Capacity for Rail

Towards an affordable, resilient, innovative and high-capacity European Railway System for 2030/2050

Design requirements, concepts and prototype test results (intermediate)

Submission date: 01/08/2017

Deliverable 11.2

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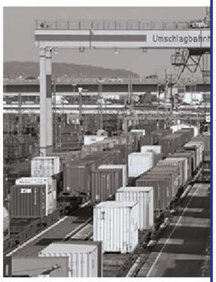

Collaborative project SCP3-GA-2013-60560
Increased Capacity 4 Rail networks through enhanced infrastructure and optimised operations
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Lead contractor for this deliverable:

- Systra

Project coordinator

- International Union of Railways, UIC

Executive Summary

This report is the second deliverable for Work Package 1.1 under Sub-Project1 (SP1) of the Capacity4Rail (C4R) project.

The aim of this deliverable is to present the 2 new slab track concepts that address the general objectives of the project, i.e. an affordable, adaptable, automated, resilient and high capacity railway infrastructure. These 2 concepts where designed in agreement with the requirements defined in D1.1.1 and they will be prototyped and tested in Task 1.1.3.

Firstly, the deliverable recaps the general requirements for designing an innovative slab track concept. These requirements are mainly based on the feedbacks from current operated slab track systems. A special attention is paid for construction costs and maintenance costs requirements in order to design a financially more attractive product.

Secondly, the generation of ideas using collaborative workshops and design thinking methodology is described. Then, selection and refinement of two most promising concepts is detailed.

Thirdly, planned construction procedure and maintenance procedure of the selected concepts are detailed.

Fourthly, prototyping and testing methodology of both concept at CEDEX TrackBox is presented.

Fifthly, Life Cycle Cost and business model studies are shown.

Further design studies and feedbacks from prototyping and testing will be put into next deliverable, D1.1.3.

Table of content

Abbreviations and acronyms

Abbreviation / Accronym	**Description**
3MB	Multi Moulded Modular Slab Track : 1st slab track concept
L-Track	Name of the 2nd slab track concept
RAMS	Reliability Availability Maintainability Safety
LCC	Life Cycle Cost

1 Introduction

The overall objective of *SP1 – WP1.1 Modular integrated design of new concepts for infrastructures* is to design, develop and test new concepts for railway track, adapted to mixed traffic and eventually adaptable to very high speed, with the following particular distinct features:

- Cost and RAMS oriented design.
- Modular design in order to enable “Plug&Play” for rapid construction or maintenance.
- Adaptability of existing infrastructure to new freight requirements.
- Energy provision, telecommunications and signalling will be incorporated, whenever possible.

The main goal of the second task on this WP (T1.1.2) is to invent then to design 2 new slab track concepts in agreement with requirements defined in previous task (T1.1.1). These 2 new concepts will be prototyped and tested later during next task (T1.1.3).

2 Objectives

The objectives of this deliverable are to present the complete process of the 2 new slab track concepts development:

- Concepts invention
- Concepts selection
- Concepts detailed design

Further studies regarding the design of these 2 concepts will be part of deliverable D1.1.3.

3 Requirements

The design requirements have been analysed in the task WP11.1 of the project and are specified in detail in the deliverable D11.1. The main conclusions are recapped hereafter.

3.1 Geometrical requirements

The geometrical requirements of the track focus on 6 specifics points:

- **Cost-Effective track and layout parameters :**
  Because of its better resistance, slab track allows narrower curve with high superelevation and higher cant deficiency. This advantages permit to have a layout with better adaptability to topographical constrains. Therefore the cost of infrastructure may be decreased compared to ballasted track.

- **Reduced height and weight :**
  Low overall track height has significant impact in tunnel because it allows to reduce the tunnel diameter compared to ballasted track. Moreover, height reduction often means weight reduction, which is very important for bridge design.

- **Integration of signalling systems :**
  Signalling equipment has to be taken into account during the design of the slab in order to avoid operation after slab construction to install such equipment.

- **Earthing of the metallic parts :**
  Optimisation of reinforcement of the concrete elements of the track is very important to avoid voltage difference and possible damages of the structure.

- **Electrical isolation of the rails :**
  A compromise has to be reached between a low bedding resistance for earth current diffusion and a high bedding resistance to preserve signalling equipment.

- **Facilitation of drainage :**
  Drainage of slab tracks is a critical requirement, as it is source of many maintenance problems. The evacuation of water between the rails and between parallel tracks may require additional drainage channels than for ballasted track.

3.2 Mechanical requirements

The mechanical requirements of the track focus on 6 specifics points:

- **Non-setting subsoil :**
  In slab track systems, correction of track geometry can be almost exclusively done by fastenings adjustment. With corrections up to 26mm in vertical position and 5mm in horizontal position only small deformations are possible to counteract. As a consequence to the small adaptability of slab tracks, any settlement in the embankments must try to be avoided.

- **High quality of supporting structure :**
  Supporting structure is not well defined in term of limits. According to the UIC 719 leaflet it is located between "Track components" and "Earthwork". The supporting structure is in many cases made with a reinforced concrete slab; it can consist of unreinforced concrete or asphalt layer too

- **High quality of earth work :**
  As explained above slab track does not admit important settlement of the soil support. When settlement criteria cannot be achieved, strengthen methods in the subsoil must be applied such as additional reinforcement layers or piles foundation.

- **Adequate track stiffness :**
  Stiffness is still an open point in the standards. The common range of values for stiffness of the overall track structure can be of the order from 50 to 100 kN/mm per sleeper which makes the rails deflects approximately 1mm to 2mm under a 20-t axle load. Such values ensure a good compromise between ride comfort and track components life duration. A minimum spreading of load is ensured and stress or strain in track components keep reasonable.

- **High track resistance :**
  One of the main function of the track is to support the train. The wheelsets transmit vertical, horizontal and longitudinal forces onto the track.
    - Resistance to vertical loads is directly linked to track stiffness
    - Resistance to dynamic horizontal loads due to accelerations not compensated by track cant and also crosswind and bogie yaw effects.
    - Resistance to longitudinal loads takes into account forces from acceleration and breaking and also thermal forces

- **Compatibility with bridge movements :**
  A bridge provides a solid foundation for slab track, but temperature changes and traffic loading can cause longitudinal movements, bend of the spans and to twist over the supports. Therefore the slab track must be able to withstand these movements. Many solutions already exists and a rail-structure interaction analysis is needed to select the best.

3.3 Environmental requirements

The environmental requirements of the track focus on 3 specifics points:

- **Possibility to install noise and vibrations absorbers :**
  Noise emissions reduction is a key issue. Two noise sources are identified:
  - Airborne noise: Can be limited with acoustic panels and rail dampers
  - Vibrations and structure-borne noise: Can be limited with rail dampers and appropriate stiffness levels (rail pad, under-slab pad etc.)

  Slab track design could include small acoustic panels close to the wheel-rail contact and noise absorption surfaces.

- **Use of waste materials :**
  The construction and renewal of railway infrastructure has an enormous potential in terms of the use of waste, including that deriving from its own activities and from other sectors. The use in track construction of materials made from recycled waste enables, on the one hand, a reduction in the demand of non-renewable natural resources, and on the other, a reduction in the amount of waste dumped without being used.

- **Non-contaminant leachate :**
  Leachate is a widely used term in the environmental sciences where it has the specific meaning of a liquid that has dissolved or entrained environmentally harmful substances which may then enter the environment. The contaminant ability of any new solid material used for slab track has to be investigate.

3.4 Construction requirements

The environmental requirements of the track focus on 5 specifics points:

- **Low number of construction steps :**
  The simpler or less sensitive the design of a slab track, the easier its construction and he more reliably and cost-effectively a high quality standard can be achieved.

- **Fast construction :**
  The construction performance of a slab track system depends on the number of in-situ works, including the assembly of precast elements and the track alignment. Manufacturing of precast elements can limit the speed of in-situ construction if the production rate is not adapted.

- **Modularity :**
  Besides reduction in cost and flexibility in design, the use of standardised construction elements allows a high degree of prefabrication (independent of building site impacts) and therefore extensive assembly works and assembly quality.

- **Easy transport of precast elements to construction site :**
  In case of prefabricated slab track, the size and total weight of individual slabs are important for the construction phase (transport and installation), and also for the removal and replacement if necessary during maintenance operation. Trucks are able to transport up to 30tn through most of European road network, while the trailer usually have a 12m long and 2,60m width area for placing cargo. Higher weights and dimensions are possible but the road authority shall give a special authorization.

- **Easy alignment of track panels :**
  Common to most of slab track construction procedures is the costly and time consuming process required for the correct positioning of the precast elements. This precise installation is essential for good long-term stability of a slab track system. Geometric imperfections during the installation stage must be avoided by using techniques adopted for road pavement construction for the track structure and the formation work, coupled with a precise dimensional control of the actual construction process.

3.5 MAINTENANCE REQUIREMENTS

The maintenance requirements of the track focus on 3 specifics points:

- **Low maintenance :**
  The low maintenance needs is one of the common features of slab track systems and should be also shared by the new developed ones.

- **Easy replacement of track components :**
  Due to the long life of slab track systems, it is expected to replace at least one time the track components subjected to the highest stresses, i.e. rails, fasteners and elastomers, so the procedure to exchange this elements shall be considered in the design phase.

- **Friendly repair procedures on unforeseeable events :**
  Repair works for the slab track use to be complicated, cost-intensive and time-consuming. The operation hindrance cost in case of long closures of slab track lines due to unexpected defects are extremely high and can hardly be calculated or predicted today.

These requirements will be achieved through a RAMS oriented design.

3.6 COST REQUIREMENTS

Total cost of ownership of slab track include construction and maintenance cost. Only this total cost is relevant for economic analysis. The cost requirements of the track focus on 3 specifics points:

- **Low construction costs :**
  Traditionally the construction cost of slab track systems is much bigger than for ballasted track. That is one reason why slab tracks is not very widespread around the world. The construction cost of a slab track system in plain lines consists of manufacturing of precast elements, delivery, assembly and installation of complementary equipment, such as noise absorbers or derailment devices.

- **Low maintenance costs :**
  Economic efficiency of slab track as against ballasted track can be calculated only from the increased maintenance expenses required for ballasted track.

- **Long life cycle :**
  Current life expectancy of slab track systems is about 60 years, while in ballasted tracks it is about 40 years. The most usual problems that lead to the end of life of the system are the following:
  - Fatigue strength of the rail fastening system and its components (intermediate layers, intermediate plates, angular guide plates, rail clamps, sleeper screws and anchor bolts)
  - Fatigue strength of the reinforcement and concrete of the track base layers
  - Fatigue strength of the elastic coating
  - Fatigue strength of the grouting concrete and the substructure (according to application: concrete subbase, hydraulically bound base layer, anti-frost layer, tunnel floor etc.)
  - Ageing of the components mentioned above

These requirements will be achieved through a Life Cycle Cost study of the new concepts.

3.7 Operational/safety requirements

The cost operational and safety requirements of the track focus on 5 specifics points:

- **Performances parameters :**
  The Capacity4Rail is focused on the core TEN lines and the new slab track systems will be developed for high-speed and mixed traffic, so the TSI categories of lines to be applied are Category I and Category IV-M.

- **Compatibility with linear eddy current brakes :**
  When a linear eddy current is applied, the rails are heated up and therefore, could diminish track stability. The average rise of rail temperature in typical conditions is approximately 16 ºC, but can amount to up to 25 ºC under extreme operational conditions. In these circumstances and under strong insulation the rail temperatures can rise to over 80ºC and cause additional rail tension due to which the “critical temperature” might be exceeded.

- **Track accessibility to road vehicles :**
  Considering the evacuation of passengers following an incident, it is important to eliminate tripping hazards on the ground. Rescue vehicles are expected to get access to the location of the incident, as well as extinguishing resources in case of fire. As stated in the specific TSI ‘safety in railway tunnels’, the infrastructure facilities shall guarantee the self-rescue evacuation routes as well as the access for rescue services.

- **Integration of derailment devices :**
  The usual arrangement of derailment retention device consists of an auxiliary rail fixed 180 mm outside the outer running rail on a special baseplate with two rail positions, but the elastic rail support points used in slab track make this arrangement unsuitable. The new slab track systems shall allow either the fixing of the auxiliary rail (standard solution) or be provided with integrated derailment protection devices.

- **Electromagnetic compatibility :**
  Slab tracks, with their reinforced concrete layers, have substantial electromagnetic properties. In their development, it is necessary to consider effective measures against lightning and catenary line breakage. These measures involve grounding elements (equipotential bonding).

4 Generation of innovative concepts

4.1 Ideation process

Two collaborative workshops were held at SYSTRA in 2014.

4.1.1 First collaborative workshop

The workshop which occurred on 24th and 25th June 2014 aimed at generating several new slab-track concepts based on Task 1.1.1 design requirements. For the productions sessions within the workshop, participants were divided into three groups of four people. Two groups were asked to focus on LCC aspects and one group on RAMS aspect to conform to Task 1.1.1 instructions.

Here is the 3 generated concepts:

- **RAMS oriented concept**

This concept is named "Moulded Modular Multi-blocks Slab-Track". It is a reinforced standard precast slab designed for both mixed traffic and high speed traffic. Vertical alignment of the track is made by modular moulded concrete blocks (8 per slab).

