delays or reductions in travel times can have significant positive impacts trough savings in value of time.

See the deliverables

D5.4.2&3 *Assessment of technologies, scenarios and impacts*

D55.6 *Final evaluation and assessment*

Potential impact

INFRASTRUCTURE AND ADVANCED MONITORING

Advances in the frame of C4R have been done in the infrastructure, regarding potential that can suppose major steps and so impacts in the technical field of infrastructure design, renewal and maintenance, covered by SP1 tasks and deliverables, and also including advanced monitoring, developed in all its depth within the frame of SP4.

The development of infrastructure solutions that aim at both cost-saving operation by low cost maintenance and extended life-cycle, lowering the total Life Cycle Cost (LCC), have been covered and include two new concepts and prototypes of modular designs of slab tracks (“3MB” and “L-Track”) for the railway track of the future and, even with greater initial expenses for investments than the ballasted track, would reduce the cost of installation from on the shelf slab track available models.

Another impact to be considered on their potential is availability for additional capacity that will be created, based on profiting from originally scheduled intervals on lines that now would require a minimised number of track possessions. These types of solutions increase potentially in each day available from 3 to 5 complementary hours, in which mainly potential new freight services can use the track at their full potential capabilities without crossing or mixing to ordinary or high-speed passenger service.

The investment cost of upgrading to slab track was assumed to be in some scenarios 1.000.000 €/(km track), which is within the typical frame of values for existing slab track designs; this value includes the installation of innovative monitoring systems, as complement to the track’s replacement. The main intended effect from the implementation of slab track is the reduction of maintenance costs and the increase of availability. It was assumed from studies that a 34 % reduction in variable maintenance costs for the track and 27% reduction for S&C wherever the consideration was that the track was upgraded to slab technology.

Investigations of the project have also determined significant impacts, in terms of understanding the behaviour of certain infrastructure components, as well as developing potential solutions to solve their current obstacles to allow very high-speed traffic (VHST) or mix of high-speed and freight train traffic. Several track components such as switches and crossings (S&Cs), where the investigation of failure modes has leaded to develop breakthrough innovative concepts to improve their reliability using optimised geometry, grades or stiffness, or rail pads and under sleeper pads (USPs) combined with sleepers, on the optimisation of their design, including geometry, elasticity, and track-train interaction behaviour in relation with operational demands in terms of speed load (VHST or heavier axle load) and volume of traffic, have received a special attention, which has been driven to obtain results not only in terms of overall performance, but also obtaining a reduced need for maintenance in these components, thus lowering the operational costs linked to their related corrective or preventive activities.

Regarding S&C, installation cost is estimated to be 1.5 times the current average value, 150,000 €/unit; as for the slab track innovation, monitoring systems will also be available for S&C, their installation cost already included in the switches and crossings installation value.

Earthworks and structures have also been the focus of specialised activities, where the analysis of the dynamic solicitations for bridges in the structural design and the innovation applied for the design and construction of transition zones (with demonstrators located on site in high speed lines in the UK (HS1) and Portugal), have obtained results applicable to the design in the field with impact of not only both VHST and upgraded freight traffic, but from their mutual combination. Such achievements required establishing a systematic and documented approach not only for new lines but for infrastructure upgrading to meet the new demands on freight operations, because upgrading scenarios tend to increase the track and infrastructure deterioration and fatigue phenomena, due to the increase of axle load, speed and total length of each individual train. These degradations need to be addressed and mitigated in advance, and now will be appropriately counteracted.

All the above-mentioned impacts, wouldn’t have been made in many cases if the developments of components, wouldn’t have undergone joint with new concepts for railway structural and operational monitoring, both in sensors and identification technologies, that combined can offer insight to their integration in operation and their behaviour and durability through simulations and automated maintenance forecasts, and allowing also a prediction of the structural lifetime. The work has been directed toward the use of innovative simple and cheap sensors and a migration to intelligent components with in-built monitoring for new tracks structures and for existing ones.

Numerous technologies were considered for their suitability for application as part of a condition monitoring system, either for current railway elements (i.e. retrofitting) or to be built-in to new elements during production or installation (as it has been proved in the new slab track concepts have been designed, developed and prototyped), going through a holistic analysis in which wireless communication transmission was the focus, finally choosing RFID passive tags as referential and low cost technology in terms of identification of both infrastructure and rolling stock components, suitable for the railway environment of work, and fully safety compatible with other features of communication and generating no electromagnetic disturbance, requiring low power to be fed, while maintaining high levels of robustness. It has been able to be combined with COTS-sensor deployment, so that the recovered data can be turned to useful information with minimal post-processing, regarding accelerometrical sensors (e.g. MEMS), or other that can measure temperature, humidity or stress, requiring also low energy harvesting to be in operation.

The introduction of advanced monitoring system will contribute for a reduction in fixed maintenance costs, the overall performance of the new system, for example leading to a reduction of S&C maintenance costs to approximately a third of that of the baseline value and will reduce the delay minutes caused by S&C by 50%.

A 60% reduction of unplanned unavailability will be obtained when combining slab track, new S&C and monitoring.

These monitoring systems have obtained an impact in the already tested railway applications, but also in such consideration into other future possible applications in the condition monitoring of pantograph-catenary interaction, weighing in motion and wheel defect detection systems and bogie condition monitoring on freight trains. Extended applications can be considered as well outside the railway system field, for example, in air-borne transportation or other different types of ground transportation.

UPGRADE OF FREIGHT SERVICES AND TERMINALS OPERATION

In the Transport White Paper 2011, the European Commission identified the need to overcome the burden that the current transportation system places on economy and society through, for example: lack of capacity; impacts on the environment (emissions, congestion etc); and the inability to cope with climate change and extreme weather events. Capacity4Rail consortium is confident about the outcomes of research and developed work carried in different SPs our over the last four years that its impact will be felt in both freight and passenger traffic and that it will to grow across European rail networks. To cope with this growth, the Capacity4Rail consortium has explored, analysed and suggested new and innovative technologies to create greater network capacity in a resource-efficient, faster, and more efficient and more flexible manner. The innovative techniques will deliver adaptable, automated, and resilient and, above all, affordable solutions to existing and projected capacity issues to the rail industry.

The outcomes of the project will provide societal benefits in several categories: economic (suggested through quantitative and qualitative CBA and FA analysis), delivered both directly (to the infrastructure and rolling stock owners and operators, as well as tax payers and ticket holders) and indirectly (to the European economy as a whole); and environmental (by providing the means to significantly increase railway capacity and thereby facilitating modal shift to railways from other less environmentally friendly transport modes).

An important impact of the outcome of SP2 (WP21 to be specific) is that the outcome of the research is published in a peer reviewed paper titled 'How to make modal shift from road to rail possible in the European transport market, as aspired to in the EU Transport White Paper 2011' an 'open access' journal of European Transport Research Review. The paper has attracted a huge readership and downloads (1800 as of August 2017).

Out study suggests that it is possible to reduce GHG emissions for all modes but rail will still be the most efficient mode by 2050. An estimation of the effects of a mode shift (as noted above) to rail transport applying the world's 'best practice' shows that such a mode shift to rail can reduce EU transport GHG emissions over land by about 20 %, compared with a baseline scenario. In combination with low-carbon electricity production a reduction of about 30% can be achieved. A developed rail system, as suggested in different deliverables, can thus substantially contribute to the EU target of reducing GHG emissions in the transport sector by 60% compared to 1990 levels. To enable such a mode shift and to manage the demand for capacity, there is a need for investment at national and European level.

Upgrading of existing lines to handle increased demands on freight operations can carry costs that are as low as 15–20% of costs for rebuilding to the same standard. At the same time, environmental impact and operational disruptions typically decrease. On the other hand, failures in upgrading procedures may carry dramatic consequences in lost revenues and increased costs. With the guideline introduced in D11.4 and enhanced in D11.5, the possibilities to carry out the upgrading in a structured manner have increased significantly. The potential savings in decreased cost savings are massive.

Introducing costs, a freight terminal upgrade cost of 100 M€/terminal may be assumed. The benefits were, however, difficult to estimate at this stage. Surely, the benefits from this innovation are related to the operating costs: one of the main effects of the upgrade for the terminal would be quicker loading and unloading operations. In the absence of detailed information, a reduction of the operating costs of freight rail transport in the order of 10% is assumed because of terminal upgrades. Quicker loading and unloading operation also mean a reduction of freight trains travel time, assumed to be in the order of 5%.

Monitoring and processing of monitoring data is a topic of increased interest throughout Europe. To this end, there are massive investments in both hardware and software. The aim is that these investments will pay off due to more efficient and reliable operations. However, this requires both collected data and interpretation of the data to be relevant with respect to the objectives. The Capacity4Rail deliverables D41.1, D41.2 and D41.3 identify relevant parameters for different parts of the railway system. The reports also show how data can be interpreted and how data that cannot be directly measured can be interpreted from measurable data. Further, the reports introduce a framework for evaluating costs and benefits (in a broad sense) of different monitoring solutions. Finally, the reports include examples of operational installations. In total, this enhances the possibilities to make well-founded and aware decisions on monitoring strategies. It also reduces the risk of failed investments substantially and enhances the usefulness of collected data. In summary, the impact on efficient future monitoring strategies in Europe should be significant.

TRAFFIC MANAGEMENT

Potential impacts produced by the uptake of SP3 results by railway Industry would be the following:

The introduction of the “Capability trade-offs” tool developed can effectively support industry strategic investment decisions by quickly and clearly indicating the scenario achieving future operational targets while providing the best capability trade-off. This definitely paves the way for potential automation of long-term planning processes leading to more cost-effective and “leaner” deployment of railway investments.

The industrial use of an automatic integrated planning tool such as the CAIN-LiU framework developed can effectively support tactical and real-time decisions by advising on scheduling strategies which maximize economic satisfaction of all the actors involved. The real-life application of this tool showed indeed that the provided solution returned the best trade-off among requests of FOCs, network capacity utilisation for IMs and punctuality for TOCs. Additionally, such a framework includes a web train schedule database which is shared among IMs, FOCs and TOCs, making the timetable amendment process more flexible and faster than current practice in providing contingency plans in case of disruption or emergency.

The SysML schematic disruption management process can be effectively used by infrastructure managers of member countries to identify criticalities and opportunities for improvements in their current disruption handling procedures. The roadmap produced for increasing levels of automation outlines step-changes which need to be implemented for each asset to enhance the grade of automation of the entire railway system. The roadmap also can support the European railway industry in identifying the most suitable Grade of Automation which is required to achieve future operational targets and meet the demand forecasted for 2030 and 2050. Industrial uptake of advanced tools for train delay prediction is expected to provide significant improvements to the quality of traffic management decisions and information to customers, consequently increasing business effectiveness of infrastructure managers as well as customer’s satisfaction.

Real-life implementation of the web-based semantic data architecture developed allows increasing the level of automation of railways by dynamically integrating asset condition monitoring directly with operation management, facilitating the implementation of integrated maintenance and timetable planning. In addition, this would enable predicting disruption events due to asset faults in order to prevent the disruption itself or mitigate its impacts on both service and customers by means of more accurate information, which is expected to lead to improved traffic management and better customer experience. The extension of the semantic web based architecture to the entire transportation system will provide the communication framework necessary to deliver the European Intermodal Transportation platform set as one of the main objectives for 2020 by the “White Paper” on transport of the European Commission.

Dissemination material, methodologies, tools and results produced by SP3 have also been included as educative material in courses which are given to students at the Faculty of Engineering of the University of Birmingham (United Kingdom) and the Technical University of Dresden (Germany).

OVERALL SYSTEM TECHNICAL AND ECONOMIC IMPACTS

The overall technical impacts of all innovations could be seen directly in the resulting generation of new designs POCs, demonstrators, and derived in the actions and guidelines recommended as seen in D56.2.

The economic part was focused in a Cost-Benefit Analysis (CBA) based on a tool developed in the frame of the project, and which was performed for two practical case studies in the EU.

The first case study has been built on the Swedish sections of the Scandinavian-Mediterranean TEN-T Corridor. Both rail and road corridor sections were modelled with input data about infrastructure, operation and traffic forecasts. The analysis is made through a set of Scenarios where different sets of C4R Innovations, operational or market conditions changes are modelled.

The first scenario (scenario 1) included the implementation of all C4R innovations throughout the Swedish rail network, as well as increases in train length up to 1500 m. The CBA resulted in a negative NPV, with the large investment not being offset by the producer surplus generated by the modal transfer. When the scenario was altered to include a very significant reduction in delays, this is enough to turn the NPV positive.

Two scenarios (2 and 3) were built with a more limited implementation of infrastructure innovations, mainly slab track. The results showed an improvement relative to scenario 1, showing the advantages of a more selective approach.

A Rail Positive Scenario (4) assumed a full migration to innovative freight wagons, including automatic couplers and EP brakes, leading to further operating costs reductions and a small speed increase. This scenario had the most positive results of all that were tested.

In order to test how some of the expected innovations in road transportation would affect the profitability of the investment in the rail sector being tested, road positive scenarios (5 and 6) were also tested. These assumed an increase in road truck gross weight and reductions in operating costs. The results showed the benefits that were present in Scenario 1 from modal transfer may be virtually obliterated. It was tested how the introduction of taxes on road transportation can partially offset these effects, boosting the rail sector.

A second case study was based on a more detailed analysis of a smaller corridor section in southern France (Montpellier-Perpignan) that was performed in the context of the demonstrations for D55.6. This corridor section has the further feature of being a bottleneck in the wider corridor it is inserted in.

A comparable set of scenarios was analysed for this corridor section showing overall positive results in terms of NPV, even for the ones with heavier investment. However, the relative changes between the different scenarios are not qualitatively different from the ones obtained in the first case study.

The results of the Montpellier-Perpignan case study in comparison with the Swedish one show how the kind of deep investment in infrastructure is more easily profitable in capacity constrained sections, even if this profitability hangs on an assumed increase in availability.

Both case studies show how improvements in operation leading to longer, higher capacity trains can have very positive impacts with relatively modest investments.

In the end, we can extract two main points on the economic impacts of the innovations that have been considered in the context of the Capacity4Rail project.

The first point to be taken is that deep infrastructure investments may or may not be profitable, depending on the conditions of the corridor. What becomes apparent from the results presented here is that there is a much higher chance of large investments, such as upgrade to slab track, being profitable in capacity constrained sections. However, local boundary conditions, which have big impact on investment cost, complexity of upgrade and operational risks must be necessarily considered in decision making. It should, however, be noted that the biggest share of the benefit is generated by gains in availability leading to increased capacity.

The second point concerns the very high profitability that the introduction of innovative operational concepts may have. We are talking about rolling stock innovations, such as automatic couplers, EP brakes, often combined with modest infrastructure investment in siding extensions to allow for longer and heavier trains.

In both the preceding issues, the main benefits generating mechanism is the modal transfer from road to rail that is allowed by the increased carrying capacity. Benefits in other categories are usually small in comparison. Still, some of the analysed scenarios show that improvements in delays or reductions in travel times can have significant positive impacts trough savings in value of time.

Further considerations on impacts deriving from the results of these case studies are made in Deliverable D56.1, specifically, concerning the European policy Targets and Roadmap as well as market share perspectives.

Address of the project public website

The CAPACITY4RAIL public website is www.capacity4rail.eu

Below is the list of the Beneficiaries:

Partner number	Partner name	Partner short name	Contact person	Email
P1	UNION INTERNATIONALE DES CHEMINS DE FER	UIC	Aline Wego	wego@uic.org
P2	ARTTIC	ARTTIC	Martin Dietz	dietz@arttic.eu
P3	TRAFIKVERKET	TRV	Agneta Wargsjo	agneta.wargsjo@trafikverket.se
P4	SYSTRA	SYSTRA	Pierre-Etienne Gautier	pegautier@systra.com
P5	DEUTSCHE BAHN	DB	Ralf Marxen	ralf.marxen@deutschebahn.com
P6	NETWORK RAIL INFRASTRUCTURE LIMITED	NR	Gwendoline Buchan	gwen.buchan@networkrail.co.uk
P7	ADMINISTRADOR DE INFRAESTRUCTURAS FERROVIARIAS	ADIF	Jose Conrado Martinez Acevedo	jcmartinez@adif.es
P8	FUNDACION DE LOS FERROCARRILES ESPANOLES	FFE	Cesar Felipe Lopez Sanchez	clopezffe@ffe.es
P9	INSTYTUT KOLEJNICTWA	IK	Witold Olpinski	wolpinski@ikolej.pl
P10	VOESTALPINE	VAE	Markus Hlatky	markus.hlatky@voestalpine.com
P11	ACCIONA INFRAESTRUCTURAS	ACCIONA	Miguel Angel Paris Torres	MParis@acciona.es
P12	INSTITUTO SUPERIOR TECNICO	IST	Olga Ribeiro	olga.ribeiro@ist.utl.pt
P13	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA	DICEA	Antonella Cammisa	antonella.cammisa@uniroma1.it
P14	ANSALDO STS	ASTS	Antonio Ruggieri	antonio.ruggieri@ansaldo-sts.com
P15	UNION DES INDUSTRIES FERROVIAIRES EUROPEENNES	UNIFE	Paulina Pineda	paulina.pineda@unife.org
P16	UNIVERSITY OF NEWCASTLE UPON TYNE	UNEW	Amanda Gregory	amanda.gregory@ncl.ac.uk

P17	INGENIERIA Y ECONOMIA DEL TRANSPORTE	INECO	Almudena Delapena	almudena.delapena@ineco.com
P18	CENTRO DE ESTUDIOS DE MATERIALES Y CONTROL DE OBRA	CEMOSA	Luis Jiménez Redondo	ljredondo@cemosa.es
P19	NEWOPERA	NEWOPERA	Franco Castagnetti	franco.castagnetti@newopera.org
P20	OLTIS GROUP	OG	Stefan Mesticky	mesticky@oltis.cz
P21	KUNGLIGA TEKNISKA HOEGSKOLAN	KTH	Marina Backer Skaar	backer@kth.se
P22	CHALMERS TEKNISKA HOEGSKOLA	CHALMERS	Mareike Lutz	mareike.lutz@chalmers.se
P23	THE UNIVERSITY OF BIRMINGHAM	UoB	Xavier Rodde	h2020@contacts.bham.ac.uk
P24	TRL	TRL	Jack Campbell	jcampbell@trl.co.uk
P25	VOSSLOH FASTENING SYSTEMS	VFS	Winfried Bösterling	winfried.boesterling@vfs.vossloh.com
P26	THE UNIVERSITY OF HUDDERSFIELD	UoH	Andrew McConnell	a.mcconnell@hud.ac.uk
P27	TECHNISCHE UNIVERSITAET DRESDEN	TUD	Chrisitan Gerhardts	epc@tu-dresden.de
P28	UPPSALA UNIVERSITET	UU	Anders Jonsson	Anders.Jonsson@uadm.uu.se
P29	TURKIYE CUMHURIYETI DEVLET DEMIR YOLLARI ISLETMESI GENEL MUDURLUGU	TCDD	Guven Kandemir	guvenkandemir@tcdd.gov.tr
P30	INFRAESTRUTURAS DE PORTUGAL	IP	Helena Peres	heperes@refer.pt
P32	UNIVERSIDADE DO PORTO	UPORTO	Maria Joao Ramos	projetos@up.pt
P33	VAN DIEREN SWEDEN	VDS	Lars Lerstorp	lars.lerstorp@vandieren.se
P34	CENTRO DE ESTUDIOS Y EXPERIMENTACION DE OBRAS PUBLICAS	CEDEX	Enrique San Juan	Enrique.sanjuan@cedex.es
P35	SNCF MOBILITES	SNCF	/	/
P36	ADEVICE SOLUTIONS	ADEVICE	/	/
P37	LINKOPINGS UNIVERSITET	LIU	Martne Rosander	marten.rosander@liu.se
P38	EUROPEAN FEDERATION OF RAILWAYS TRACKWORKS CONTRACTORS	EFRTC	Imrich Korpanec	SG-EFRTC@fntp.fr