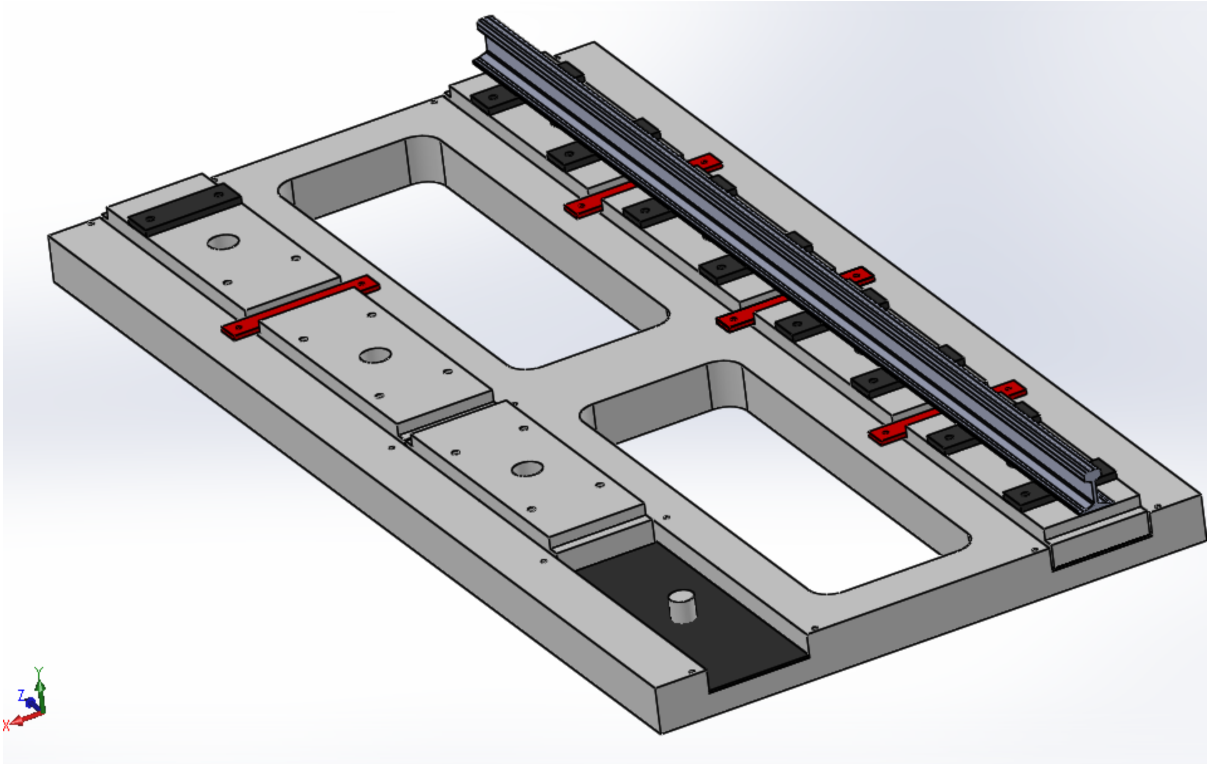

Figure 1 : General view of RAMS Concept slab

There is no need to have a precise subgrade layer levelling and as a result a precise positioning of the slab because there are different types of blocks with different heights in order to assure a correct rails position in relation to the track profile.

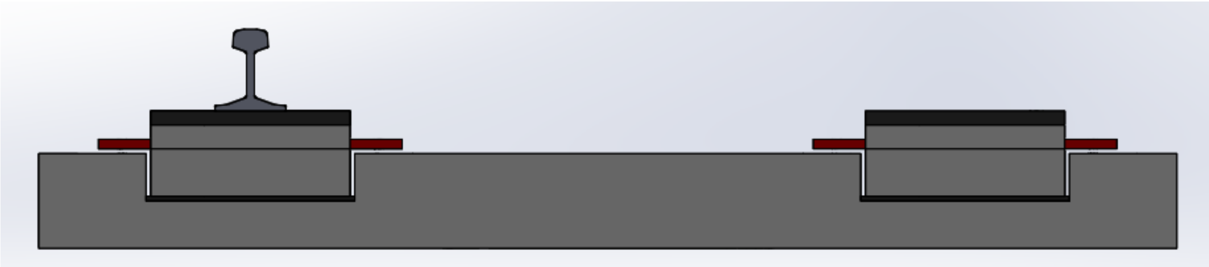

FIGURE 2 : FRONT VIEW OF RAMS CONCEPT SLAB

Precast blocks are positioned on a continuous pad and a concrete centring pin. Then a rubber layer is put in between the blocks and the pin. Blocks are stuck with special fasteners (red parts on the drawings).

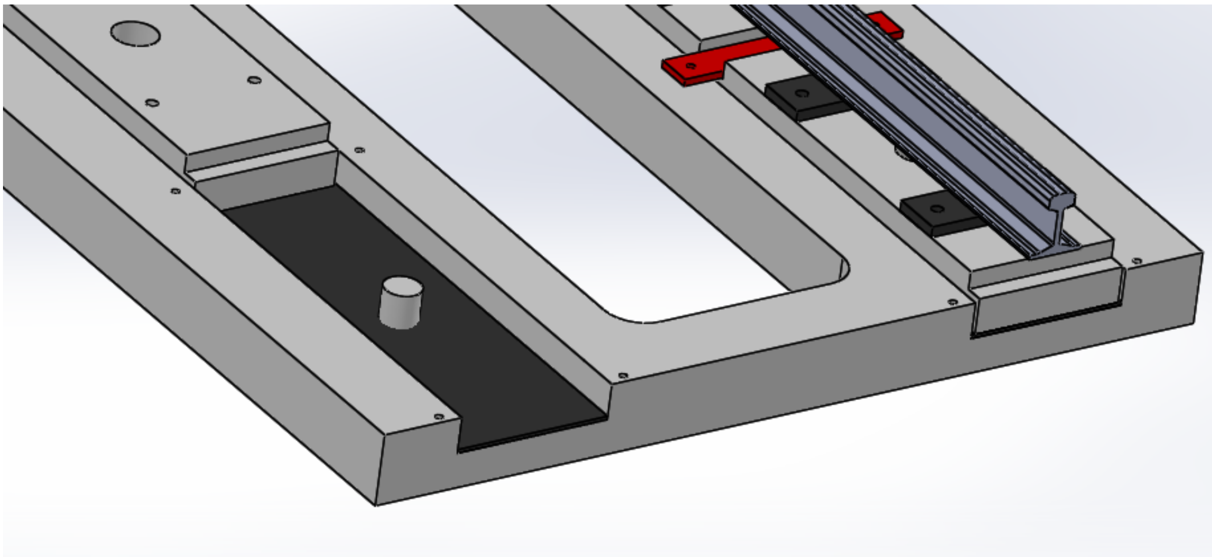

FIGURE 3 : DETAIL VIEW OF RAMS CONCEPT SLAB

Each modular block supports 2 rail fasteners supporting one rail. The slab panel is hollowed in order to be lighter compared to other precast slab-track concepts. Slab panels can be set up both on bituminous or concrete subgrade layer.

- **LCC oriented concept 1**

This concept is named “L-Track”. It is a suitable slab-track for most subgrade conditions. It is modular and low-cost.

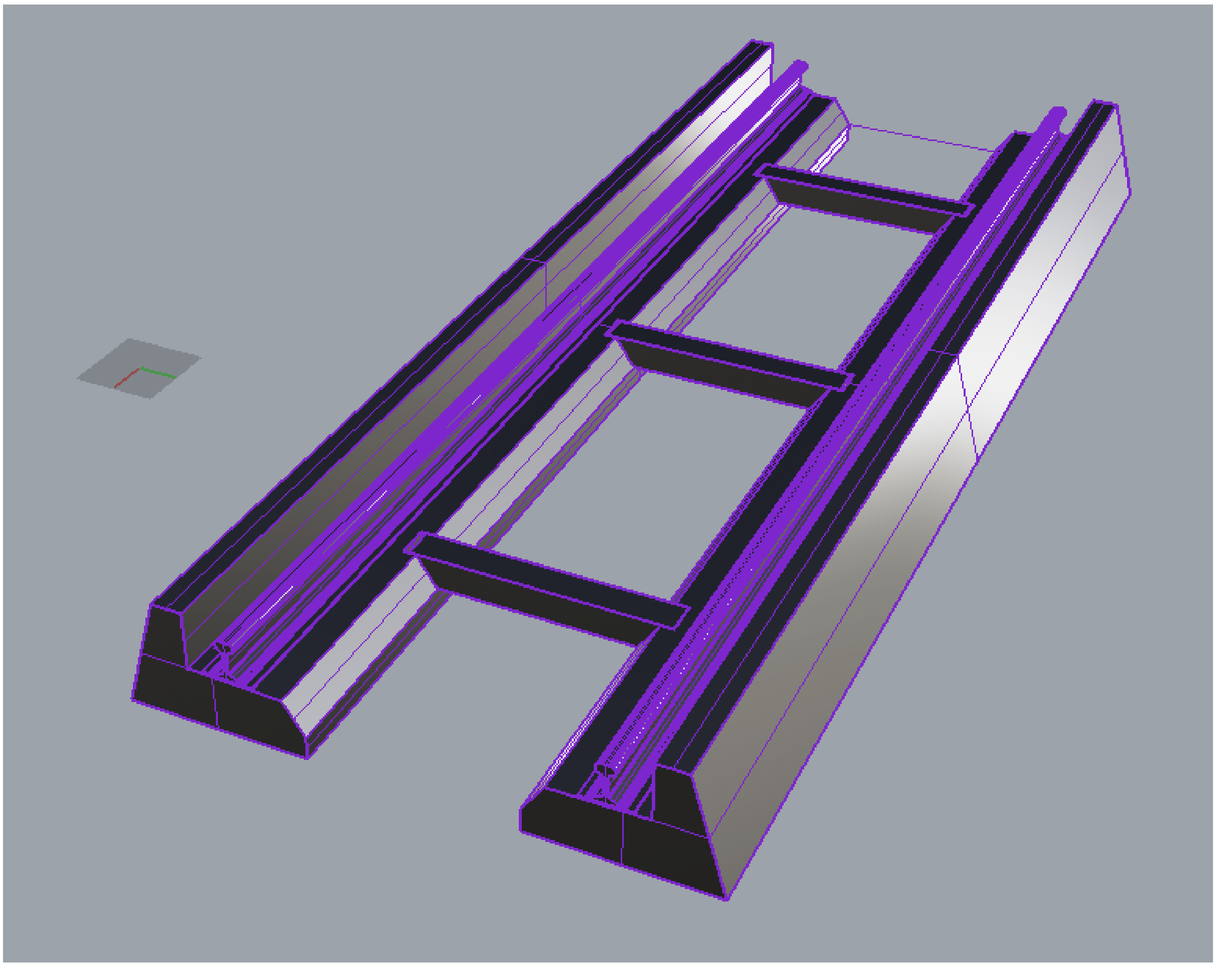

FIGURE 4: GENERAL VIEW OF LCC1 CONCEPT SLAB

There are 2 parallel slabs linked by 3 sleepers. The slab is positioned on a bituminous subgrade layer shaped with a large central rib.

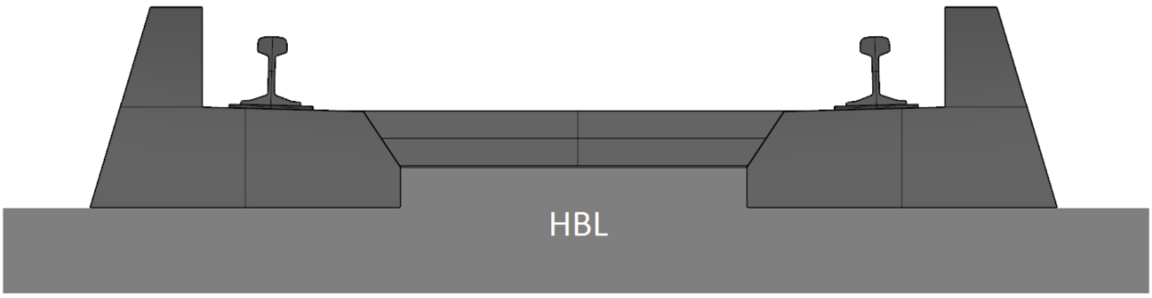

FIGURE 5: FRONT VIEW OF LCC1 CONCEPT SLAB

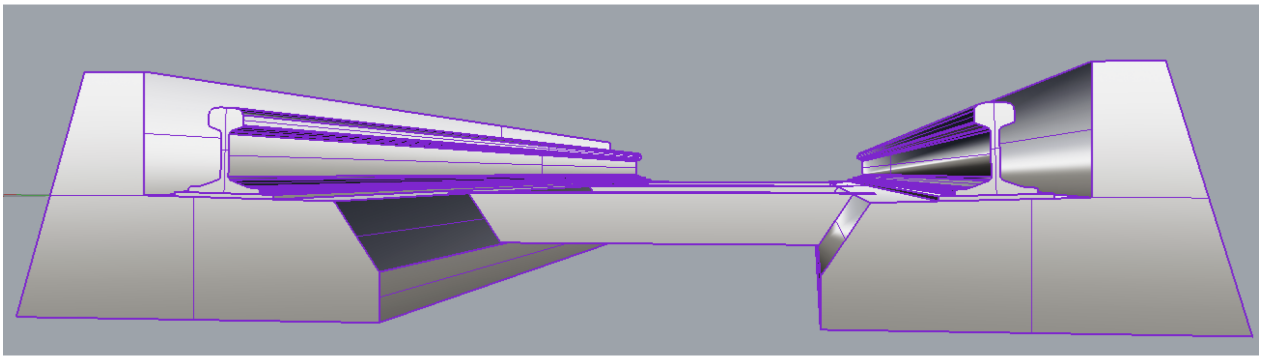

FIGURE 6: DETAIL VIEW OF LCC1 CONCEPT SLAB

- **LCC oriented concept 2**

This concept is named "Steel Track". It is an entirely steel slab made with 2 parallel steel I beam connected with tubes regularly placed perpendicularly.