P39	VOSSLOH COGIFER	VCSA	Raymond Schnepp	Raymond.Schnepp@vossloh cogifer.com
P40	FUNDACION DE LA COMUNIDAD VALENCIANA PARA LA INVESTIGACION, PROMOCION Y ESTUDIOS COMERCIALES DE VALENCIAPORT	VPF	Antonio Torregrosa Maicas	atorregrosa@fundacion.vale nciaport.com
P41	CARGOSPED SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA	CARGOS PED	Magda Wieczorkiewicz	m.wieczorkiewicz@cargospe d.pl
P42	THE UNIVERSITY OF SHEFFIELD	USFD	Deborah Mc Clean	d.mcclean@sheffield.ac.uk
P43	COMSA	COMSA	Valentí Fontserè	vfontsere@comsaemte.com
P44	SOCIETE DE TRANSPORTS DE VEHICULES AUTOMOBILES	STVA	Pierre Enderle	bfeurprier@stva.com
P45	KNORR-BREMSE SYSTEME FUR SCHIENENFAHRZEUGE	KB	Johannes Graeber	johannes.graeber@knorrbre mse. com
P46	SNCF RESEAU	SNCF-R	Laurent Boutin	laurent.boutin@reseau.sncf.f r
P47	INSTITUT FRANCAIS DES SCIENCES ET TECHNOLOGIES DES TRANSPORTS, DE L'AMENAGEMENT ET DES RESEAUX	IFF	Marie-Françoise Sherratt-Roux	marie-francoise.sherratt@ifsttar.fr
P48	NTnet	NTnet	Roger Jönsson	roger.jonsson@ntnetab.se

2. Use and dissemination of foreground

Based on the results achieved in the project, a general strategy for the exploitation of them has been established and gathered in the public deliverable ***D61.5 "Exploitation of results from CAPACITY4RAIL".***

This strategy comprises an overview of the consortium strategy and strategic impacts, amongst the stakeholders, divided into different sectors: railway undertakings (RUs) and infrastructure managers (IMs), rail supply industry, academia and sector associations, and set in different timeframes, short-term actions after the project end and long-term actions.

A SWOT analysis has been performed based on a general overview of the Strengths, Weaknesses, Opportunities and Threats of the C4R project, according with the general aspects of the project, taking into consideration the opinion of the stakeholders of railway system, some of them already participating as members of the C4R project. A questionnaire was prepared to pick up the aims and objectives perceived by each individual member to do so.

The strategy also includes the proposals to ERA, regarding recommendations to be proposed for the update/modification of the Infrastructure TSI's and also identifies the Standards (ENs) in need of review or elaboration.

A plan for use and dissemination of foreground has been also included.

All consortium partners have contributed and will continue contributing to some extent to the dissemination and communication activities.

Dissemination and exploitation of results have been crucial to the acceptance and implementation by railway undertakings, suppliers and end-users of the technologies developed in the project.

At the final stage, dissemination activities have been focused on promoting the results achieved and making the appropriate target audience aware and sensitive to their potential benefits, in order to facilitate implementation of the project results.

All along the project duration, ongoing communication activities have been necessary to keep dissemination active to continuously present, discuss and get feedback on the progress of the project.

With a global system view, C4R have covered a wide range of technical areas, and a large variety of dissemination targets.

The C4R dissemination strategy tries to accomplish the following objectives:

- To raise awareness for the project approach and results;
- To generate active involvement of railway stakeholders in the evaluation and usage of C4R results;
- To stimulate active involvement of researchers into C4R related research activities;
- To dissemination the scientific and technical new knowledge;
- To encourage the implementation of outcomes by end-users.

Because of its fairly broad representativeness, both in terms of railway stakeholders and in terms of geographical scope, the market penetration of the C4R results has been guaranteed by the participation of:

- Railway operators (undertakings and infrastructure managers), guaranteeing that project solutions satisfy user needs and fulfil railway requirements;
- Research groups and universities.
- Railway suppliers, large industrial groups as well as SMEs
- International professional associations, Railway organizations at EU and international level

Thanks to the worldwide membership of UIC, the international outreach of universities and the wide presence of major industrial partners and European associations, the consortium in itself is the primary base for dissemination.

The uptake and implementation of the research findings by the players themselves and their active participation in the dissemination process ensure a fairly large and effective spreading of the information among the different railway stakeholders.

The present chapter consist of:

Section A

This section gathers all the dissemination measures, including any scientific publications relating to C4R.

Section B

This section specify the exploitable foreground and provide the plans for exploitation.

See also,

deliverable ***D56.2 "Guidelines for further research and development activities",***
deliverable ***D61.5 "Exploitation of results from CAPACITY4RAIL".***

Section A (public)

This section includes two templates,

- **Template A1:** List of all scientific publications relating to the foreground of the project.
- **Template A2:** List of all dissemination activities.

These tables are cumulative; they show all publications and activities from the beginning until after the end of the project.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS

No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers (if available) - DOI	Open access provided?	Internet link to the publication
1	Assessment Methods for Innovative Operational Measures and Technologies for Intermodal Freight Terminals	Stefano Ricci , Luigi Capodilupo , Barbara Mueller , Juergen Karl , Jens Schneberger	Transportation Research Procedia	Vol. 14, 01/01/2016	Elsevier	Netherlands	2016	2840-2849	10.1016/j.trpro.2016.05.351	Yes	http://www.sciencedirect.com/science/article/pii/S235214651630357X
2	How to make modal shift from road to rail possible in the European transport market, as aspired to in the EU Transport White Paper 2011	Dewan Md Zahurul Islam , Stefano Ricci , Bo-Lennart Nelldal	European Transport Research Review	Vol. 8/Issue 3, 01/09/2016	Springer Verlag	Germany	2016	janv-14	10.1007/s12544-016-0204-x	Yes	https://link.springer.com/article/10.1007/s12544-016-0204-x
3	Switch panel design based on simulation of accumulated rail damage in a railway turnout	Jens C.O. Nielsen , Björn A. Pålsson , Peter T. Torstensson	Wear	Vol. 366-367, 01/11/2016	Elsevier BV	Netherlands	2016	241-248	10.1016/j.wear.2016.06.021	Yes	https://www.researchgate.net/publication/305062012_Microstructure_and_wear_performance_of_heat_treated_WC-12Co_microwave_clad

No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers (if available) - DOI	Open access provided?	Internet link to the publication
4	Train Delay Prediction Systems: A Big Data Analytics Perspective	Luca Oneto , Emanuele Fumeo , Giorgio Clerico , Renzo Canepa , Federico Papa , Carlo Dambra , Nadia Mazzino , Davide Anguita	Big Data & Society	Vol 9, 01/05/2017	SAGE Publications		2017	in Press	10.1016/j.bdr.2017.05.002	Yes	http://www.sciencedirect.com/science/article/pii/S2214579617300060?via%3Dihub
5	A microscopic evaluation of railway timetable robustness and critical points	Emma Solinen , Gemma Nicholson , Anders Peterson	Journal of Rail Transport Planning and Management	in Press	Elsevier BV	Netherlands	2017	in Press	10.1016/j.jrtpm.2017.08.005	Yes	https://www.researchgate.net/publication/319439500_A_microscopic_evaluation_of_railway_timetable_robustness_and_critical_points
6	Dynamic Delay Predictions for Large-Scale Railway Networks: Deep and Shallow Extreme Learning Machines Tuned via Thresholdout	Luca Oneto , Emanuele Fumeo , Giorgio Clerico , Renzo Canepa , Federico Papa , Carlo Dambra , Nadia Mazzino , Davide Anguita	IEEE Transactions on Systems, Man and Cybernetics	Vol. 47/Issue 10, 01/10/2017	IEEE	United States	2017	2754-2767	10.1109/TSMC.2017.2693209	Yes	http://ieeexplore.ieee.org/document/7917288/

No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers (if available) - DOI	Open access provided?	Internet link to the publication
7	Datenformate, Datenmodelle und Datenkonzepte für den Eisenbahnbetrieb	Suzanne Wunsch-TUD	Der Eisenbahningenieur	Issue 11 (November 2016)	Eurail Press	Hamburg, Germany	2016	pp 8-14		yes	http://www.eurailpress.de/archiv/fachartikelarchiv/ergebnisliste/artikelansicht.html?tx_it24archiv_list%5Barticle%5D=12880&tx_it24archiv_list%5Baction%5D=show&tx_it24archiv_list%5Bcontroller%5D=Article&cHash=65a4f8203aca6811728b903153e3ce1a
8	Big Data Analytics for Train Delay Prediction	Emanuele Fumeo , Luca Oneto , Giorgio Clerico , Renzo Canepa , Federico Papa , Carlo Dambra , Nadia Mazzino , Davida Anguita	Innovative Applications of Big Data in the Railway Industry	Bookchapter on "Innovative Applications of Big Data in the Railway Industry"	IGI Global		2017		10.4018/978-1-5225-3176-0.ch014	yes	https://doi.org/10.1016/j.bdr.2017.05.002
9	Looking towards 2030-2050 for an affordable, automated, adaptable, resilient and high-capacity railway	UIC	European Railway Review	Vol. 3, 2014	European Railway Review	Kent, United Kingdom	2014	20		Yes	https://www.globalrailwayreview.com/digital/err-issue-3-2014/index.html

No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers (if available) - DOI	Open access provided?	Internet link to the publication
10	Delay Prediction System for Large-Scale Railway Networks Based on Big Data Analytics	Luca Oneto , Emanuele Fumeo , Giorgio Clerico , Renzo Canepa , Federico Papa , Carlo Dambra , Nadia Mazzino , Davide Anguita	Advances in Big Data	Vol. 529	Springer International Publishing, Cham	Cham	2017	139	10.1007/978-3-319-47898-2_15	Yes	https://link.springer.com/chapter/10.1007%2F978-3-319-47898-2_15

LIST OF PAPERS IN PROCEEDINGS OF A CONFERENCE/WORKSHOP

No	Title	Main author	Number, date or frequency	Publisher	Start Date of Conference/ Workshop	End Date of Conference/ Workshop	Permanent identifiers (if available) - DOI	Publisher	Open access provided?	Internet link to the publication
1	C4R: The wagon load activity technology innovations: new freight wagons and trains. How the various innovative concepts developed around wagon technology in the C4R "Freight" subproject are expected to improve the rail freight transport competitiveness, reliability and attractiveness.	New Opera, Trafikverket	30/06/2014	Transport Research Arena 2014,	14/04/2014	17/04/2014		TRA 2014, Paris, France	Yes	http://www.capacity4rail.eu/IMG/pdf/tra2014_-_capacity4rail_project._the_wagon_load_activity_technology_innovations_-_new_freight_wagons_and_trains.pdf
2	State-of-the-art of European rail freight system and future needs	NewRail	14/07/2015	RailNewcastle conference 2015	14/07/2015	17/07/2015		NewRail, Newcastle, Great Britain	No	
3	Designing future turnouts - where research capabilities meet industry needs	Bezin, Yann / University of Huddersfield	26/04/2016	Rail Technology Conferences 2016	26/01/2016	28/01/2016		University of Huddersfield Repository, Huddersfield, UK	Yes	http://eprints.hud.ac.uk/id/eprint/28132/
4	Discrete Events Simulation of Intermodal Terminals Operation: Modelling Techniques and Achievable Results	S. Ricci , L. Capodilupo , E. Tombesi	05/04/2016	Proceedings of the Third International Conference on Railway Technology: Research, Development and Maintenance	01/04/2016	08/04/2016	10.4203/ccp.110.288	Civil-Comp Press, Stirlingshire, UK	No	http://www.ctresources.info/ccp/paper.html?id=9179

5	Understanding Track Loading Requirements to achieve Better Track Design	Y. Bezin , S. Neves , I. Grossoni , A. Kaushal	26/04/2016	Proceedings of the Third International Conference on Railway Technology: Research, Development and Maintenance	01/04/2016	08/04/2016	10.4203/ccp.110.230	Civil-Comp Press, Stirlingshire, UK	Yes	http://www.ctresources.info/ccp/paper.html?id=9121
6	Optimization of support stiffness at a railway crossing panel	Grossoni, Ilaria, Bezin, Yann and Neves, Sérgio	19/04/2016	Railways2016, Cagliari (Italy).	05/04/2016	08/04/2016		University of Huddersfield Repository, Huddersfield, UK	Yes	http://eprints.hud.ac.uk/id/eprint/28063/
7	Analytical methods and simulation models to assess innovative operational measures and technologies for rail port terminals: the case of Valencia Principe Felipe terminal	Stefano Ricci	07/06/2016	Libro de Actas CIT2016. XII Congreso de Ingeniería del Transporte	01/06/2016	09/06/2016	10.4995/CIT2016.2016.3398	Universitat Politècnica València, Valencia, Spain	Yes	http://ocs.editorial.upv.es/index.php/CIT/CIT2016/paper/viewFile/3398/1645
8	Railway turnout damage prediction and design implications	Yann Bezin, University of Huddersfield	24/10/2017	International Conference on Train/Track Interaction & Wheel/Rail Interface, Hall of Railway Sciences (CARS), Beijing, China.	20/06/2016	22/06/2016		University of Huddersfield Repository, Huddersfield, UK	Yes	http://eprints.hud.ac.uk/id/eprint/28063/

9	Advanced Analytics for Train Delay Prediction Systems by Including Exogenous Weather Data	Luca Oneto , Emanuele Fumeo , Giorgio Clerico , Renzo Canepa , Federico Papa , Carlo Dambra , Nadia Mazzino , Davide Anguita	01/10/2016	2016 IEEE International Conference on Data Science and Advanced Analytics (DSAA)	01/10/2016	19/10/2016	10.1109/DSAA.2016.57		Yes	http://ieeexplore.ieee.org/document/7796932/

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audience	Countries addressed
1	Press releases	UNION INTERNATIONALE DES CHEMINS DE FER	Grant Agreement signed for Capacity4Rail	17/09/2013	Paris	Scientific community (higher education, Research) - Industry - Medias		5000	Worldwide
2	Web sites/Applications	UNION INTERNATIONALE DES CHEMINS DE FER	Set up of C4R website and private platform	01/10/2013	Paris, France	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias			Worldwide
3	Oral presentation to a wider public	EUROPEAN FEDERATION OF RAILWAYS TRACKWORKS CONTRACTORS	General Information on C4R project to EFRTC members in the framework of DG activity report	11/10/2013	EFRTC General Meeting in London	Industry		65	UK, France, Italy, Germany, Spain, Netherlands, Switzerland, Luxembourg, Belgium, Sweden
4	Press releases	UNION INTERNATIONALE DES CHEMINS DE FER	Announcement of Capacity4Rail project launch	22/10/2013	Paris, France	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		5000	Worldwide
5	Flyers	UNION INTERNATIONALE DES CHEMINS DE FER	Issuing of the project flyer	01/04/2014	Paris, France	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias			Worldwide
6	Press releases	UNION INTERNATIONALE DES CHEMINS DE FER	Looking towards 2030-2050 for an affordable, automated, adaptable, resilient and high-capacity railway	08/04/2014	European Railway Review vol.2, 3, 2014	Scientific community (higher education, Research) - Industry - Policy makers			Worldwide
7	Posters	NEWOPERA Aisbl	Poster C4R	14/04/2014	Transport Research Arena 2014	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		2900	Worldwide

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audien ce	Countries addressed
8	Oral presentation to a scientific event	UNION INTERNATIONALE DES CHEMINS DE FER	Capacity4Rail: towards a resilient, innovative and high capacity European railway system for 2030/2050	15/04/2014	Transport Research Arena 2014, Paris, France	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		2100	Worldwide
9	Oral presentation to a wider public	UNION INTERNATIONALE DES CHEMINS DE FER	SIAFI	16/04/2014	Paris, France	Scientific community (higher education, Research)		25	Worldwide
10	Flyers	UNION DES INDUSTRIES FERROVIAIRES EUROPEENNES - UNIFE	Distribution of C4R flyers	23/04/2014	Innotrans 2014, Berlin, Germany	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		150000	Worldwide
11	Oral presentation to a scientific event	OLTIS GROUP AS	Ways to optimize the utilisation of the railway infrastructure", ?Ways to meet the requirements imposed on the railway transport of future towards the year 2030 and 2050: the FP7 project Capacity4Rail	22/05/2014	Colloquium ?elAktuel 2014	Scientific community (higher education, Research) - Industry		70	Czech Republic, Slovak Republic
12	Oral presentation to a scientific event	UNIVERSITY OF NEWCASTLE UPON TYNE	Scope, objectives and progress (in general and in particular of WP21) of the C4R project	01/10/2014	European Transport Conference 2014, Frankfurt, Germany	Scientific community (higher education, Research) - Industry - Policy makers - Medias		70	European
13	Oral presentation to a wider public	TECHNISCHE UNIVERSITAET DRESDEN	Update from the EU projects ON-TIME and Capacity4Rail with focus on railML	08/10/2014	RailML conference in Paris, France	Scientific community (higher education, Research) - Industry		70	Austria, Belgium, Czech, France, Germany, Great Britain, Japan, Netherlands, Norway, Spain, Switzerl

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audien ce	Countries addressed
14	Flyers	EUROPEAN FEDERATION OF RAILWAYS TRACKWORKS CONTRACTORS	Overall Information on the progress of C4R project to EFRTC members in the framework of Secretary General's activity report,	10/10/2014	EFRTC General Meeting in Luxembourg	Industry		80	UK, France, Italy, Germany, Spain, Netherlands, Switzerland, Luxembourg, Belgium, Sweden
15	Oral presentation to a scientific event	EUROPEAN FEDERATION OF RAILWAYS TRACKWORKS CONTRACTORS	Information on the outcome of C4R and presentation of SP1 proposals of innovative non-conventional slab and frame tracks	04/02/2015	EFRTC Policy and Research Committee meeting, London,	Industry - Policy makers		80	UK, France, Italy, Germany, Spain, Netherlands, Switzerland, Luxembourg, Belgium, Sweden
16	Oral presentation to a scientific event	INGENIERIA Y ECONOMIA DEL TRANSPORTE S.A.	Project FP7 Capacity4Rail (C4R): Vision for the European Rail of 2030 and 2050	19/03/2015	International Rail Freight Conference 2015, Prague, Czech Republic	Scientific community (higher education, Research) - Industry - Policy makers - Medias		300	Worldwide
17	Press releases	FUNDACION DE LOS FERROCARRILES ESPANOLES	Promotion of participation at the CAPACITY4RAIL Dissemination Workshop	24/04/2015	Spanish Railways Technological Platform weekly bulletin	Scientific community (higher education, Research) - Industry		400	Spain
18	Oral presentation to a scientific event	UNION INTERNATIONALE DES CHEMINS DE FER	Capacity4Rail objectives, structure and achievements to date	28/04/2015	UIC Track & Structure sector experts, Paris, France	Scientific community (higher education, Research) - Industry		50	Worldwide
19	Organisation of Workshops	UNION INTERNATIONALE DES CHEMINS DE FER	Productivity Increase with Heavier & Longer Trains	22/05/2015	Workshop UIC Asia Pacific, Saint Petersbourg, Russia	Scientific community (higher education, Research) - Industry		100	Worldwide
20	Organisation of Workshops	UNION INTERNATIONALE DES CHEMINS DE FER	First dissemination workshop	10/06/2015	UIC, Paris	Scientific community (higher education, Research) - Industry		50	Belgium, France, Germany, Italy, Switzerland, Sweden, UK, Spain, Austria, Luxembourg, Czech Republic