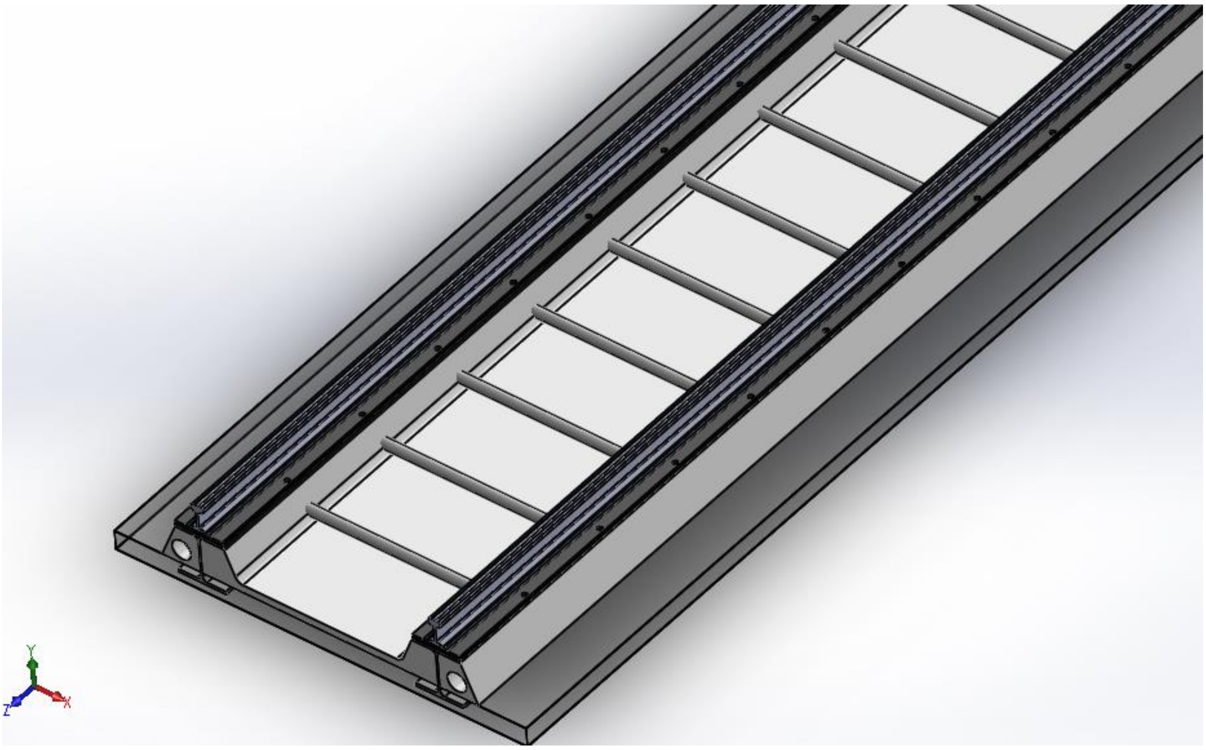

FIGURE 7: GENERAL VIEW OF LCC2 CONCEPT SLAB

Owing to the fact that concrete slabs track are made with reinforcement in order to control the distension of the concrete due to thermal effect, the main idea from this concept is to remove the concrete and issues linked with it.

FIGURE 8: FRONT VIEW OF LCC2 CONCEPT SLAB

Rails are consistently supported by 2 continuous pads set on the upper faces of the 2 main beams.

Every slab panel is 12 metres long. A continuous rubber trim placed through the slab mitigate noise and vibrations.

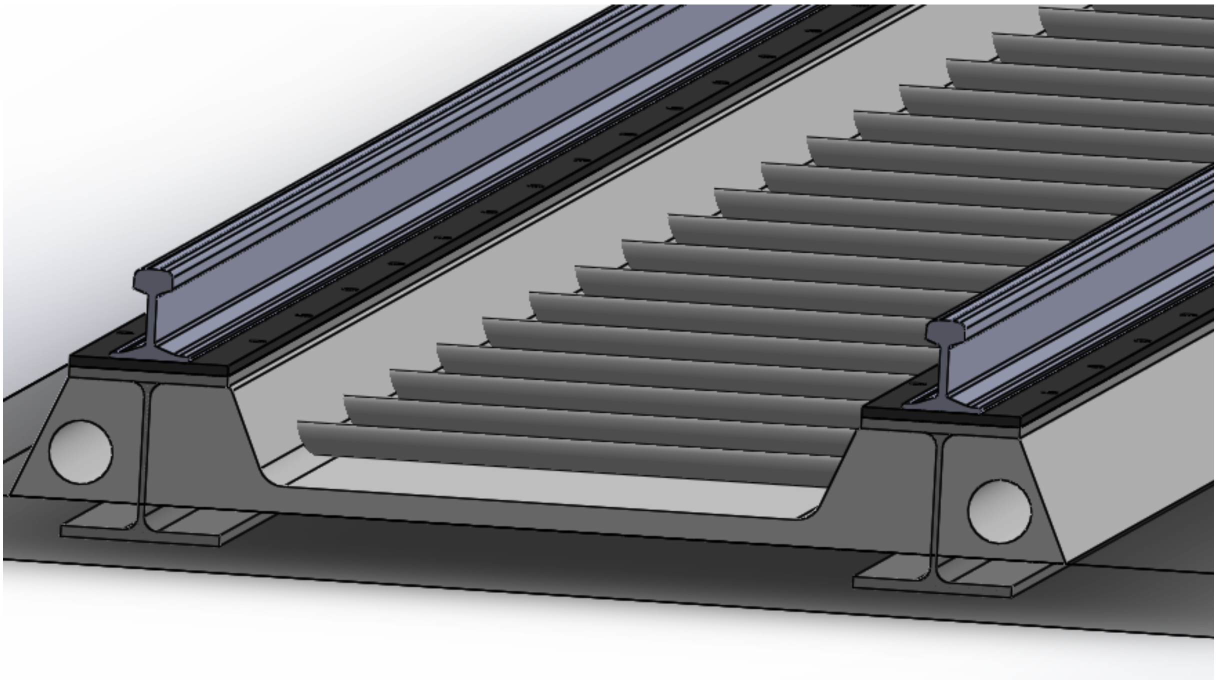

FIGURE 9: DETAIL VIEW OF LCC2 CONCEPT SLAB

4.1.2 SECOND COLLABORATIVE WORKSHOP

The first objective of this second workshop was to create 3 new slab-track concepts based on the improvement of the 3 concepts developed during the first workshop.

The second objective was to define a LCC and RAMS assessment grid in order to evaluate the 3 new concepts designed during the workshop.

Here is the 3 generated concepts:

- **Team A Concept**

The Team A Concept is a kind of ladder track.

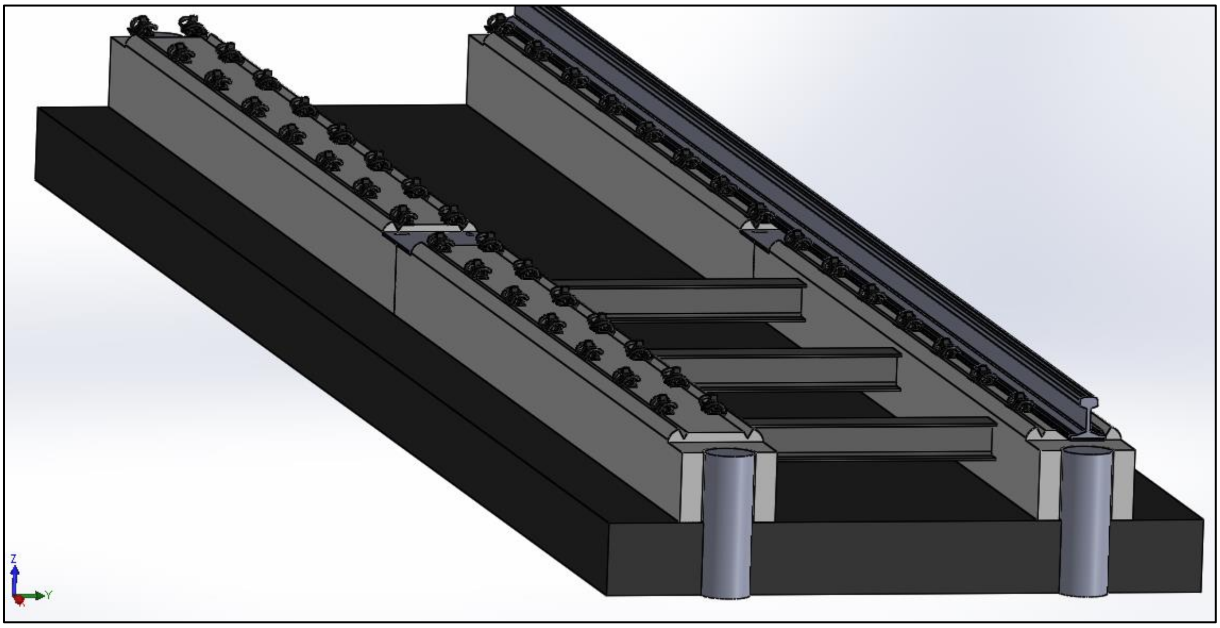

FIGURE 10: GENERAL VIEW OF THE CONCEPT

- The modular frame consists of two longitudinal precast concrete beams and two transversal steel or composite beams.
- It consists on a continuous supported rail with standard fastenings.
- The subgrade layer is very precise asphalt layer.
- Longitudinal and lateral forces are transmitted by a steel or composite plate to the stoppers.
- The stoppers are embedded in the asphalt layer.
- Connections plates could be monitored to detect movement on the adjacent beams.

- **Team B Concept**

The Team B Concept is a kind of ladder track and look like Team A concept except there is no stopper between the longitudinal beams.

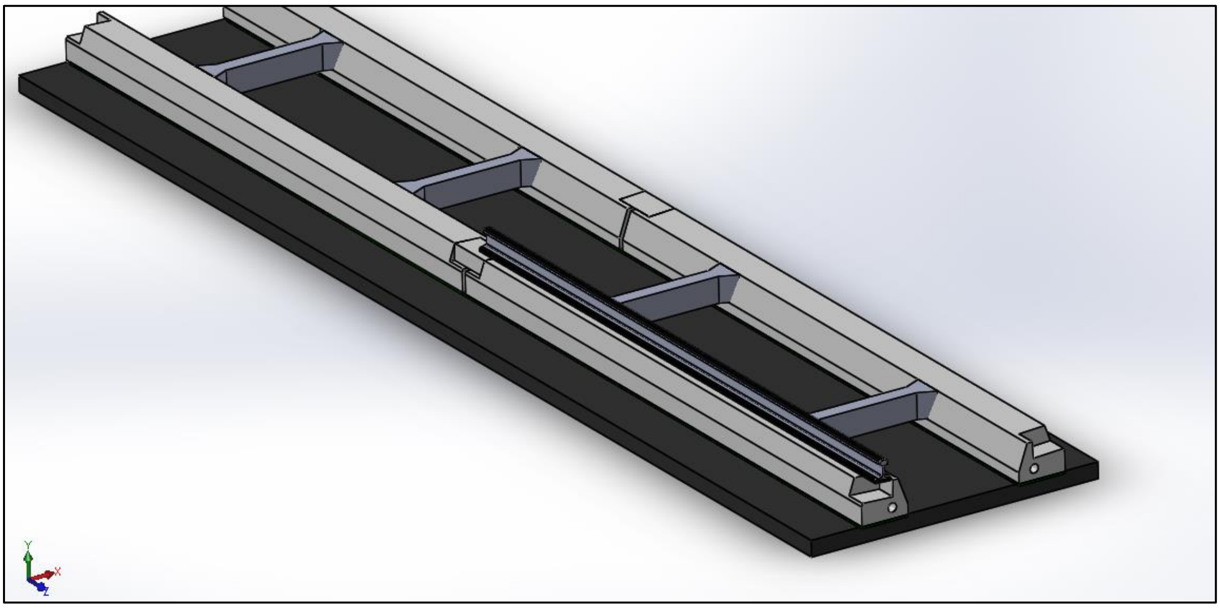

FIGURE 11: GENERAL VIEW OF TEAM B CONCEPT

The transversal beam are made of concrete. The slab is set on an asphalt layer. A fine mortar layer insures the contact between the slab and the asphalt layer.

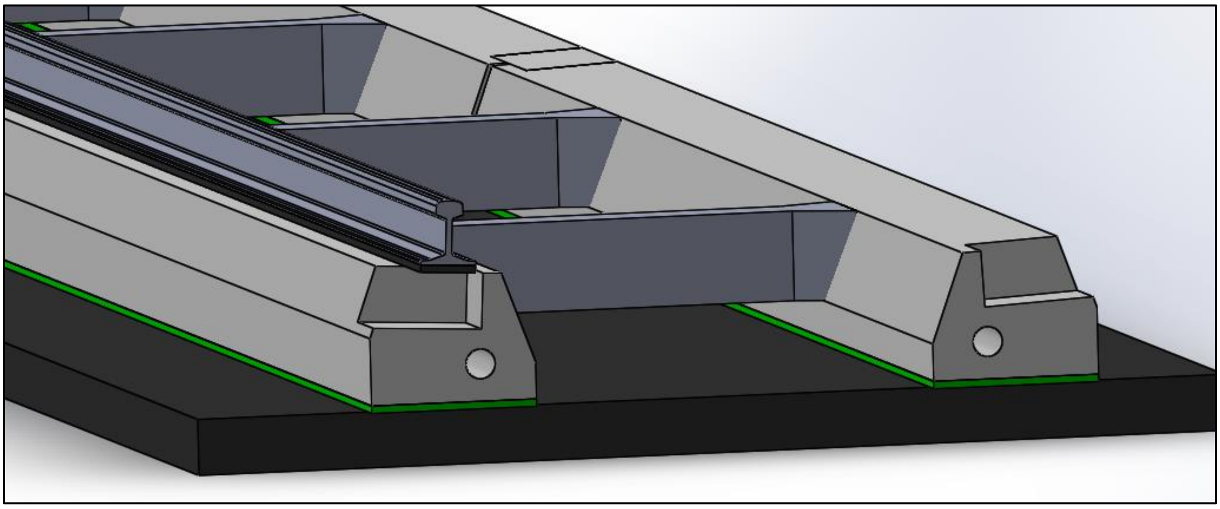

FIGURE 12: DETAIL VIEW OF TEAM B CONCEPT

- **Team C Concept**

The Team C Concept is very similar to Team A and Team B Concepts.