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audien ce	Countries addressed
21	Organisation of Workshops	UNIVERSITY OF NEWCASTLE UPON TYNE	Key parameters for an intermodal rail-road terminal-Dissemination of the C4R project	30/06/2015	Three multimodal terminals in Antwerp, Belgium	Scientific community (higher education, Research) - Industry		20	Belgium
22	Oral presentation to a scientific event	FUNDACION DE LOS FERROCARRILES ESPANOLES	Methodology to determine the optimal design speed in a High-Speed Line	07/07/2015	9th UIC World Congress on High Speed Rail 2015, Tokyo, Japan	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		1000	Worldwide
23	Organisation of Conference	UNIVERSITY OF NEWCASTLE UPON TYNE	State-of-the-art of European rail freight system and future needs	14/07/2015	RailNewCastle conference 2015, Newcastle University	Scientific community (higher education, Research) - Industry - Policy makers - Medias		70	Worldwide
24	Organisation of Workshops	NEWOPERA Aisbl	Freight Dissemination workshop	10/09/2015	Brussels, Belgium	Scientific community (higher education, Research) - Industry		40	Belgium, France, Germany, Italy, Switzerland, Sweden, UK
25	Oral presentation to a scientific event	INSTITUT FRANCAIS DES SCIENCES ET TECHNOLOGIES DES TRANSPORTS, DE L'AMENAGEMENT ET DES RESEAUX	RECIFE-MILP for real-time railway traffic optimization: main results and open issues	10/09/2015	Airo 2015 conference in Pisa, Italy	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		150	European
26	Oral presentation to a wider public	CHALMERS TEKNISKA HOEGSKOLA AB	Presentation of C4R	28/09/2015	GOTHENBURG, SWEDEN	Scientific community (higher education, Research) - Industry		25	Sweden
27	Oral presentation to a wider public	NEWOPERA Aisbl	Perspektive wasserstoff als kraftstoff. Intense discussion on the developments of the rail transport of chemical material, with possible applicability of C4Rail solutions	14/10/2015	Meeting at Vienna chamber of commerce, Austria	Scientific community (higher education, Research) - Industry - Policy makers		70	Austria, Germany
28	Oral presentation to a wider public	NEWOPERA Aisbl	C4Rail project presented and discussed, with applicability of the founded solutions to the Austrian situation	28/10/2015	Meeting at Vienna chamber of commerce with Harald Bollman	Civil society - Policy makers		20	Austria

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audien ce	Countries addressed
29	Oral presentation to a wider public	NEWOPERA Aisbl	C4Rail project presented and discussed, with applicability of the founded solutions to the Austrian situation	28/10/2015	Meeting at Vienna chamber of commerce with Harald Bollman	Civil society - Policy makers		20	Austria
30	Oral presentation to a scientific event	TRAFIKVERKET - TRV	Increasing capacity by improving tactical planning and operational Traffic	17/11/2015	KAJT network expert group, Stockholm, Sweden	Scientific community (higher education, Research) - Industry		70	Sweden
31	Oral presentation to a wider public	NEWOPERA Aisbl	C4Rail project presented and discussed, interoperability topics treated and intensely discussed, questions on C4R answered	04/12/2015	EU Rail freight days 2015, Vienna, Austria	Scientific community (higher education, Research) - Industry - Policy makers - Medias		200	European
32	Oral presentation to a wider public	NEWOPERA Aisbl	C4Rail project presented and discussed in particular with high level politicians, with applicability of the founded solutions to the Austrian situation (particularly on connectivity and wagon design issues)	20/01/2016	Conference transport infrastructure in Vienna, Austria	Industry - Policy makers		20	Austria
33	Oral presentation to a wider public	NEWOPERA Aisbl	C4Rail project presented and discussed. Information on future developments of logistics in Europe collected, with particular attention to Austrian and German situation.	21/01/2016	Conference logistic life in Vienna, Austria	Scientific community (higher education, Research) - Industry - Policy makers		80	Austria, Germany
34	Oral presentation to a wider public	NEWOPERA Aisbl	C4Rail project presented and discussed, with distribution of material regarding the innovations foreseen and the ones developed, questions on C4R answered and a lot of information regarding the last mile distribution and safety/sustainability issues collected.	02/02/2016	Meeting in Vienna, Austria	Scientific community (higher education, Research) - Industry		120	European
35	Oral presentation to a wider public	CHALMERS TEKNISKA HOEGSKOLA AB	Presentation of C4R	08/02/2016	GOTHENBURG, SWEDEN	Scientific community (higher education, Research) - Industry		25	Sweden

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audience	Countries addressed
36	Oral presentation to a scientific event	NEWOPERA Aisbl	C4Rail project presented and discussed in a dedicated workshop with professors and students of Innsbruck university. Information on future developments of logistics in Europe collected, with particular attention to Austrian situation	22/02/2016	Meeting at university of Innsbruck, Austria	Scientific community (higher education, Research) - Industry - Policy makers		60	Austria
37	Flyers	UNION INTERNATIONALE DES CHEMINS DE FER	Issuing of 2nd newsletter	04/04/2016	UIC, Paris	Scientific community (higher education, Research) - Industry - Policy makers - Medias			Worldwide
38	Oral presentation to a scientific event	NEWOPERA Aisbl	Presentation of the innovative train design studied in C4R	19/04/2016	SMART RAIL 2016, Amsterdam, Netherlands	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		350	Worldwide
39	Oral presentation to a scientific event	NEWOPERA Aisbl	Project objectives, foundings, ongoing initiatives and innovations of C4R project	19/04/2016	SMART RAIL 2016, Amsterdam, Netherlands	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		350	Worldwide
40	Oral presentation to a scientific event	NEWOPERA Aisbl	Rail transport subsidized optimally	11/05/2016	Conference at Vienna Hafen	Industry		20	Austria
41	Oral presentation to a scientific event	NEWOPERA Aisbl	Objectives and Innovations in C4Rail project, with particular regards to the topics of connectivity and digitalization in rail transport	17/05/2016	GSV Forum Vienna, Austria	Scientific community (higher education, Research) - Industry - Policy makers		80	European
42	Posters	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA	Analytical and simulation based methods for assessing measures and technologies capable to improve operation in railway freight terminals	30/05/2016	WCRR 2016, Milano, Italy	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		1000	Worldwide

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audien ce	Countries addressed
43	Oral presentation to a wider public	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA	Analytical and simulation based methods for assessing measures and technologies capable to improve operation in railway freight terminals	30/05/2016	WCRR 2016, Milano, Italy	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		1000	Worldwide
44	Oral presentation to a wider public	INSTITUTO SUPERIOR TECNICO	Optimization algorithm applied to VHS track design towards enhanced track dynamic performance and reduced settlement	30/05/2016	WCRR 2016, Milano, Italy	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		1000	Worldwide
45	Oral presentation to a wider public	NEWOPERA Aisbl	Innovations, objectives and goals in C4Rail project presented and discussed	30/05/2016	WCRR 2016, Milano, Italy	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		1000	Worldwide
46	Oral presentation to a wider public	NEWOPERA Aisbl	Innovations foreseen in C4R project, with possible applicability of C4Rail solutions in real operating conditions.	31/05/2016	Meeting at University, Vienna, Austria	Scientific community (higher education, Research)		20	Austria
47	Oral presentation to a wider public	NEWOPERA Aisbl	Presentation of objectives and innovations in C4Rail project	02/06/2016	Freight and Logistics Leaders? Forum	Scientific community (higher education, Research) - Industry		120	European
48	Oral presentation to a wider public	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA	Assessment of operational performances of rail freight terminals	16/06/2016	RailNewcastle Talks 2016, Newcastle, UK	Scientific community (higher education, Research) - Industry		20	Great Britain
49	Flyers	UNIVERSITY OF NEWCASTLE UPON TYNE	Promotion and dissemination of C4R project through the distribution of project flyers and project newsletters at the beginning of numerous sessions	01/09/2016	Royal Geographical Society Conference 2016, London, UK,	Scientific community (higher education, Research) - Industry		80	European
50	Flyers	UNION INTERNATIONALE DES CHEMINS DE FER	Issuing of 3rd newsletter	05/09/2016	UIC, Paris	Scientific community (higher education, Research) - Industry - Civil society - Policy makers			Worldwide

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audience	Countries addressed
51	Oral presentation to a wider public	NETWORK RAIL INFRASTRUCTURE LIMITED	Latest developments of the different work packages of SP3 and illustration of the prototypes delivered	21/09/2016	INNOTRANS 2016, Berlin, Germany	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		150000	Worldwide
52	Organisation of Workshops	UNION INTERNATIONALE DES CHEMINS DE FER	Second dissemination workshop	03/11/2016	Brussels, Belgium	Scientific community (higher education, Research) - Industry		50	European
53	Organisation of Workshops	NEWOPERA Aisbl	Second dissemination workshop	03/11/2016	Brussels, Belgium	Scientific community (higher education, Research) - Industry		50	European
54	Web sites/Applications	TECHNISCHE UNIVERSITAET DRESDEN	Datenformate, Datenmodelle und Datenkonzepte für den Eisenbahnbetrieb	08/11/2016	Der Eisenbahningenieur	Scientific community (higher education, Research) - Industry			German speaking countries
55	Oral presentation to a wider public	CHALMERS TEKNISKA HOEGSKOLA AB	Presentation of C4R	23/11/2016	Alvesta, Sweden	Industry		10	Sweden
56	Posters	TECHNISCHE UNIVERSITAET DRESDEN	A SysML formalization of the disruption management process in European railway	01/01/2017	Transportation Research Board 96th Annual Meeting - TRB	Scientific community (higher education, Research) - Industry			Worldwide
57	Oral presentation to a wider public	CHALMERS TEKNISKA HOEGSKOLA AB	How to use D11.4 when upgrading the Iron Oreline to 32.5 tonnes	16/02/2017	Lulea and by video	Industry		6	Sweden, Norway
58	Oral presentation to a wider public	TRAFIKVERKET - TRV	Presentation of C4R results	27/02/2017	KAJT network expert group, Borlänge, Sweden	Industry		25	Sweden
59	Organisation of Workshops	UNION INTERNATIONALE DES CHEMINS DE FER	Training Platform infrastructure: Increasing Track Performance & Capacity	15/03/2017	Paris, France	Scientific community (higher education, Research) - Industry		50	European
60	Organisation of Workshops	EUROPEAN FEDERATION OF RAILWAYS TRACKWORKS CONTRACTORS	Training Platform infrastructure: Increasing Track Performance & Capacity	15/03/2017	Paris, France	Scientific community (higher education, Research) - Industry		50	European