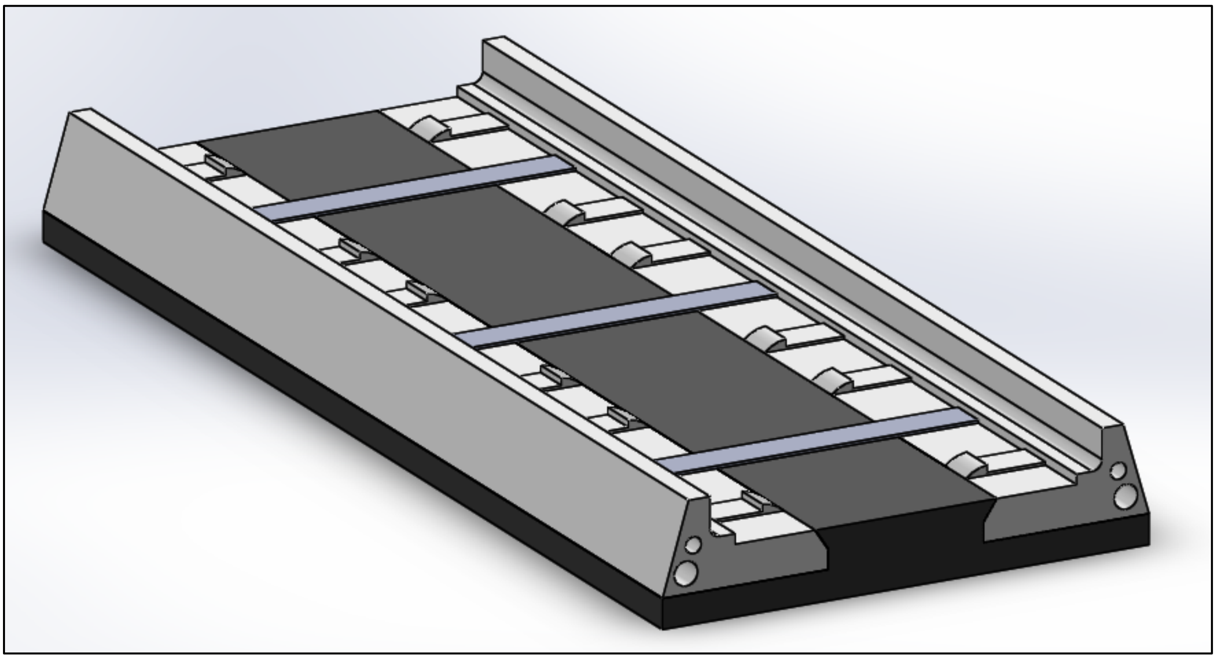

FIGURE 13: GENERAL VIEW OF TEAM C CONCEPT

- For each panel there is two “L-shape” concrete beams linked by transversal steel sleepers.
- Sleepers are “T-shape” steel beams
- Panels are not connected to each other.
- Concrete beams include 2 tubes for cables.

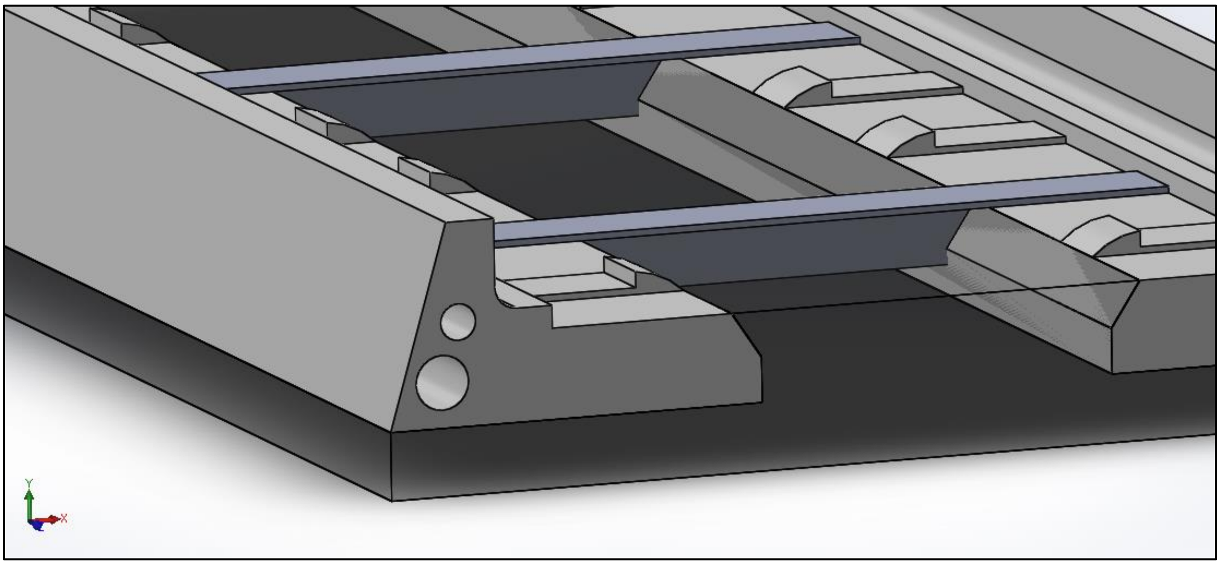

FIGURE 14: DETAIL VIEW OF TEAM C CONCEPT

4.2 Selection of the most promising concepts

The two concepts selected were the "Multi-Moulded Modular Blocks" and the "Team B Concept" renamed after "Ladder Track". The first one was chosen because of its innovative design compared to the existing slab tracks and its RAMS oriented design. The second one was chosen for its simple and economical design.

4.2.1 First concept: 3MB Concept

This concept has a RAMS oriented design and the partners involved in the design are: ACCIONA, CEMOSA, INECO and SYSTRA.

4.2.1.1 Description of the concept

This concept is named "Moulded Modular Multi-blocks Slab-Track" ("3MB"). It is a reinforced standard precast slab designed for both mixed traffic and high speed traffic. 8 precast blocks goes upon the slab. Precast blocks are positioned on a continuous pad and a concrete centering pin. Each modular block supports 2 rail fasteners supporting one rail. The slab panel is hollowed in order to be lighter compared to other precast slab-track concepts. Slab panels can be set up both on bituminous or concrete subgrade layer.

4.2.1.2 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.
- There are two stiffness levels: Fasteners and under block pad.
- Realignment of the tracks because of soil settling is easy to achieve.

4.2.1.3 Economic aspects

- There must be a high initial investment on slab production factories.
- Standardization of production process may decrease cost.
- Installation of slab panels can be fully mechanized which may increase laying speed of track.

4.2.1.4 Maintenance aspects

- Every single element can be repaired separately.
- Block replacing is easy to achieve
- Heavy machine are not required to repair or to change an element except for the slab panel.

4.2.2 Second concept: L-Track Concept

This concept has a cost oriented design and the partners involved in the design are: ACCIONA, INECO, SYSTRA, UoH and VCSA.

4.2.2.1 Description of the concept

This concept is named “L-Track”. It 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.

4.2.2.2 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.

4.2.2.3 Economic aspects

- There must be a high initial investment on slab production factories.
- Standardization of production process may decrease cost.
- Installation of slab panels can be fully mechanized which may increase laying speed of track.

4.2.2.4 Maintenance aspects

- Every single element can be repaired separately.
- Heavy machine are not required to repair or to change an element except for the slab panel.

4.3 Detailed design of the selected concepts

Two working sessions were held in Madrid (December 2015) then Paris (February 2016) in order to do the detailed design of the two concepts. Since these meetings complementary studies were done by each partners.

- **3MB:**

Studies		Responsible partners
Structural design	Static calculation	ACCIONA
	Stiffness levels calculation	SYSTRA
	Dynamic calculation	SYSTRA
	Fatigue calculation	SYSTRA
	Digital model	SYSTRA
	Fastenings selection	VFS
Geotechnical design	Subgrade calculation	CEMOSA, SYSTRA
	Drainage design	CEMOSA
Integration	Earthing, Stray currents	SYSTRA
	Transition zones with bridges and ballasted tracks	INECO
	Signalling equipment	SYSTRA
RAMS and LCC	Construction process and costs	INECO

	Maintenance plan and costs	SYSTRA
	LCC model	SYSTRA
Business model	Business model	CEMOSA

- **L-Track:**

Studies		Responsible partners
Structural design	Static calculation	ACCIONA
	Stiffness levels calculation	VCSA
	Dynamic calculation	VCSA
	Fatigue calculation	ACCIONA
	Digital model	VFS
	Fastenings selection	VCSA
Geotechnical design	Subgrade calculation	CEMOSA
	Drainage design	CEMOSA
Integration	Earthing, Stray currents	SYSTRA
	Transition zones with bridges and ballasted tracks	INECO
	Signalling equipment	SYSTRA
RAMS and LCC	Construction process and costs	INECO
	Maintenance plan and costs	SYSTRA
	LCC model	SYSTRA
Business model	Business model	CEMOSA

At the time of writing this deliverable, all the studies below are not completed yet. All the results of these studies will be included in deliverable D.1.1.3.

5 Construction procedure

This chapter sets the guidelines that must be followed in the assembly and construction of the 3MB and the L-Track concepts. Some stages described might be modified if the modular slab track is to be constructed on tunnel, bridge, embankments, metropolitan railways, etc.

5.1 3MB Concept: Construction procedure

5.1.1 General procedure for the construction of the 3MB system

The 3MB modular slab track is composed of prefabricated elements that are partially assembled before the transport to the construction site.

On track site, the modules are laid over a concrete layer previously constructed. The levelling and flatness of the layer surface and the absence of any irregularity and defect must be carefully observed. Then, the module and the blocks will be installed on the concrete layer.

Finally, the fastening systems and the rails will be assembled over the blocks by following a Top-down construction procedure.

5.1.2 Stages for the 3MB system construction

The following is a description of the main stages needed for the construction and assembly of the 3MB modular slab track.

Materials

1. **Materials and transport**

The 3MB modules are transported by truck from the factory to the platform. The modules will be placed in a pile of 3 levels. The distance between the catenary poles must be observed for the final storage calculation. The rest of pieces and elements composing the whole system will be likewise placed close to the modules.

Sequences of operation for the assembly of the 3MB system

2. **Preparatory works**

As stated, a mass concrete layer must be constructed over the platform before the modules are installed. The layer must be concreted in advance in order to ensure a proper curing, and check the flatness and levelling and the absence of any defect.

Dowels-like elements have to be inserted in the mass concrete layer to ensure the anchorage of the module.

3. **Surveying and marking**

A complete surveying has to be done to check the correct levelling of the whole platform. Marking will be prepared as well.

4. Installation of the modules

The installation of the modules and the blocks will be handled with a crane. The proper position of the modules is very important to avoid big geometry modifications in the following stages.

5. Preparation of the track panels at the track side.

The track panels are composed of the rails and the fastening system and can be assembled at the factory or at track site. The track panels will be then moved to the modules and metallic frames will be installed to hold the track panel. Metallic frames (alternatively, spindles) must allow vertical and transversal levelling adjustment.

6. Levelling of the track panels.

A fine levelling of the track panels must be done before doing the final assembly.

7. Earthing

The earthing must be considered and installed. Layout and criteria for testing of resistance of the earthing system will be done under current standards in force.

8. Final adjustment and check before concreting

Following must be done:

- Final adjustment of horizontal and vertical alignment with total station system must be done as short as possible time before the concreting begins.
- The track is properly secured vertical and horizontal.
- Elements of the fastening system (clip, plates and rail) must be protected with covers.
- Final check of the track geometry.

9. Concreting

Fresh concrete is poured on each block hollows. The concrete will be poured directly from the concrete mixer or through concrete pump. Concrete must cover the anchorages completely without overflowing the block.

10. Finishing

After every move of the rails after concreting, the rails shall be inspected. The rails shall be without damages and cleaned from concrete and other dirt.

11. Curing

Recommended time for curing will be respected before doing any action or applying any load.

12. Releasing of fastenings and metallic frames.

Once the concrete has become hard enough, within approx. 4hours, the rail fastenings are released. This is to avoid forces resulting from the thermal length fluctuation of the rails that would affect the structure of the setting fresh concrete.

13. Final check

Following day, a final recording of horizontal and vertical alignment with total station shall be done.

5.2 L-Track Concept: Construction procedure

5.2.1 General procedure for the construction of the LT system

The LT modular slab track is composed of a prefabricated module and the components to fasten and support the rail on. The final assembly of the set is done at the construction site.

On track site, the modules are laid over an asphalt layer previously constructed. The levelling and flatness of the layer surface and the absence of any irregularity and defect must be carefully observed.

Finally, the fastening systems and the rails will be assembled over the module.

5.2.2 Stages for the L-Track system construction

The following is a description of the main stages needed for the construction and assembly of the LT modular slab track.

Materials

1. **Materials and transport**

The LT modules are transported by truck from the factory direct to the platform. The modules will be placed in a pile of four modules. The distance between the catenary poles must be observed for the final storage calculation. The rest of pieces and elements composing the whole system will be likewise placed close to the modules.

Sequences of operation for the assembly of the LT system

2. **Preparatory works**

As stated, an asphaltic layer must be constructed over the platform before the modules are installed. The layer must be done in advance in order to ensure a proper curing and check the flatness and levelling and the absence of any defect.

The module will afterwards lay on this layer. In order to ensure the stability of the module, a further asphalt layer (alternatively, mas concrete) will be poured inside the module beams.

3. **Surveying and marking**

A complete surveying has to be done to check the correct levelling of the whole platform. Marking will be prepared as well.

4. **Installation of the modules**

The installation of the modules will be handled with a crane. The proper position of the modules is very important to avoid big geometry modifications in the following stages.

5. **Installation of the fastening elements and the elastic pad.**

The elements composing the fastening system will be preinstalled over the module. Likewise, the elastic pad will be laid.

Once all elements are preinstalled, the rail will be positioned.

6. Earthing

The earthing must be considered and installed. Layout and criteria for testing of resistance of the earthing system will be done under current standards in force.

7. Final adjustment and check before concreting

Following must be done:

- Final adjustment of horizontal and vertical alignment with total station system must be done as short as possible time before the concreting begins.
- The track is properly secured vertical and horizontal.
- Final check of the track geometry.

8. Correction of any levelling imperfection.

The rail is fastened and a fine levelling of the whole module must be done before doing the final assembly.

Any correction in levelling can be done by adding mortar underneath the module. In this case, metallic frames to hold and ensure proper levelling may be used.

9. Finishing

The rails shall be without damages and cleaned from concrete and other dirt.

10. Final check

Following day, a final recording of horizontal and vertical alignment with total station shall be done.

6 Maintenance

6.1 Overview of maintenance aspects

Great increase in traffic experienced by railway networks forces to look for solutions able to minimize maintenance and conservation costs.

An effective solution for this issue is the slab track, which offers important advantages:

- Minimization of maintenance operations.
- Reduction of operating costs (20%-50%)
- Larger loads support in each axle
- Lightening of bridges
- Reduction of tunnel section
- Greater security and reliability
- Reduction of intervention time
- Increase of infrastructure availability

All these advantages explain why the slab track use is being increased as a real alternative to traditional ballast track.

Moreover, criteria for its construction are much more challenging than in conventional track regarding levelling, alignment and track gauge. Once installed, correction of errors is complex.

In operation and maintenance the following issues should be taken into account:

- Maintenance techniques
- How to increase operating speed
- Availability periods
- Compatibility of activities
- Preventive maintenance: inspections
- Corrective maintenance

6.2 Maintenance operations in slab track

Maintenance operations in modular slab track can be classified in:

- **Ordinary or preventive maintenance:** It includes visual inspection and periodic grinding to eliminate deformations wear or lubrication.
- **Exceptional or corrective maintenance:** It consists of crack or break repair, improvement of electrical insulation conditions or local corrections regarding track geometry.

Geometric corrections are the most significant operations in slab track maintenance and conservation. In conventional track are usual activities which are performed almost systematically. In slab track, due to it is a practically immovable; those operations are avoided due to the difficulties and costs it represents.

Geometric corrections, in general, are infrequent if the implementation has been accurate. If any defect happens, the track should be disassembled and reassembled in the estimated length in which the defect could affect the rolling stock ride.

6.3 MAINTENANCE ANALYSIS TO SLAB TRACK SYSTEMS.

The next table shows the performance of each typology in slab track against conservation and maintenance operations.

Table 1: Summary of performance of different types of slab track against maintenance operation.

TRACK TYPE	**PREVENTIVEREPARATION**	**CORRECTIVEREPARATION**	**GEOMETRIC CORRECTION**
Embedded rail	Low frequency	Low frequency	Complicated
Direct support	Frequent	High frequency	Need for reconstruction
Indirect support	Frequent	High frequency	Need for reconstruction
Elastomeric coated blocks	Periodic, especially in fastening systems	Problems with water filtrations	Possible replacement of elements
Monolithic with sleeper	Periodic, especially in Fastening systems	Possible replacement of elements	Possible replacement of elements
Elastomer coated sleepers	Periodic, especially in Fastening systems	Problems with water filtrations	Possible replacement of elements
Sleepers on slab	Periodic, especially in Fastening systems	Possible replacement of elements	Possible replacement of elements
Floating slab with Sleepers	Periodic, especially in Fastening systems	Possible replacement of elements	Possible replacement of elements
Slabs on non- elastic mortar	Periodic, especially in Fastening systems	Possible replacement of elements	Possible replacement of elements
Floating slabs without sleepers	Periodic, especially in Fastening systems	Possible replacement of elements	Possible replacement of elements

Conclusion:

The slab track typology which permits the higher reduction in operations and maintenance costs is the embedded rail. Although, in the event, geometric corrections are required, this one is complicated. The rest of families have a similar performance besides the block systems or elastomer coated sleepers in which a great care shall be taken in case of frost and defrost cycles of infiltrated water.

6.4 DEFECTS IDENTIFIED

In the design, it should be considered the system future maintenance and the different elements which could be impaired or distressed, for this reason it will be necessary to repair or replace.

The different defects of the elements which form the modular slab track are listed following:

Slab

- Structural breaks:The slab breaks compels to do a substitution of the same or the affected slabs, being necessary to determine the cause of the plate break, to proceed with the appropriate action in order to avoid a new break.
- Fissures and cracks: repairable and non-repairable: The existence of fissures/cracks could be caused by different factors, it is necessary to be evaluated their severity (whether they require replacement of the plate or not), their cause (if it is a casual origin or is due to an external cause that can re-break the plate), depth and length (these parameters are connected with the plate damage, it can be controlled if the fissures grows or propagates, which can indicate the useful time of the same, until the moment that the fissures is several enough to be necessary to replace the slab). The location of the fissures is another important parameter, it can affect others elements.
- Water infiltrations under the slab: Water presence under the slab must be avoided, because it may cause breaks and damages in lower layers because of the water compression, which is due to train passage, and it spreads through existing fissures what increases their size.
- Settlements: Should be expected the formation of differential settlements along the live in operation that can caused holes under the slab, these can caused causes unexpected stresses consequently the break of the plate. Therefore it is needed to avoid and fix possible settlements.

Rail

It is important to do visual inspections in the rail for detect with anticipation the eventual pathology. The possible defects are:

- Corrosion
- Ordinary wear
- Wave wear
- Punctual defects (cavities, fissures, lamination, corrosion, cavities, blows, hits…)
- Inclination: it is important to take into account the rail inclination, a fault in the rail can came from the fastening system or a problem in the plate.
- Fatigue
- Welds: It is important to take into account cuts and rail welds to avoid the damage of elements which can cause major damages.

Fastening system and anchorage

The break or loss of the clips involves a loss of strength as well as the loss of elasticity at the fastening system.

The break or loosen of a screw means a loss in the clamping force. In the case a screw is broken, a replacement should be prescribed. Corrosion in this elements must be observed at any inspection.

Elastomeric elements

The degradation of the plate elastomers involves a change at the vertical rigidity. It should be considered the possible replacement of those elements

6.5 General procedure for the maintenance of the 3MB system

If the general procedures for the different slab track systems are observed, a particular procedure for maintenance of the 3MB modular systems can be defined.

6.5.1 Overview

The 3MB modular system is composed of a number of elements, which makes an advantage in the need of replacing any elements that has been damaged or broken. It also creates more points where defects can happen. The design of the system allows a certain flexibility if any geometry or alignment correction in the modules has to be done. The fixing of the block to the module allows the regulation of the block. Besides, the elastic pad situated between the block and the module means an additional elastic layer that reduces the vibration emission.

6.5.2 Preventative maintenance

Regarding preventative maintenance, the main works are listed following:

- Stocking of spare components: on depots and workbases a proper quantity of 3MB modules and spare parts must be stored. Machinery, vehicles and transportation means must be ready for service at any moments. Specific tools for the assembly and disassembly of the different elements must be available at any time. As an approach, a stock of 10 complete modules must be stocked, meaning a defect of up to 50 meters being able to repair or to replace. A specific study of the total quantity of 3MB modules and elements is necessary, taking into account the type of railway and the requirements of the rail traffic.
- Track geometry maintenance: 3MB system allows keeping a good track geometry along the life in service. Geometry will be checked periodically by geometry and dynamic inspection, applying similar criteria to those in ballasted tracks. The lack of squareness can affect the rail condition and create defects; if the defect is too severe the global alignment can be affected.
- Rail maintenance: a preventative grinding will be done to the rail Rolling surface right before the entry in service of the line. Periodically, the rail condition will be inspected in order to

detect any damage or defect. A full grinding of the rail will be done once per year (as an initial approach).

- Blocks and fastening systems maintenance: a periodic inspection shall be done in order to check the condition of the fastening systems. The condition of the blocks and the anchorage of the whole system must be also inspected.
- Platform maintenance: geometric and dynamic inspections must be carried out periodically. This will give information about any defect or damage related to the platform (settlements, lack of levelling, etc.) Additionally, any other defect caused by external issues must be inspected and checked: big rains, herbages, dust, mud, small objects, etc. Drainage and water escapes must be cleared.

6.5.3 Corrective maintenance

Regarding the corrective maintenance for the 3MB, the points to observe in the case of a corrective works are listed:

Slab: in this system, it is formed by a module and a set of blocks with an anchorage to the module. Main aspects to check are listed:

- Full crack of the module: low probability; if it occurred, the whole module must be replaced.
- Cracks and flaws in the module: low probability. If any is detected at an early stage, a careful vigilance must be given and assess whether or not a replacement is needed.
- Water infiltrations: If water is retained inside the modules, the drainage and any water escape must be cleared. If big water presence is detected under the module or platform, the track must be externally supported and schedule a repairing action on the spot.
- Settlements: if any settlement is detected during ordinary inspections, a thorough check of the area affected must be done. Then the track must be supported and stabilized. A partial of complete repair must be scheduled.

Rail: periodical inspections must help in the assessment of the rail condition. Any defect may be studied under the same criteria as in ballasted tracks. In the case of a rail break, the 3MB system is fitted with a proper geometry that allows a quick rail welding.

Single elements: If any defect on a single element of the 3MB system is detected, a specific assessment must determine the repair or replacement of the element. The modular system allows easy and quick replacement of single elements like the blocks or the fastening system

Elastic elements and anchorage: Special attention will be given to the elastic elements condition – rail elastic pads, under block pads. Anchorages of the rail, blocks and modules will be also inspected. If any defect or damage is detected, an assessment must determine the repair or replacement.

Geometry: If any geometry defect is detected, an assessment must determine the severity and extension of the defect and check if it affects a small distance, the whole module or a set of modules. If the geometry defect is small it can be corrected by adjusting the rail seat plates. If the defect is severe and exceeds the tolerance limits, a repair work must be scheduled. The nominal geometry must be restored and replace any element affected. In the 3MB system, the module seats on a concrete platform, therefore no settlements or levelling defects are expected.

6.6 General procedure for the maintenance of the LT system

If the general procedures for the different slab track systems are observed, a particular procedure for maintenance of the 3MB modular systems can be defined.

6.6.1 Overview

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. However, the adaptability to the desired geometry and the repair of elements and defects is more complicated. The continuous rail support will extend the life in service of the rail and reduces the maintenance works associated.

6.6.2 Preventative maintenance

Regarding preventative maintenance, the main works are listed following:

- Stocking of spare components: on depots and workbases a proper quantity of 3MB modules and spare parts must be stored. Machinery, vehicles and transportation means must be ready for service at any moments. Specific tools for the assembly and disassembly of the different elements must be available at any time. As an approach, a stock of 10 complete modules must be stocked, meaning a defect of up to 50 meters being able to repair or to replace. A specific study of the total quantity of LT modules and elements is necessary, taking into account the type of railway and the requirements of the rail traffic.
- Track geometry maintenance: LT system allows keeping a good track geometry along the life in service. Geometry will be checked periodically by geometry and dynamic inspection, applying similar criteria to those in ballasted tracks. The lack of squareness can affect the rail condition and create defects; if the defect is too severe the global alignment can be affected.
- Rail maintenance: a preventative grinding will be done to the rail Rolling surface right before the entry in service of the line. Periodically, the rail condition will be inspected in order to detect any damage or defect. A full grinding of the rail will be done once per year (as an initial approach).
- Blocks and fastening systems maintenance: a periodic inspection shall be done in order to check the condition of the fastening systems. The condition of the continuous rail pad must be carefully checked. It is also important to check the fastening of the module anchorages.
- Platform maintenance: geometric and dynamic inspections must be carried out periodically. This will give information about any defect or damage related to the platform (settlements, lack of levelling, etc.) Additionally, any other defect caused by external issues must be

inspected and checked: big rains, herbages, dust, mud, small objects, etc. Drainage and water escapes must be cleared.

6.6.3 Corrective maintenance

Regarding the corrective maintenance for the LT, the points to observe in the case of a corrective works are listed:

- **Slab:** in this system, it is formed by one module composed of two beams and connections between them. Rail is supported directly to the module. Main aspects to check are listed:
  - Full crack of the module: low probability; if it occurred, the whole module must be replaced.
  - Cracks and flaws in the module: low probability. If any is detected at an early stage, a careful vigilance must be given and assess whether or not a replacement is needed.
  - Water infiltrations: If water is retained inside the modules, the drainage and any water escape must be cleared. If big water presence is detected under the module or platform, the track must be externally supported and schedule a repairing action on the spot.
  - Settlements: if any settlement is detected during ordinary inspections, a thorough check of the area affected must be done. Then the track must be supported and stabilized. A partial of complete repair must be scheduled.

- **Rail:** periodical inspections must help in the assessment of the rail condition. Any defect may be studied under the same criteria as in ballasted tracks. Given the continuous rail seat on the module, the occurrence of defects is reduced. Rail performance is similar as in embedded systems.

- **Single elements:** If any defect on a single element of the LT system is detected, a specific assessment must determine the repair or replacement of the element. The modular system allows easy and quick replacement of single elements like the fastening system or the anchorages.

- **Elastic elements and anchorages:** Special attention will be given to the elastic rail pads condition. Anchorages of the rail and modules will be also inspected. If any defect or damage is detected, an assessment must determine the repair or replacement.

- **Geometry:** If any geometry defect is detected, an assessment must determine the severity and extension of the defect and check if it affects a small distance, the whole module or a set of modules. If the geometry defect is small it can be corrected by adjusting the rail seat plates. If the defect is severe and exceeds the tolerance limits, a repair work must be scheduled. The nominal geometry must be restored and replace any element affected. In the LT system the module lays on an asphalt layer. In the case any levelling defect occurs, it can be repaired by adding mortar underneath or carrying out a modification in the asphalt layer.

7 Testing and prototyping

The testing process will include a preliminary verification test of a 3MB single-block at VCSA workshop. After this, both new slab track concepts will be tested at the CEDEX Track Box.

7.1 Tests for the 3MB single block

First of all, we want to verify the design of the 3MB system before the final prototype construction. A single block with the below supporting slab and all elements needed for the fastening system and elastic layers will be constructed in ACCIONA. Then the set will be sent to the VCSA workshop to perform a fatigue test.

The idea is to make a fatigue test (EN 33°) on a bloc in order to verify the interface bloc-slab through the tubes. Force is applied between two fasteners (load value = EN load x 2).

7.2 Test at the CEDEX Track Box

Once the two concepts have been prototyped, ACCIONA will launch a transport to CEDEX. It is crucial to ensure the lifting and handling of the modules at all time during the transport.

The entrance of the modules at the track box room is possible. The installation will be done preferably on the 1st section.

7.2.1 3MB Tests

The 3MB module will be tested in first place as the installation needs of an asphalt layer to be constructed before.

Expected date of the tests: March to May 2017

Preliminary operations before 3MB testing:

0. Check CEDEX facilities are free to start the preparation
1. Removal of the existing instrumentation, superstructure, ballast, subgrade?
2. New subgrade layer? Or adaptation of the existing one.
3. Construction of the asphalt layer (thickness?). Installation of instruments at track bed.
4. Transport of the 3MB module, stockpiling nearby.
5. Installation in the track box section. Installation of instruments on the module.

List of tests for 3MB:

- Settling: 300.000 cycles
- Static test (vertical load to get vertical stiffness)
- Dynamic test (3 actuators per rail, vertical load ~ 10.000 cycles)
- Fatigue test (providing symmetrical inclination loading), according to Standard (3.000.000 axles. 1 month)

- Static test (vertical load to get vertical stiffness)
- Dynamic test (3 actuators per rail, vertical load ~ 10.000 cycles)
- Curve simulation test (TO CONFIRM WITH CEDEX)

7.2.2 L-TRACK TESTS

A module of the L-Track will be tested in the same track box section. For the installation of the module, we need to construct a concrete slab underneath, in a similar way as the Top-down process.

Expected date of the tests: June to August 2017

Preliminary operations before L-Track testing:

0. Disassembly the instruments on the module.
1. Lifting of the 3MB module
2. Set in place of the L-Track module
3. Installation of metallic frame, set the levelling of the module (assembly process similar to Top-down)
4. Pour the concrete underneath.
5. Installation of instrumentation on the module.