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audien ce	Countries addressed
61	Organisation of Workshops	UNIVERSITY OF NEWCASTLE UPON TYNE	Training Platform infrastructure: Increasing Track Performance & Capacity	15/03/2017	Paris, France	Scientific community (higher education, Research) - Industry		50	European
62	Organisation of Workshops	OLTIS GROUP AS	Training Digital operations workshop	27/04/2017	Olomouc, Czech Republic	Scientific community (higher education, Research) - Industry		30	France, Germany, Italy, Sweden, UK, Czech Republic, Ireland, Nederlands
63	Oral presentation to a wider public	CHALMERS TEKNISKA HOEGSKOLA AB	How C4R results about upgrading can reduce costs for long distance freight traffic in Sweden	19/06/2017	Swedish Ministry of Enterprise, Energy and Communications	Policy makers		12	Sweden
64	Organisation of Workshops	ARTTIC	Second freight dissemination workshop	26/06/2017	Brussels, Belgium	Scientific community (higher education, Research) - Industry		50	Belgium, France, Turkey, Italy, Austria Germany, Sweden Spain, UK, Netherlands, Poland
65	Oral presentation to a scientific event	NEWOPERA Aisbl	Dissemination of C4R	06/07/2017	Graz, Austria	Scientific community (higher education, Research) - Industry		100	European
66	Press releases	INGENIERIA Y ECONOMIA DEL TRANSPORTE S.A.	Presentation of the C4R project	06/09/2017	internal INECO bulletin, Spain	Industry		2500	Spain
67	Organisation of Workshops	CHALMERS TEKNISKA HOEGSKOLA AB	Presentation of C4R results	06/09/2017	Trafikverket, Stockholm and by video, Sweden	Industry		25	Sweden
68	Organisation of Conference	UNION INTERNATIONALE DES CHEMINS DE FER	Final conference	21/09/2017	FFE, Madrid, Spain	Scientific community (higher education, Research) - Industry - Policy makers		100	European

No	Type of activities	Main leader	Title	Date	Place	Type of audience	Additional type of audience	Size of audien ce	Countries addressed
69	Press releases	FUNDACION DE LOS FERROCARRILES ESPANOLES	C4R final conference	22/09/2017	Vía Libre Magazine + online	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		7000	Spain
70	Press releases	FUNDACION DE LOS FERROCARRILES ESPANOLES	C4R final conference	22/09/2017	Spanish Railways Technological Platform weekly bulletin + FFE's website	Scientific community (higher education, Research) - Industry		500	Spain
71	Press releases	UNION INTERNATIONALE DES CHEMINS DE FER	C4R final conference	26/09/2017	E-NEWS	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		5000	Worldwide
72	Articles published in the popular press	INSTITUTO SUPERIOR TECNICO	Railway track design optimization for enhanced performance at very high speeds: experimental measurements and computational estimations	16/11/2017	Taylor & Francis (under review process)	Scientific community (higher education, Research)			Worldwide
73	Articles published in the popular press	THE UNIVERSITY OF HUDDERSFIELD	Optimisation of support stiffness at railway crossings	16/11/2017	Vehicle System Dynamics NVSD-2017-0248 (accepted for publication)	Scientific community (higher education, Research) - Industry - Policy makers - Medias			Worldwide
74	Posters	CENTRO DE ESTUDIOS DE MATERIALES Y CONTROL DE OBRA SA	Presentation of C4R	21/11/2017	Madrid, Spain	Scientific community (higher education, Research) - Industry		80	Spain
75	Oral presentation to a wider public	CHALMERS TEKNISKA HOEGSKOLA AB	Upgrading of freight railways to meet operational and market demands	16/04/2018	TRA 2018	Scientific community (higher education, Research) - Industry - Policy makers - Medias		2100	Worldwide

Section B (Confidential or public: confidential information to be marked clearly)

Part B1

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	Yes	13/03/2017	PCT/ES2017/070140	3MB slab track	SYSTRA, CEMOSA, ACCIONA, INECO

Part B2

Please complete the table hereafter:

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	A Decision Support Tool to help IMs and RUs to obtain Value for Money from investments to increase capacity of the rail network. - An on-line high-level tool to evaluate rail capability trade-offs when considering different options to increase the capacity of a route - The tool enables a whole-systems approach when planning upgrades to ensure early consideration of a full range of options - The tool allows the user to input data related to the infrastructure, rolling stock and operations related to the route under reinvestigation http://c4r.jerid.cz/	NO	N/A	Capability Trade-offs tool	F42.1, H49.1, H49.2, M71.1, C26.5, C30.2, M72.1, P85.4	Short/Medium term	N/A	Railway community, Infrastructure managers, Railway operators, Engineering companies, Universities

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Integrated methodology for scenario evaluation based on Multi-criteria Analysis (MCA) and Cost-Benefit Analysis (CBA) - The MCA is built around the five key aspects of the C4R project, Affordability, Adaptability, Resilience, Automation and Capacity - The CBA is based on standard life cycle cost analysis methodology, taking into account direct and indirect costs and benefits Report on the potential of the innovations from C4R to contribute to the 2050 vision for EU Railway Network.	NO	N/A	Scenario Analysis - Evaluation and impact of new technologies and innovations	F42.1, H49.1, H49.2, M71.1, C26.5, C30.2, M72.1, P85.4	Short/Medium term	N/A	Railway community, Infrastructure managers, Railway operators, Engineering companies, Track system suppliers, Universities Universities
Exploitation of results through EU policies	High-level roadmaps setting the 2050 vision for European Railways based on a review of published literature Definitions and targets for the C4R characteristics, Affordability, Adaptability, Resilience, Automation and High-capacity Contribution of the research and development work in C4R to achievement of the targets Relevant outputs that can contribute to the achievement of the targets, including relevant transport industry trends and drivers (facilitators and disruptors) Subjects for R&D broken down into three broad categories (infrastructure & Rolling Stock, Operating Models & Documentation)	NO	N/A	Roadmap - Railway system 2030/2050	F42.1, H49.1, H49.2, M71.1, C26.5, C30.2, M72.1, P85.4	Short/Medium/ Long term	N/A	Railway community, Stakeholders, EU-Policies makers

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Knowledge Guidelines on new track designs with potential to meet both the functional and technical requirements of a railway carrying significantly more freight within a mixed high-speed traffic environment. The guidelines provide a robust foundation for **further development, through other R&D programmes** (e.g. Shift2Rail)	NO	N/A	Design requirements/guidelines for design of new track concepts	F42.1, F42.1.3, M71.1, M72.1, P85.4	Medium term	N/A	Railway community, Infrastructure managers, Engineering companies Track system suppliers
Exploitation of R&D results via standards	Knowledge. Standards in review For Track design general questions: EN 13803 "Railway applications - Track - Track alignment design parameters - Track gauges 1 435 mm and wider" For rail fastening design: EN 13481 series on "Railway applications. Track. Performance requirements for fastening systems" For the use of Under Sleeper Pads: EN 16730 "Railway applications - Track - Concrete sleepers and bearers with under sleeper pads" IRS 71301 "Under Sleeper Pads (USP) Recommendations for Use". For Ballastless track system design questions: EN 16432 series on "Railway applications. Ballastless track systems" To solve open points in TSIs related to VHST and ballastless track systems: TSI Infrastructure (INF TSI)	NO	N/A	Design requirements/guidelines for design of new track concepts for Very High Speed Train (VHST) service and ballastless track systems	F42.1, F42.1.3, M71.1, M72.1, P85.4	Medium term	N/A	N/A

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Knowledge. The computer model enabled numerical analysis of alternative track design solutions to examine the impacts on performance of rail pad and USP vertical stiffness variations. **More work is required** to extrapolate the results to provide information on long-term performance & enable a robust LCC evaluation. The selected theoretical solution itself has **to be validated through laboratory testing.** The tool can support the development of a more efficient maintenance management strategy based on predictive maintenance and thereby deliver cost savings, better performance and improved services for passengers and freight. This will contribute to the policy objective of a modal shift of passengers and freight from road to rail.	NO	N/A	Computer Model for track design optimisation	F42.1, F42.1.3, M71.1, M71.2, M72.1, P85.4	Long term	N/A	Railway community, Infrastructure managers, Engineering companies, Track system suppliers

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of R&D results via standards	Knowledge. Standards in review For Track design general questions: EN 13803 "Railway applications - Track - Track alignment design parameters - Track gauges 1 435 mm and wider" For rail fastening design: EN 13481 series on "Railway applications. Track. Performance requirements for fastening systems" For the use of Under Sleeper Pads: EN 16730 "Railway applications - Track - Concrete sleepers and bearers with under sleeper pads" IRS 71301 “Under Sleeper Pads (USP) Recommendations for Use”. For Ballastless track system design questions: EN 16432 series on "Railway applications. Ballastless track systems" To solve open points in TSIs related to VHST and ballastless track systems design: TSI Infrastructure (INF TSI)	NO	N/A	Computer Model for track design optimisation on VHST and mixed train freight services	F42.1, F42.1.3, M71.1, M71.2, M72.1, P85.4	Long term	N/A	N/A
Commercial exploitation of R&D results	Product A demonstrator version of the 3MB design has been developed and installed at the CEDEX test site. Laboratory trials of the prototype have been completed. Potential for **reduced maintenance costs** (less frequent interventions & faster maintenance) is high. Increase in the **availability** of the track to traffic, better use of the high-speed potential of the infrastructure.	YES	13/03/17	Innovative Modular slab-track concept - Moulded Modular Multi-blocks slab track **(3MB)**	F42.1, F42.1.3, M71.1, M72.1, P85.4	Medium term	PCT/ES2017/070140	SYSTRA, CEMOSA, ACCIONA, INECO

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	Product A demonstrator version of the L-Track design has been developed and installed at the CEDEX test site . Laboratory trials of the prototype are underway. Potential for reduced maintenance costs (less frequent interventions & faster maintenance) is high. Increase in the availability of the track to traffic, better use of the high-speed potential of the infrastructure.	NO		Innovative Modular slab track concept (2) - **L-Track concept**	F42.1, F42.1.3, M71.1, M72.1, P85.4	Medium term	N/A	Railway community, Infrastructure managers, Engineering companies, Universities
General advancement of knowledge	Knowledge This early-stage research carried out train-track-bridge dynamic simulations to get a better understanding of the dynamic response of bridges to very high-speed trains (up to 480km/h) in order to improve the designs and increase the reliability and resilience of these services. ull-scale trials have been carried out on an 8m portal frame bridge on the Madrid-Barcelona high-speed line. **urther field trials and research are needed** to better understand the dynamic behaviour under different circumstances and develop robust & implementable bridge designs that can cope with the dynamic impacts of very high-speed trains.	NO	N/A	Modelling of dynamic response of bridges to very high speed trains	F42.1.3, M71.1, M71.2, M72.1, P85.4	Long term	N/A	Railway community, Infrastructure managers, Engineering companies, Universities

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of R&D results via standards	Knowledge. Standards in review For Line Categories on load limits (concerning VHST and mixed freight services): EN 15528 "Railway applications - Line categories for managing the interface between load limits of vehicles and infrastructure" For design bases on structures and dynamic factor application for VHST: EN 1990 "Eurocode - Basis of structural design" EN 1991-2 "Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges" EN 1992-2 "Eurocode 2: Design of concrete structures - Part 2: Concrete bridges - Design and detailing rules" EN 1993-2 "Eurocode 3: Design of steel structures - Part 2: Steel bridges" IRS on "Exceptional and Over-Loads on Existing structures" To solve open points in TSIs related to VHST and mixed traffic load design: TSI Infrastructure (INF TSI)	NO	N/A	Modelling of dynamic response of bridges to very high speed trains	F42.1.3, M71.1, M71.2, M72.1, P85.4	Long term	N/A	N/A

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Knowledge Proposed short-term, mediun-term and long-term solutions, weather resilience (preventative measures to reduce buckling due to high temperatures) and condition monitoring (mitigate failure impacts - switch blade movement, dynamic forces, switch heating). **Further validation** (of models), l**aboratory tests and field measurements are needed to realise improved performance.** Improving the resilience of S&Cs has the potential to contribute significantly to reducing disruptions to services due to infrastructure issues.	NO	N/A	Resilient S&Cs (Simulations & numerical modelling)	F42.1, M71.1, M72.1, P85.4	Long term	N/A	Railway community, Infrastructure managers, Engineering companies, Track system suppliers, Universities
Exploitation of R&D results via standards	Knowledge. Standards in review EN 13674-2 "Railway applications - Track - Rail - Part 2: Switch and crossing rails used in conjunction with Vignole railway rails 46 kg/m and above" EN 13232 series on "Railway applications. Track. Switches and crossing" To solve open points in TSIs related to VHST and mixed traffic load design: TSI Infrastructure (TSI INF)	NO	N/A	Resilient S&Cs (Simulations & numerical modelling)	F42.1, M71.1, M72.1, P85.4	Long term	N/A	N/A

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Knowledge Live trials have been carried out on the rail network in service. Evaluation of the performance of crossings with new materials (bainitic frognose & R350 head hardened steel in the wing rails) has been carried out. Results from the early part of the trial has shown that hardness has increased and there is no wear on the material. It is expected that the relative short installation time (~3.5h) making in-track repair feasible and the increases hardness of the material will improve internal quality, increase the lifetime of the asset and reduce maintenance costs.	NO	N/A	S&Cs - innovative concepts to improve performance	F42.1, M71.1, M72.1, P85.4	Long term	N/A	Railway community, Infrastructure managers, Engineering companies, Track system suppliers, Universities

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of R&D results via standards	Knowledge. Standards in review EN 13674-2 "Railway applications - Track - Rail - Part 2: Switch and crossing rails used in conjunction with Vignole railway rails 46 kg/m and above" EN 13232 series on "Railway applications. Track. Switches and crossing" For the use of Under Sleeper Pads: EN 16730 "Railway applications - Track - Concrete sleepers and bearers with under sleeper pads" IRS 71301 "Under Sleeper Pads (USP) Recommendations for Use" For Ballastless track system S&Cs design questions: EN 16432 series on "Railway applications. Ballastless track systems" To solve open points in TSIs related to VHST and mixed traffic load design: TSI Infrastructure (TSI INF)	NO	N/A	S&Cs - innovative concepts to improve performance	F42.1, M71.1, M72.1, P85.4	Long term	N/A	N/A
Commercial exploitation of R&D results	Product Trials of sensors embedded in slab track have been carried out.- this has shown that live data from SHM is recoverable. The use of these sensors will deliver savings on work & reduce possession time. **The results are extendable to other used of RFID tags.**	NO	N/A	Embedded sensor: Passive RFID tags	C26.5.1, F42.1, FF42.1.3, M71.1, M72.1, P85.4	Medium term	N/A	Railway community, Infrastructure managers, Engineering companies, Track system suppliers, Universities

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of R&D results via standards	Knowledge. Standards in reviewFor RFID technology standards:ISO/IEC 18000 series on "Information technology - Radio frequency identification for item management", specially Part 6prEN on RFID in Railway Applications as required by TC225/WG4 to be developed	NO	N/A	Embedded sensor: Passive RFID tags	C26.5.1, F42.1, FF42.1.3, M71.1, M72.1, P85.4	Medium term	N/A	N/A
Commercial exploitation of R&D results	Product Following laboratory trials, live trials of the vibration based track movement monitoring sensor have been carried out on high speed lines. The trials have confirmed that the low-cost sensors are easy to install, require low power, an energy harvesting system (e.g. solar panel) can be used to power the sensor and data can be accessed remotely. Also that the sensor are a cost-effective addition to the monitoring toolbox.	NO	N/A	Embedded sensor: Accelerometer on sleepers (wireless vibration monitoring)	C26.5.1, F42.1, FF42.1.3, M71.1, M72.1, P85.4	Medium term	N/A	Railway community, Infrastructure managers, Engineering companies, Track system suppliers, Universities

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of R&D results via standards	Knowledge. Standards in review For general use as on-site measurement systems: prEN 15654-1 "Railway Applications - Measurement of vertical forces on wheels and wheelsets: Interoperable On-Track measurement sites for vehicles in service" prEN 15654-3 "Railway applications - Measurement of vertical forces on wheels and wheelsets: Approval and verification of on-track measurement sites for vehicles in service" For specific use as "Wheel Impact Load Detector (WILD)" or "Weight in Motion (WIM)": IRS on "Exceptional and Over-Loads on Existing structures"	NO	N/A	Embedded sensor: Accelerometer on sleepers (wireless vibration monitoring)	C26.5.1, F42.1, FF42.1.3, M71.1, M72.1, P85.4	Medium term	N/A	N/A
Exploitation of results through EU policies	Guidance - Evaluation of development trends in Europe - Requirements to deliver incremental & system changes - High level analyis of the measures and costs of the proposed 2030/2050 freight system This provides the **base point** from which a transformational change will need to be achieved the meet the rail freight targets and deliver on the stated objectives to reduce operational costs, carbon and noise enissions and incentivise the modal shift of freight from road to rail.	NO	N/A	Freight system requirements of the 2030/2050 European Railway (meeting the EU White Paper targets)	C30.2, F42.1, H49.1, H49.2, M71.1, P85.4	Long term	N/A	Railway community, Stakeholders, EU-Policies makers

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General advancement of knowledge	Knowledge - Conceptual designs - Technical feasibility of new designs - 12-axle bogie wagon with Jacob-bogies for five 45 ft containers - 12-axle wagon with 4 pocket frames & Jacobs bogies - 6-axle wagon for transport of cars - Electronically controlled pneumatic (EP) brakes, electric line along the train, (first only pneumatic (P) with End-of-Train (EOT) device) Expected impacts have been assessed The initial technical feasibility analysis using analytical methods and high-level CBA indicate potential reduction in transportation costs alongside a significant increase in the efficiency of operations. Further work is needed to define the overall benefits, technical & contextual feasibility of the designs and their contribution to rail freight system performance	NO	N/A	Concepts & innovations in wagon design to enhance rail freight efficiency	C30.2, F42.1, H49.1, H49.2, M71.1, P85.4	Long term	N/A	Railway community, Railway operators, Rolling stock manufacturers, Wagon keepers, Logistic providers, Engineering companies, Universities

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Exploitation of R&D results via standards	Knowledge - Guidance. Standards in review For brake systems and performance in train compositions: EN 14198 "Railway applications. Braking. Requirements for the brake system of trains hauled by locomotives" EN 14531 series on "Railway applications. Methods for calculation of stopping and slowing distances and immobilization braking" EN 15625 "Railway applications. Braking. Automatic variable load sensing devices" EN 15612 "Railway applications. Braking. Brake pipe accelerator valve" For operational static brake testing: EN 15806 "Railway applications. Braking. Static brake testing" For brakes components specifications: UIC Leaflet 541-1 "Brakes - Regulations concerning the design of brake components" UIC Leaflet 541-03 "Brakes - Specifications for the construction of various brake parts - Driver's brake valve / Driver's brake controller" UIC Leaflet 541-04 "Brakes - Regulations concerning the manufacture of brake components - Self-adjusting load-proportional braking system and automatic "empty-loaded" control device"	NO	N/A	Concepts & innovations in wagon design to enhance rail freight efficiency related to braking systems and performance	C30.2, F42.1, H49.1, H49.2, M71.1, P85.4	Long term	N/A	N/A

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of R&D results via standards (continuation)	UIC Leaflet 541-6 "Brakes - Electropneumatic brake (ep brake) and Passenger alarm signal (PAS) for vehicles used in hauled consists" UIC 541-2 "Dimensions of hose connections (brake hoses) and electric cables; types of pneumatic and electric connections and their positioning on wagons and coaches equipped with automatic couplers of the UIC and OSJD Member Railways" To solve open points and introduce innovation in TSIs related to braking in rolling stock for railway freight systems: TSI Locomotives and passenger rolling stock (LOC&PAS TSI) TSI Freight wagons (WAG TSI) TSI Operation and Traffic Management (TSI OPE)	NO	N/A	Concepts & innovations in wagon design to enhance rail freight efficiency related to braking systems and performance	C30.2, F42.1, H49.1, H49.2, M71.1, P85.4	Long term	N/A	N/A