List of tests for L-Track:
Settling: 300.000 cycles
Static test (vertical load to get vertical stiffness)
Dynamic test (3 actuators per rail, vertical load ~ 10.000 cycles)
Fatigue test (providing symmetrical inclination loading), according to Standard (3.000.000 axles. 1 month)
Static test (vertical load to get vertical stiffness)
Dynamic test (3 actuators per rail, vertical load ~ 10.000 cycles)
Curve simulation test (To confirm)

Steps after the 2nd test:
Uninstallation of instrumentation
Lifting the module
Uninstallation of the instruments on the track bed.

9 Life Cycle Cost

9.1 CONSTRUCTION COSTS

The following assumptions are made to calculate the cost of manufacture and construction of the modular slab track system.

- Calculations are made for a total length of 100 meters of single track constructed.
- Average cost of the raw materials purchased in Europe.
- Manufacturing costs are calculated on the basis that the manufacture procedure is optimised and on a commercial stage, not prototyping stage.
- Transport costs are calculated on a €/ton/km basis. This may vary if the construction site is offshore.
- The price for construction is based on similar cases of slab track system. The experience shows that the global cost for all works involved in the construction of non-modular slab track is estimated in 2,5 times the cost of the materials used. This factor may be modified when the sequence of operations in the construction process is optimised.

At the time of delivering this deliverable, all the construction costs needed to produce a life cycle cost estimation were not available. The complete life cycle cost estimation will be included in deliverable D1.1.3.

9.2 MAINTENANCE COSTS

The following assumptions are made to calculate the costs of maintenance and renewal operations of the modular slab track system.

- Calculations are made for a total length of 106 km of double track.
- Operational life duration is 102 years with tonnage of 40MT/ year for 320 km/h maximum speed.
- Average of SNCF workers hourly costs.
- Maintenance and renewal operation are adapted from SNCF standards for ballasted track.
- Only track is taken into account that means than all operations related to catenary, sub-station, signalling, bridges and tunnels, low currents and stations are out of the scope.

At the time of delivering this deliverable, all the maintenance costs needed to produce a life cycle cost estimation were not available. The complete life cycle cost estimation will be included in deliverable D1.1.3.

10 Business model

10.1.1 INTRODUCTION

The business model supports the viability of the business regarding the new concepts of slab tracks developed during the Capacity for Rail project. This business model includes different sections in which the external and internal factors, purpose, goals, and on-going plans for achieving them, are analysed.

At the level of develop of the new concepts of slab track reached at the date of publishing of this deliverable, it has been not possible to analyse with the level of details the entire variable involved in the business and decision support model. Besides, some of the different stages of the business model require a particular analysis by every one of the partners related with its internal costs and business strategy. However a global and well-oriented analysis has been possible to perform where different internal and external factors has been detected, analysed and a number of strategic decisions has been proposed.

In order to get accurate outcomes, a set of several steps have been followed. These steps represent different phases of a more complex analysis. Shown below the explanations and analysis of every one of the different phases of this global study.

10.1.2 PEST ANALYSIS

PEST analysis develops a framework of external environmental factors used in the environmental scanning component of strategic management. It is a widely used tool that let analyse the political, economic, social and technological environments related with your business. Normally, it is part of a wider analysis which finalizes with the business operation and management plan.

As a result, a global idea or 'big picture' is obtained that helps corporations or businesses to understand the changes which they are exposed to, and from this, exploit the opportunities that they present.

10.1.2.1 Political

Current political world situation lives a period of convulsion and turbulences. Recent events such as jihadist terrorism, migration crises, demographic changes in different regions of the world along with an unstable political scenario in diverse countries of the first world such as United States, United Kingdom or European Union, provides us with an general idea about the global policy state where the opportunities dwindle in contrast with the weaknesses.

United States presents an unstable framework forecast regarding the policy due to the 2016 general election, where the master lines followed during the last years could be drastically change in dependence on the result of the election. On the other hand, terrorism with ISIS as the most powerful terrorist organisation in history has led to made hard decisions in terms of safety and security. This problem connected US with other countries which are in the ISIS' hit list. This list includes nations with a high number of unintegrated communities such as France, Russia or Turkey.

In Europe the situation is not quite different. The leaving of United Kingdom from the European Union, also known as *Brexit*, might provoke unexplored consequences which are not totally evaluated by the international economic and political associations. In political terms, *Brexit* may signify some serious issues in the development of current European treaties. A proceed for the formal leaving of the EU has to be implement to regulate the process and save the rights and obligations with the rest of European partners. Moreover, *Brexit* could help to the increase in the number of anti-European movements in some countries as Netherland or Austria.

The effects of financial and economic crisis are still presented in the European policy. Slow growth and lower living standards are going to make people discontented. One of the most considerable consequences of the crisis is the appearance of a new phenomenon of radicalization in the political scope which has recently happened. The raise of extreme movements in terms of ultra-left and far-right parties, in the majority of European countries, supposes an added unstable factor to a situation still extremely fragile.

The latter is owed to add the uncertainties in the political future of some countries such as Spain or Austria. The case of Spain is extremely relevant due to its important weight in the EU GDP, strategic location, the size and large population of the country. After two elections the political parties do not come to an agreement to choose a government and the next budget for 2017 is totally paralyzed. The case of Austria is seriously worrying. The raise of extreme parties which question the membership of the country to the EU and relationship and frontiers policy could be represent a risk in a short-term.

This convulse political state in Europe is directly linked with the situation in Middle East. Turkey lives with a recent *coup d'état* attempt and the direct consequences of it. This instability in the area is directly linked with the war in Syria, which has triggered a set of migration movements, originating the 'Refugee crises'. The destiny of the most of this people is the main European countries such as Germany where more than 1 million of emigrants from areas war areas are living now. These movements have provoked some racism episodes which have resulted in the emerging of new ideas related with the close of borders or the restriction in the traffic of people.

Regarding South American countries, the most serious and unpredictable case of policy state is Brazil. The celebration of World Football Championship in 2014 and the Olympics in 2016 has meant a great expense for the public finances. However, this great amount of money has not translated into improvements for the people in matter of public services. In addition the suspicion of corruption has led to riots, disturbs and protest marches. All these events have provoked the deposition of the former president due to fraud charge.

China, the only country of scale with a global economic strategy, stands out as the most important, but uncertain, driver of many global outcomes. However, some experts agree with the fact that most international players are not ready for this or do not agree with China priorities.

In the rest of the world, the volatility is presented because of an unusually amount of leaders known for their erratic behaviour. In this pack of personalities could be included Vladimir Putin (Russia's president), Tayyip Erdongan (Turkey's president) along with Mohammed bin Salman (Saudi Arabia's Deputy Crown Prince) or Petro Poroshenko (Ukraine's president).

All these facts draw a difficult scenario of uncertainty and instability where it is not easy to have a clear idea about the national infrastructures plans forecast in the short and mid-term.

10.1.2.2 Economic

Global economic environment has suffers relevant changes in the last times. The uncertainties surrounding the forecast are extraordinarily high. Despite of the fact that we are in an expansive phase of the economy, the effects of the financial crisis are yet presented in the most of European countries particularly in the southern countries such as Greece or Portugal where the bailouts has strong effects on the capacity of investment for the national governments.

According to the European Economic Forecast Spring 2016 (European Commission, Spring 2016), the European economy continues to expand modestly. Some facts such as the low oil prices, the relatively low exchange rate of the euro, very ample monetary policy and slightly supportive fiscal policy continue to underpin growth this year.

However the same report shows some risks which must have taken into account. These risks are related with the possible lift in the price of the oil and the lagged boost from the euro's depreciation that is likely to have run its course.

Regarding the GPD, this one in the euro area has now achieved its pre-crisis peak of eight year ago but it has taken much longer to reach this milestone than in other advanced economies. The level of investment remains depressed and structural unemployment rate far too high. The latter is critically relevant in important economies such as Spain or Italy. Besides, other factors, as the slow trend growth of productivity, could delay the recovery.

Brexit may signify a serious threat to the economic recovery. Moreover the FMI predictions talk about a decrease of around of 1-1.5% in the British GDP and 0.2-0.5% of EU GDP due to *Brexit*. This fact along with the investment shortfall, due to the budget restrictions, could represent the most likely risk to the European economy in the next years.

Regarding the global economic outlook, it remains weak in last months, amid heightened financial market volatility and commodity prices. According the prospects, the emerging countries' economy will remain fragile due to the commodity price declines, tightening financial conditions and a host of home-grown vulnerabilities. In fact, economy growth fell to 3.2% in 2015, its slowest value since 2009. There are many causes in this decrease, but the main reason is the gradual slowdown in the growth of emerging countries.

Advanced economies, such as US and Japan, also show signs of deterioration in the last times. Growth in both countries has been lower than expectations in advanced, while recessions in Brazil and Russia have been deeper than expected, and the rebound in other emerging economies has disappointed.

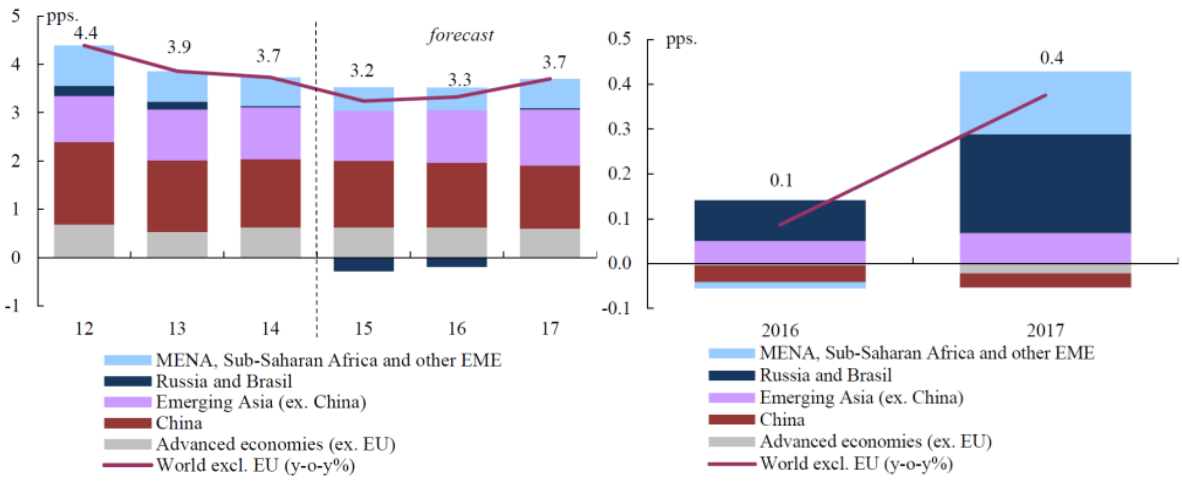

FIG. 15. GLOBAL GDP GROWTH AND SOURCES OF REBOUND OUTSIDE THE EU (EUROPEAN COMMISSION, SPRING 2016)

These analyses do not offer the best outlook for the future of infrastructures plans which require great amount of money and resources which are not currently available.

10.1.2.3 Social

Currently, social demands play an important role in the infrastructure plans. Not only from an economical point of view, but also considering the environment, the sustainability, the efficiency, the security, the smart and green transport, social inequality or climate action. All of these are part of the current social concerns. As a result of this new social sensitivity, all these demands must take into account in any planning or operation what it directly translate into a new challenge for planners, technicians and engineers.

Due to the financial and economical restrictions, one of the most important demands in our society is the efficiency of the new infrastructures. These must be useful and economically sustainable at the same time. They must be accurately adapted to the current and future needs, but not be over dimensioned. Besides, the cost should not be only evaluated in matter of money but also in societal benefits, particularly in those countries which has suffered most severely the effects of the financial crisis.

Sustainability is one of the more relevant challenges in this new mentality. The new infrastructures must be sustainable in a long-term. Expenses in infrastructures are considered as investments for the future generation but not as debts for them. This change in the way of thinking is related with serious issues due to past huge investments in infrastructure. These investments have not tackled to the social problems and have result in a large increase of public debts for decades.

Smart and green transport is other of the main new challenges which must be taken into account in the development of the new infrastructure programs. A new policy in relation the environmental has emerged mainly due to find a way to tackle to the pollution and environmental issues, because of the use of fossil fuels. In alignment with this issue, the *smartization* of the transport constitutes another possible line of action which is currently in a constant development. This technology must minimize the fuel costs; reduce the pollution and optimizing the travel times.

One of the main social concerns is in relation with the inequality in the society. There are many theories about the causes, pros and cons of the inequality. Inequality is defined as the gap between the highest income earners and the lowest income earners. However, nowadays a new concept of inequality has appeared. It defines the inequality as the difference not only in financial sense but also in wealth, education or culture. The assessment whether the inequality is beneficial or not is not as important as the knowledge of the causes of inequality. The causes of inequality are varied and diverse. Among the causes could be mentioned the lack of facilities, problems in the access to education, the different skills and abilities or the social environment where people grow. Moreover the social inequality is closely related with the economic troubles. Market failure occurs when there is an inefficient allocation of resources in a free market (Pettinger, 2011).

Global warming is beginning to create serious troubles on the Earth. Floods, droughts, hurricanes or other extreme meteorological phenomena represent important hazards in housing and infrastructures. One of the crucial and critical challenges in XXI century is related with overcome and mitigate these hazards. New methodologies and tools in order to achieve this challenge must be implemented during the first decades of the century. Society is completely aware of this need, what has provoked a change in the policy, both in national governments and private corporations, in relation this issue in the last times.

10.1.2.4 Technological

The boost of technology in the last decades has supposed radical changes in the most of areas of life. The world of working, health, communications, transports or social interactions have been completely transformed by the use of technological devices which to a large extent have eased and helped to improve our quality of life.

However, there are yet many challenges in relation with the technological development to address during the XXI century. In this challenge, information and use of it (*information and communications technology – ICT)* plays a primary role. Many areas of traditional operations could be transformed by applying information technology. The application of new technology of information must fulfil some of the following aspects (Popper):

- Enhancing the efficiency of information gathering and production
- Achieving synergy by combining different databases
- Horizontal and vertical connectivity
- Ensuring wider accessibility
- Use of smart grid
- Multiplying contacts thus increasing the density of information-sharing networks
- Increasing the ultimate effectiveness of information utilization

In the field of transport infrastructures, some of the ideas previously mentioned are being applied in the new developments carried out from the first decade of 21st century. Particularly, among the land transports, it is the rail, the mode of transport which has shown the larger advance in the use of ICT tools.

Mainly, the use of advances technologies in the infrastructure are linked with the monitoring and data analysis. The principal target in the use of ICT is the use of data from monitoring in order to detect possible defects or failures in the general statement of the infrastructure before these defects could affect the operational capacity of the infrastructure. As a result, an improvement in the conditions and a better planning for maintenance tasks could be achieved. Moreover, all of these will translate into a safety in operational costs and a reduction in the downtimes.

Apart from the use of ICT in rail, the recent developments show a clear tendency in the design and construction of new models of ballast-less rail through the use of the slab track. The ballast presents a number of drawbacks in comparison with the ballast-less systems that makes it an unsuitable system for high speed rail. Some phenomena as flying ballast could be effectively overcome with the use of slab track systems. On the whole, slab track offers a solid and robust solution for high speed rail with fewer issues thereby facilitating and reducing maintenance tasks. However this system also presents some notable inconveniences which make difficult its generalization as the main rail system. Among the more remarkable drawbacks it is possible to mention the embankment height limitation due to the little tolerance regarding settlements and the difficulty in the replacement tasks of the slabs once they are broken or deteriorated.

In alignment with these ideas a set of commercial systems has been developed from the last decades of 20th century. These systems, mainly European, offer different alternatives in the use of slab tracks.

Among the different systems could be highlighted the system Rheda2000® which is widely used in stations and some lines in Germany, Züblin, LVT-Sonneville, Stedef, Bögl, BBER or Shinkansen.

Every one of above systems has a number of special features which make the system more appropriate for several case of use. Along with these features, a number of drawbacks and benefits are presented in every one of these systems.

For all above reasons, slab track represent a major challenge in the development of high speed rail. Some of the main drawbacks regarding some phenomenon as ballast-flying could be avoided with the use of this technology. Despite this fact, slab track technology presents some disadvantages related with its own geometry and its features which provoke restrictions in the height of embankments or complicate the switches and crossings.

10.1.3 SWOT ANALYSIS

SWOT analysis is a business technique for a project or an idea which identifies the strengths, weaknesses, opportunities for growth and improvement and the threats the external environment presents to its survival.

	Helpful	Harmful
Internal origin	Strengths	Weaknesses
External origin	Opportunities	Threats

Therefore, it is a type of analysis in 4-steps which cover different point of view of the business. Every step of the analysis is defined as:

- Strengths, characteristics of the project which give advantages over others
- Weaknesses, characteristics that place the project at a disadvantage relative to others
- Opportunities, elements in the environment that the project could exploit to its advantage
- Threats, elements in the environment that could cause problems for the project.

10.1.3.1 Strengths (internal origin)

Despite their disadvantages, ballastless rail systems such as slab track present a number of benefits over the traditional ballast systems. These advantages are mainly related with the fact of the absence of aggregates (ballast) allow implementing cleaner, dust-free and environmentally friendly engineering solutions. Moreover, the non-presence of ballast, and its substitution for a slab allow the access of road rescue vehicles in the track in case of emergencies or accidents, not only in tunnels but also in open plain rail sections.

Regarding the maintenance tasks, although they are lower in number than in ballast systems, these one are more complex and intensive in workforce, due to the fact that the need of replace the damage o cracked slab by a healthy slab in case of failure. However, the new concept of slab track developed during Capacity for Rail project avoids this issue, due to its modular design which allows replacing damaged components of the slab without the need for the replacement of the whole slab. This represents a great leap in the generalisation of use of the slab track systems in longer rail stretches, because until now, this technology is generally used in small stretches or singular points such as stations or tunnels.

The avoidance of ballast flight in the slab track systems represents other of the main benefits over the traditional ballasted track systems. This fact is particularly remarkable in case of high speed rail where the phenomenon could causes important damages in the rolling stocks.

Technological advances in the last decades have provided us with a great amount of tools whose use could help and improve some of the main weak points of the transport infrastructures. Current technologies of slab track present a number of limitations regarding the use of ICT in monitoring of the structural health for the whole system (slab, rail and so on). In fact, these kinds of technologies are not use yet in the most of cases, and the evaluation of the state is carried out by traditional methods.

Both typologies of slab track developed during Capacity for Rail Project, included an innovative monitoring system specially implemented for its design and special features. This system will represent a major step in the knowledge of the stress and strain state of the concrete and steel bars of the slab. Data from the monitoring could be used in order to optimize the maintenance tasks what means in cost reductions and improvements in the level serviceability of the corridor. Besides, the use of data mining and analytics techniques could redound in the development of advanced algorithms for preventing failures in the diverse elements of the system.

Fabrication of the track base slabs at an off-site production facility increases the reliability of the construction quality and execution schedule. Mistakes on-site are kept to a minimum by using track base slabs which are precast in factory conditions

Furthermore, the new concept of slab track is specially designed for very high speeds which are expected to achieve in the next decades. Current systems are designed for medium or high speed, in spite of the fact that speeds over 400 km/h are expected to achieve in some years.

10.1.3.2 Weaknesses (internal origin)

These disadvantages are mainly related with the limitation of the height of the embankments and the restricted geometry designing and execution. The limitation will mean the main obstacles in order to market this technology of track. This intrinsic feature to the technology will represent one of most relevant weaknesses of the system, since, the limitations will mean in notable increase of the costs in the rail projects. In fact, the special needs in the conditions of the embankments along with the costs of the slabs make the slab track system more expensive in the construction phase than the traditional ballast system although this increase of the costs is offset by lower maintenance costs during the life of the infrastructure. The overcosts in the construction phase of the slab track in relation with ballast rail (1.5-2 times) are approximately compensated from the age of 30 (Figure).

Other important issue regarded with this technology is the lack of experience in the use of the models developed during the Capacity for Rail project. While the experience with ballasted track systems exceeds 150 years, the slab technology barely reaches 50. This lack of experience in the use of these prototypes makes the engineers more confident to deal with ballasted systems and could mean in the possibility of reticence by the rail administrator at the time of includes these technologies in the different national rail specifications.

Although the number maintenance tasks are lower in the slab track systems, these tasks are intensive in workforce and complexity and make difficult to keep the level of serviceability and maintainability with costs, at least, similar to the ballasted track systems.

As for the noise, the level of acoustic emissions is notable higher in the existing slab track systems than in the conventional ballasted track systems.

10.1.3.3 Opportunities (external origin)

Some of the XXI century challenges are related with the use of data and information from different sources. This fact could represent a major opportunity in the use of the new technology of rail track developed during Capacity for Rail project which, through its monitoring system, allows the acquisition of big volume of data related with the current state of the different elements of the system.

The international and financial environment in which the budgetary constraints are on the agenda of most of the countries and administrations, the use of modular systems in the engineering works will mean in a better adjust of resources and a more and accurate planning of the great transports networks.

Nowadays, the society demands high level of comfort and wealth. Slab track systems should improve these levels through a set of the intrinsic characteristics of the system. Regarding these special features, the reduction of noise due to the non-presence of sleepers or the absence of dust since the non-existence of ballast are the more notorious.

The economic recovery and the intense transport infrastructure planning in the emergent countries will represent a great opportunity of the development and market of the results of the Capacity for Rail project. The growth prospects in the rail market are positive, with annual mean increase around 2.7% for the period 2014-2020. According to the World Rail Market Study, made by UNIFE, average investments worldwide of around 176,000 m€ are planned for the period 2017-2019.

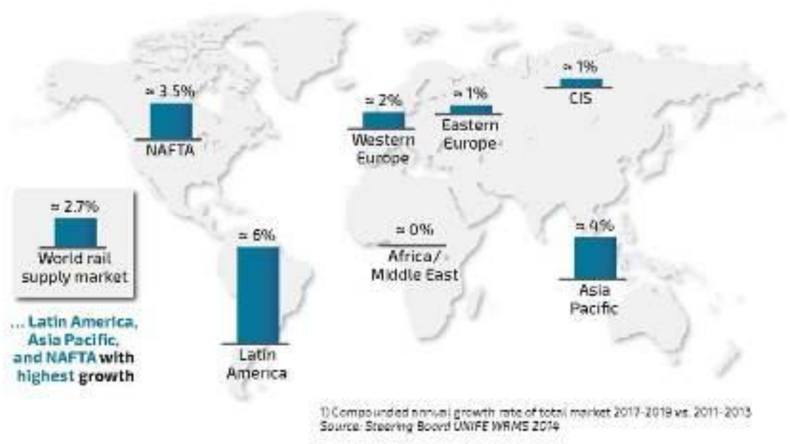

Figure 16. Annual growth estimates of the rail market by regions (2014-2020) (Source: World Rail Market Study. UNIFE)

Within the high-speed sector, the evolution of kilometers built during the last years has undergone an exponential growth whose tendency is estimated to continue along the same lines according to the International Union of Railways (UIC).

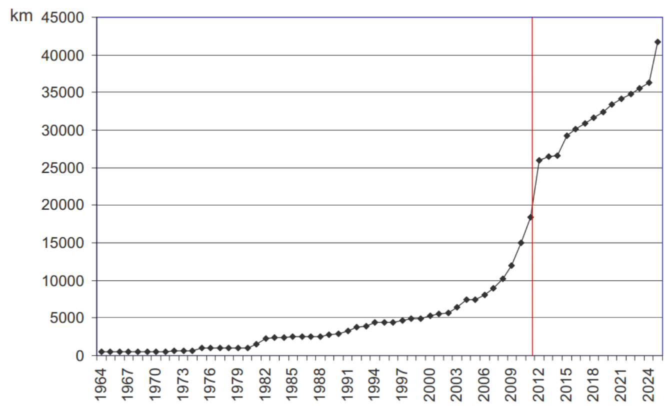

Figure 17.Evolution of high speed kilometers built worldwide (UIC,2012)

This evolution is accompanied by a greater number of countries interested in the implementation of this type of infrastructure, which are mainly concentrated in Europe and Japan, to spread to the US, Latin America, India or the Middle East in the year 2025.

10.1.3.4 Threats (external origin)

The initial investment for the slab track systems is notably higher than the traditional ballast systems. This fact along with the current monetary restrictions in the national budgets due to the financial crisis, which is still present, and the uncertainties in the future of the economy, could represent a major challenge at the time to start to commercialize the product.

As said before, the lack of experience in the generalized use of the slab track in long sections along with the great experience over the 150 years in the use of ballasted systems, supposes the more important obstacle to overcome. Engineers, contractors and administrator are still reticent in the use of new technologies different from the traditional ones.

On the other hand, the unstable framework regarded with the policy in some advanced economies such as USA or UK due to different factors, it does not allow us to see a promising horizon for the infrastructure investments. The national debt in UK will raise 143.000 m€ more than previous predictions due to the effects of *Brexit*. Together with this raise in the national debt level, the growth of economy has been cut from 2.2% predicted for 2017 until 1.4%. All of this will impact on the national infrastructure planning which is under the risk of severe cuts.

10.1.4 CAME ANALYSIS

10.1.4.1 Correct the weaknesses

Despite the costs of execution of the slab tracks are twice or three times higher than the costs of execution of the traditional ballasted systems, the costs of maintenance tasks are quite lower, because the system is notably more robust and the needs of maintenance are lower. If the Life Cycle Cost analysis (LCCA) is made (Figure), the results show crystal clear conclusions about the total amount of costs which both system required during all the period of life of the infrastructure (under the hypothesis of 100 years of life).

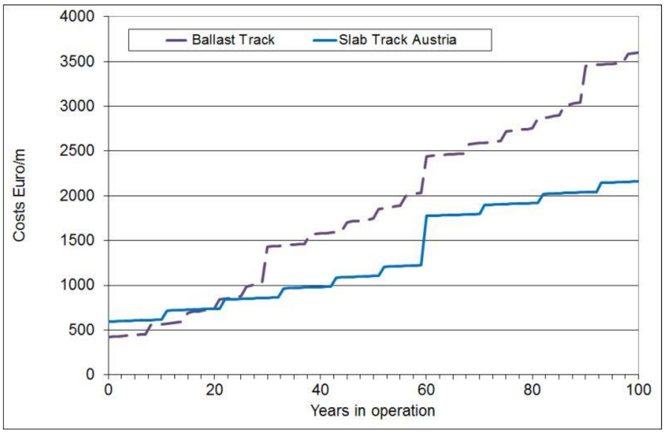

FIGURE 18. TOTAL COSTS (CONSTRUCTION & MAINTENANCE) FOR BALLASTLESS AND SLAB TRACK SYSTEMS DURING THEIR PERIOD OF LIFE (TRACK)

This fact through of the whole life period of the infrastructure will mean in the assumption of the slab track systems are cheaper than the ballasted ones.

The lack of experience in the construction and exploitation of this typology of track supposes other of its great challenges to overcome in order to get the access to the market. The lack of experience about its behaviour under rolling stock could make amend through a research works, where some of the uncertainties were solved. Together with the research works, the public presentations, transport engineering congresses and other dissemination events will help to take over the use of the developments reached during the Capacity for Rail projects.

The construction of demos where the technology will probe the developments and achievements in the field of the slab track systems are other relevant way of overcome the reservations at the time of implement the system in real tracks.

Regarding the comfort and service levels, noise and vibrations represent other of the most relevant issues to overcome. In this case, several attenuation measures as the use of elastomeric pads, sheets and other technologies, has been developed in the last times. Accordingly, the different models of slab track developed during Capacity for Rail project, are designed taking into account all these technologies.

10.1.4.2 Adapt/adjust to the threats

Threats are mainly related with the economic and unstable framework worldwide situation. This is a non-possible factor to control. However it is possible to deal with this fact paying attention over the areas where the investments in infrastructures are still powerful.

Emerging countries such as India or China still offers solid and robust index of growth and very challenging infrastructures plans. These ones are remarkable markets where the number of potentially passengers and the length of the main routes, offers great possibilities. Along with these countries, other ones, such as Arab Emirates, Panama, Colombia or Mexico shows good forecasts in matter of infrastructures plans.

In spite of the political instability in the biggest economies, some countries such as USA or Norway has been planning extensive infrastructure plans for the next decades which includes important investments in matter of high speed rail. This fact could represent important possibilities in order to access to important engineering rail projects.

10.1.4.3 Maintain the strengths

Modular system used by the models of slab track designed during the Capacity for Rail project represents one of the most advanced technologies developed regarded with the slab track systems. This technology will mean in important reduction of the maintenance tasks in matter of time and costs. This fact linked with the special features of the slab track systems, supposes the generation of a track system with remarkable safe of money and maintenance time where the operation tasks are noticeably easier to do than the other slab track systems.