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Knowledge - Conceptual designs - Interchange types: Rail to road, rail to rail, rail to waterways - Three Case studies for evaluation of future scenarios - Technological & Operations innovation to improve terminal performances Further work is required to assess the improvement in performance of terminals and its contribution to making rail freight more competitive (through lower cost & higher efficiency) with regard to rail freight; work is also required to evaluate and implement appropriate technologies to enable greater automation of the activities (e.g. loading/unloading) within the terminals/interchanges	NO	N/A	Concepts/innovations of transhipment technologies & interchanges to handle future freight	C30.2, F42.1, H49.1, H49.2, M71.1, P85.4	Long term	N/A	Railway community, Railway operators, Wagon keepers, Logistic providers, Engineering companies, Universities

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of R&D results via standards	Knowledge - Guidance. Standards in review For Structural design of freight wagons: EN 12663 series on "Railway applications. Structural requirements of railway vehicle bodies", specially for part 2 Freight wagons For wheelsets and bogies design: EN 13749 "Railway applications. Wheelsets and bogies. Method of specifying the structural requirements of bogie frames" For buffers and couplers design: EN 15551 "Railway applications. Railway rolling stock. Buffers" UIC Leaflet 524 "Wagons - Technical specifications governing spring devices for wagons fitted with automatic couplers belonging to the UIC and OSJD member railways" UIC Leaflet 577 "Wagon stresses" For vehicles reference masses: EN 15663 "Railway applications. Vehicle reference masses" To solve open points and introduce innovation in TSIs related to rolling stock for railway freight systems: TSI Locomotives and passenger rolling stock (LOC&PAS TSI) TSI Freight wagons (WAG TSI)	NO	N/A	Catalogue of rail freight systems for Rail 2050 - Impacts on TSIs and requirements for new/revised Standards	C30.2, F42.1, H49.1, H49.2, M71.1, P85.4	Long term	N/A	N/A

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Simulations and models to support Infrastructure Managers (IMs) in evaluating enhanced line and train capacities (from innovations) of rail networks, including longer trains and more efficient freight wagons. More efficient linking of the timetable and operational planning. Gap Analysis to identify further development needs	NO	N/A	Improving tactical and operational processes for Infrastructure Managers	F42.1, H49.1, H49.2, M71.1, M72.1, P85.4	Short/Medium term	N/A	Railway community, Infrastructure managers
General advancement of knowledge	A statistical model to predict delay propagation on the rail network. Evaluate impact on capacity /performance from the addition of a train path Data requirements - stations and timetable for the trains on the simulation network	NO	N/A	The LIU optimisation model	F42.1, H49.1, H49.2, M71.1, M72.1, P85.4	Short/Medium term	N/A	Railway community, Infrastructure managers, Railway operators, Engineering companies, Universities
General advancement of knowledge	Developed by extending an existing system KADR for timetable and operational traffic to link with the statistical model LIU (Timetable evaluation) Designed to:incorporate additional train paths into an existing, optimise the existing timetable, simulate and evaluate different options for additional paths. Further research and development is proposed to refine the optimisation process and improve the robustness of the analysis and the new timetable created.	NO	N/A	CAIN (CApacity of the INfrastructure) - Demonstrator (IT Tool)	F42.1, H49.1, H49.2, M71.1, M72.1, P85.4	Medium term	N/A	Railway community, Infrastructure managers, Engineering companies, Universities

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Exploitation of R&D results via standards	Knowledge - Guidance. Standards in review To solve open points and introduce innovation in TSIs related to operation and traffic management in terms of operational planning, traffic capacity and timetables: TSI Operation and Traffic Management (TSI OPE), specially chapters 4.2.3. and 4.4.	NO	N/A	Concepts & innovations to increase and optimise operational planning, traffic capacity and timetables	F42.1, H49.1, H49.2, M71.1, M72.1, P85.4	Long term	N/A	N/A
General advancement of knowledge	Collation of practices from several European countries to enable a single formalised process for disruption management. The aim is to inform the rail industry about current practices for small & large disruptions and also inform the development of a process based on a whole systems approach to better manage traffic operations during unexpected and severe disruption conditions. Enabling the network to return to regular operations as quickly as possible will contribute significantly to improved performance and making rail the mode of choice for passengers and also freight.	NO	N/A	European practices and levels of automation for management of large disruptions	F42.1, H49.1, H49.2, M71.1, M72.1, P85.4	Long term	N/A	Railway community, Infrastructure managers, Railway operators, Engineering companies, Universities

Type of Exploitable Foreground	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Recommendations for increasing levels of automation that will contribute to faster recovery and reduced impacts of disruptions as well as delivering increased capacity. Integration of weather forecast models to improve preparedness to extreme weather events and their consequences for railway operation. Instantaneous and automated sharing of information between all interested parties enabling prompt and correct response to evolving condition. Automated DSTs for optimising resource allocation. Automating process to monitor and report on changing traffic conditions so that decisions are made with accurate and timely knowledge of the state of operations.	NO	N/A	Roadmap for automation strategies	F42.1, H49.1, H49.2, M71.1, M72.1, P85.4	Short/Medium term	N/A	Railway community, Infrastructure managers, Engineering companies, Universities
Exploitation of R&D results via standards	Knowledge - Guidance. Standards in review To solve open points and introduce innovation in TSIs related to operation and traffic management in terms of operational planning, traffic capacity and timetables: TSI Operation and Traffic Management (TSI OPE), specially chapters 4.2.3.4 and 4.2.3.6.	NO	N/A	Concepts & innovations to manage operation in case of large disruptions and extreme weather events	F42.1, H49.1, H49.2, M71.1, M72.1, P85.4	Long term	N/A	N/A

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General advancement of knowledge	Data achitectures to support future TMS, Improve railway operations, Meet evolving requirements. Review of existing models and emerging approaches for data exchange used by the European Railway organisations. Data formats and models for data exchange in railway operations. Collection, storage and effective utilisation of data. Data models, resources, interpretation to support the C4R visions of the 2030/2050 railways.	NO	N/A	Ubiquitous data for improving railway operations and enabling a high-capacity railway	F42.1, H49.1, H49.2, M71.1, M72.1, P85.4	Medium/Long term	N/A	Railway community, Infrastructure managers, Engineering companies, Universities

3. Report on societal implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*

Grant Agreement Number:	605650
Title of Project:	Increasing Capacity 4 Rail networks through enhanced infrastructure and optimised operations (CAPACITY4RAIL)
Name and Title of Coordinator:	Álvaro Andrés, UIC

B Ethics

1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***0Yes 0No***
2. Please indicate whether your project involved any of the following issues (tick box) :	***YES***
RESEARCH ON HUMANS	
• Did the project involve children?	NO
• Did the project involve patients?	NO
• Did the project involve persons not able to give consent?	NO
• Did the project involve adult healthy volunteers?	NO
• Did the project involve Human genetic material?	NO
• Did the project involve Human biological samples?	NO
• Did the project involve Human data collection?	NO
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	NO
• Did the project involve Human Foetal Tissue / Cells?	NO
• Did the project involve Human Embryonic Stem Cells (hESCs)?	NO
• Did the project on human Embryonic Stem Cells involve cells in culture?	NO
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	NO
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	NO
• Did the project involve tracking the location or observation of people?	NO
RESEARCH ON ANIMALS	

• Did the project involve research on animals?	NO
• Were those animals transgenic small laboratory animals?	NO
• Were those animals transgenic farm animals?	NO
• Were those animals cloned farm animals?	NO
• Were those animals non-human primates?	NO
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	NO
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	NO
DUAL USE	
• Research having direct military use	NO
• Research having the potential for terrorist abuse	NO

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	5	13
Work package leaders	5	17
Experienced researchers (i.e. PhD holders)	23	71
PhD Students	4	10
Other	13	62

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**8**
Of which, indicate the number of men:	6

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	○ X	Yes No

6. Which of the following actions did you carry out and how effective were they? Not applicable

		Not at all effective … Very effective
❑	Design and implement an equal opportunity policy	○ ○ ○ ○ ○
❑	Set targets to achieve a gender balance in the workforce	○ ○ ○ ○ ○
❑	Organise conferences and workshops on gender	○ ○ ○ ○ ○
❑	Actions to improve work-life balance	○ ○ ○ ○ ○
○	Other:	

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

X No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

X Yes- please specify, Website, roadmaps, publications

○ No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

X Main discipline[1]: Engineering and Technology

X Associated discipline[1]: Civil engineering | X Associated discipline[1]: Other engineering sciences

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	X ○	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

X No

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

○ Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ X	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

○ No

1 Insert number from list below (Frascati Manual).

- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- X Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- X Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture		Energy		Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and Monetary Affairs		Food Safety		X **Research and Innovation**	
Education, Training, Youth		Foreign and Security Policy		Space	
Employment and Social Affairs		Fraud		Taxation	
		Humanitarian aid		X **Transport**	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- X European level
- ○ International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**21**
To how many of these is open access[2] provided?	**15**
How many of these are published in open access journals?	**15**
How many of these are published in open repositories?	
To how many of these is open access not provided?	**4**
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[3]: ……………	
15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**1**

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	
	Registered design	
	Other	

17. How many spin-off companies were created / are planned as a direct result of the project?	
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	❑	In small & medium-sized enterprises

[2] Open Access is defined as free of charge access for anyone via Internet.

[3] For instance: classification for security project.

❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	X	None of the above / not relevant to the project
X	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*
Difficult to estimate / not possible to quantify	❑

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

X Yes ○ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes X No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

X	Press Release	X	Coverage in specialist press
❑	Media briefing	X	Coverage in general (non-specialist) press
❑	TV coverage / report	X	Coverage in national press
❑	Radio coverage / report	X	Coverage in international press
X	Brochures /posters / flyers	X	Website for the general public / internet
❑	DVD /Film /Multimedia	X	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

X	Language of the coordinator	X	English
X	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]

4. FINAL REPORT ON THE DISTRIBUTION OF THE EUROPEAN UNION FINANCIAL CONTRIBUTION

This report shall be submitted to the Commission within 30 days after receipt of the final payment of the European Union financial contribution.

Report on the distribution of the European Union financial contribution between beneficiaries

Name of beneficiary	Final amount of EU contribution per beneficiary in Euros
1.	
2.	
n	
Total	