The implementation of a monitoring system inside the slab allows getting a better knowledge about the tensional and behaviour state of the track. This better knowledge will translate into a best planning of the conservation tasks, the development and application of deterioration models in order to optimize the maintenance and operation tasks and the possibility of early detection failures. Along with these facts, the use of ICT in civil engineering represent a great step forward in the use of large volumes of data and its use in the improvements of the different phases of the engineering: design, construction, operation and maintenance. The monitoring system installed in the different models of slab track developed in the Capacity for Rail project allows the access of a great amount of data which help to improve and optimize the different phases of the construction process. This monitoring system is totally innovative and no one of the existing slab tracks systems includes something similar. This represents a notably differentiating factor over the rest of technologies which could raise the promotion of the system in the near future.

10.1.4.4 Explore the opportunities

The systems developed during the Capacity for Rail project could be not only use in the construction of new infrastructures. The field of renewal and upgrading of the existing ones should be put in value at time to market the designed models of slab track. Modern economies such EU or USA, might have not the needs of construction large rail network, however the upgrading and renewals of existing ones represents major challenges in a medium-term. The raise in the loads and the speeds of rolling stocks requires new capabilities. This one linked with the raise in the comfort and safety demands by passengers and the reduction of operational costs by the administrators, supposes a great opportunity to commercialize a new system of track which help to carry out all this new prescriptions and societal and economical concerns.

10.1.5 BUSINESS MODEL CANVAS

10.1.5.1 Fundamentals

The business model Canvas is a strategic management and lean start-up template for developing new or documenting existing business models. Initially was proposed by Alexander Osterwalder based on this earlier work on Business Model Ontology. Formal business descriptions become building blocks for your activities. There are many different conceptualizations of business. The model proposes a unique reference model based on the similarities of a wide range of conceptualizations of the business model. According to your business template design, a company can easily describe your business model.

The business model Canvas consists of 9 key blocks which are following described in the next paragraphs. Each key blocks of the model could be clustered in major blocks which meet and associate activities with strong links in common. This formal framework is arranged as the following structure:

- Infrastructure: key activities, key partners and key resources.
- Offer: value propositions.
- Customers: customers segments, channels and customer relationships.
- Finances: cost structure and revenue streams.

The name of Canvas comes from the possibility of representing all the key blocks in a unique scheme in which add all the information. The next figure shows this scheme (Figure).

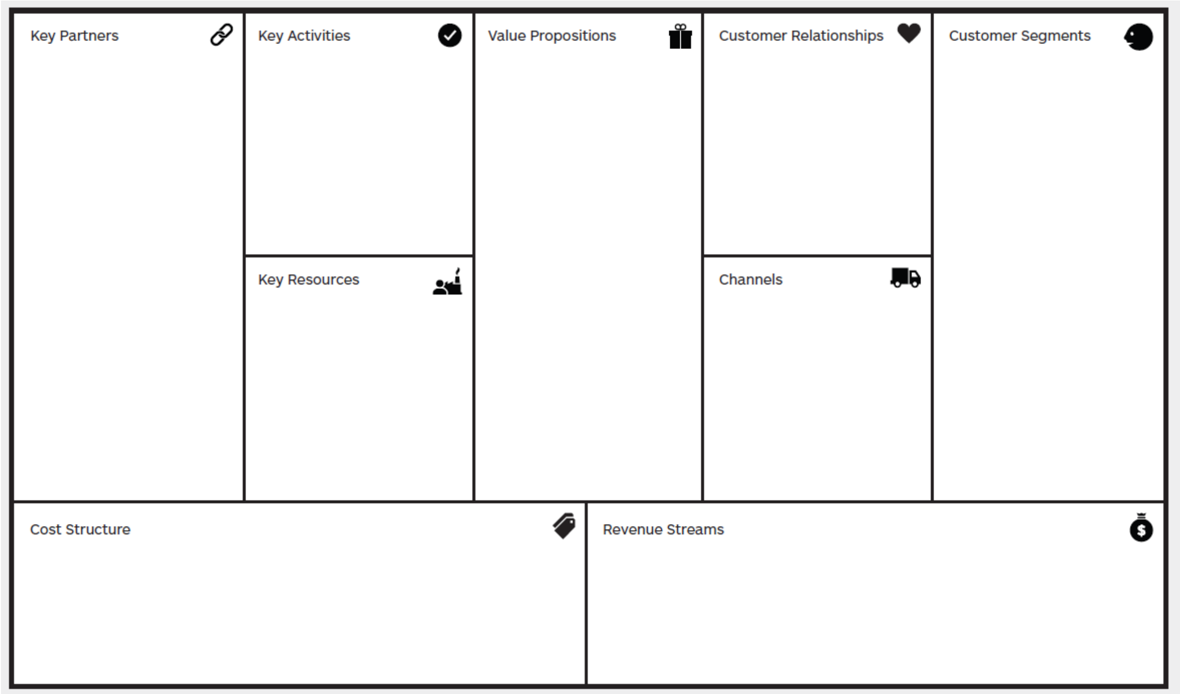

FIGURE 19. THE BUSINESS MODEL CANVAS

10.1.5.2 Key partners

The different members of the consortium involved in the developments reached during SP1 perform the most of the relevant and required roles in order to cover the different phases or stages in the engineering process.

Despite of the fact that the consortium is solid and robust in its own composition, some key partners could be required in order to speed up the process to get the market. On this subject, the active and strongly participation of some additional recognized prestige construction and engineering firms as associated partners will help to include the new concepts of slab track in the new rail engineering project. In addition the involvement of some additional administrator could be relevant, so the development could be tested in different demonstrator before reach the market.

Other main possible gap in the composition of the consortium related with this SP1 is the participation of a dissemination company who could help to spread and implement the developments, achieving the end-users and the possible customers.

10.1.5.3 Key activities

The production process will depend on the business model of every one of the partners involved in the developments of new systems.

In the case of engineering firms, it will recommended the specialization and training in the designing department of some group of technicians who are involved in the application and use of the new concepts of slab track in the rail engineering projects. Construction companies should do the same, not only in case of designing but also in the construction and maintenance tasks.

Administrators and other parties must be receptive in the use of the new concepts in existing lines, which could be used as demonstrators to probe the correct performance of the new systems under real conditions.

10.1.5.4 Key resources

- Human resources

R&D departments of the different members of the consortium plays a relevant role in the process of development and technical support regarding the new models of slab track designed in the project Capacity for Rail. As generators and creators of the new concepts of slab track, they should support the technical viability and solve all possible doubts and uncertainties about the implementation of this technology in real conditions. In addition, one of their most crucial tasks is the transference of information from them to the engineering departments, which must be involved and are in charge of include the new solutions in the rail engineering projects.

Commercial departments are the key factor of the partners which is crucial to be included at the time of spreading the developments reached in the Capacity for Rail project. In order to get an strengthen of the market links between the customers, i.e. infrastructure managers, railway administrator, and the designers and owners of the new designs, will be needed to arrange technical meetings, close contacts and any other type of relationship. This will mean the needed of great amount of work hours and personal resources involved in the process of dissemination and transference of information.

- Financial

Innovation and development process for every one of the designs developed during the project requires a substantial amount of resources by the different partners involved in the project. Although the final design of products will achieve at the end of the project, new improvements, and upgrades will be needed to implement during the post stages of the innovation process. For those stages, some financial support must be guaranteed.

Publicity and commercialization of the results will require a strong investment in publicity in order get and consolidate the distribution channels which will serve as ways of achieve the total commercialization of the designs and developed of the project.

- Intellectuals

The protection of results will require the previous definition of who are the co-owners of the developments achieve during the project. Once this will have been done, the partner should decide the need to come to a join ownership agreement. This ownership agreement could represent the more appropriate solution when a consortium is not sufficiently specific. This mean of protection has associated a set of costs which will be shared between the parties.

10.1.5.5 Value propositions

The proposal at the time to offer the new systems must be aligned with the advantages and benefits which the system brings over the rest of existing slab tracks systems. These benefits are previously detected in the SWOT analysis.

- Dust-free system which will mean in environmentally friendly engineering solutions.

- Easy access of road and other kinds of vehicles in the track in case of emergencies or accidents.
- Modular system where the maintenance tasks are notably easier than in the current slab track systems.
- Low number of maintenance tasks what will mean in lower costs of maintenance.
- Avoidance of ballast flight and its issues regarded with the rolling stocks.
- Use of ICT tools to monitor and check the external and internal behaviour of the different components of the system.
- Fabrication off-site which will increase the reliability of the construction processes.
- New design specially designed for very high speeds keeping the comfort and safety conditions.

10.1.5.6 Customers relationships

The innovative designs developed during the SP1 of the Capacity for Rail project requires the need of a close relationship between the customers and the different members of the consortium in order to spread the benefits in the use of these ones and to solve the possible doubts in relation with them.

In this way, the existence of a direct assistance line between customers and the consortium is considered crucial at the time to obtain good results in the commercialization of the results. This assistance must be both technical and financial, explaining and solving the advantages and possible doubts and issues occurred during the design and construction process.

It is highly recommended the creation of a technical and commercial committee in order to attend all this possible issues related with the slab track systems developed in the project.

10.1.5.7 Channels

This block deals with the different possible ways at the time to achieve the customers. Because of this project addresses to set of new solutions for the slab track, the issue is not only focusing on the improvements of existing channels but also in the search and business strategy to commercialization of these ones.

The procedure to obtain, develop, create and consolidate a set of channels to commercialize the results obtained in the C4R project consists of a set of steps which are following described:

- Raise awareness

The new models and developments reached during the Capacity for Rail project should be spread and disseminated in order to raise awareness over the new engineering solutions for the slab track. A number of different alternatives could be checked in order to release the results of the project. The main and more relevant ones are:

- Attendance to specialized events in transport and civil engineering such as Transport Research Arena (TRA), Congreso Panamericano de Ingeniería de Transito, Transporte y Logística, International Congress on Transport Infrastructure and systems (TIS) or the International Conference on Transportation and Traffic Engineering (ICTTE).
- Celebration of workshops and dissemination events during and post the project where experts in the field of rail and transportation engineering, infrastructure managers, construction companies and other stakeholders will be invited.

- Elaboration of technical reports where technical characteristics of the new systems of slab tracks are crystal clear reflected.

- Assessment

The assessment by the possible customers of the new systems of slab track developed in the project could be done by several ways:

- Standardization: the models developed must comply the current normative and prescriptions in every country where they will be implemented and constructed. The only way to get this is through the test and standardization of the different components which be part of the systems. This procedure will guarantee the post adequate behaviour and the safety prescriptions.
- Elaboration of design guides and engineering solutions where the slab track models developed in the Capacity for Rail project will be included resulted in alternative to the current solutions.
- The execution of demonstrators in rail stretches will help the adequate assessment of the new models of slab track in real conditions.

- Purchase

The commercialization of the new slabs by the consortium must be object of a deep study where every partner will play a role according to its business. In this way, the different partners of the consortium are totally complementary between themselves, and no relevant overlapped are detected.

- Post-assistance services

Technical assistance during the different stages of the construction process: planning, design, construction and maintenance will help and speed up the implementation of the new systems of slab tracks developed in C4R.

10.1.5.8 Customers segments

Among the customers, national governments, infrastructure managers and railway administrators plays a primary role as end-users of the developments and designs reached during the SP1 in the Capacity for Rail project.

Some of the main infrastructure manager and railway administrator in Europe and worldwide are following listed:

- Germany: *Deutsche Bahn Netze (DB Netze)*
- France: *Société Nationale des Chemins de fer Français (SNCF)*
- United Kingdom: *Network Rail (NR)*
- Spain: *Administrador de infraestructuras ferroviarias (ADIF)*
- Italy: *Rete Ferroviaria Italiana (RFI)*
- Poland: *Polskie Linie Kolejowe*
- The Netherlands: *ProRail, Infraspeed*
- Portugal: *Infrastuturas de Portugal (IP)*
- Sweden: *Trafikverket*
- Belgium: *Infrabel*
- Austria: *ÖBB-Infrastruktur*
- Hungry: *Magyar Államvasutak (MAV)*

- Czech Republic: *Sprava zeleznicni dopravni cesty (SZDC)*
- Denmark: *Banedanmark*
- Greece: *Οργανισμός Σιδηροδρόμων Ελλάδος (OSE)*
- Croatia: *HZ Infrastruktura*
- Norway: *Jernbaneverket*
- Japan: *Japan Railway Construction, Transport and Technology Agency, Railway Technical Research Institute*
- Korea: *Korea Rail Network Authority*
- Iran: *Railway Services and Technical Construction Engineering Company*
- Algeria: *Anesrif*
- Australia: *Australian Rail Track Corporation*
- New Zealand: *KiwiRail Network*

In addition to these great infra managers, the main construction companies along with the engineering design firms must get in touched with the developments of the SP1 due to the possibility of speed up the procedure of inclusion the new models of slab track in the great rail infrastructure projects.

10.1.5.9 Cost structure and revenue streams

Cost and revenue structure should be calculated in dependence of the business and engineering sector of every one of the partners in the consortium. The definition of the different costs and revenue streams address the different stages of the engineering cycle and must be objected of a post in-depth individually study. Generally, the traditional and different cost structure could be classified as the following way:

- Fixed costs
- Variable costs

This structure of costs will be different between the members of the consortium. The particular and possible changes in the chain due to the effect of the new concepts of slab track should be studied for the particular case of each partner. As said before, in the case of study, this structure of costs and revenues could be related with the different phases of the engineering process:

- Engineering
- Construction
- Technical assistance
- Maintenance tasks

In the general case of the engineering firms, this change should not be really accurate because of the same engineering department could address the design of new rail solution taking into account the new models of slab track. In the case of constructors and administrator, the new slab tracks models represent a good chance of improve and upgrade the existing construction methods what could have repercussions in the cost and management structure of the company as well as the rail administrator where the new concepts supposes a crucial opportunity in order to reduce variable costs associated with the maintenance tasks.

On the other hand, the revenue streams will be also very different depending on the kind of business of each partner. In the case of study, this revenue streams will bring through the commercialization of the new concepts of slab track through the usual exploitation channels. These channels will be regarded with the different tasks carried out by the partners in the project. One of the main changes in the revenue streams due to the results of the project is the promotion and technical status that every partner could reach. The gateway to new markets and the access to the public administration through the developments of the project will allow the possibility of come to agreements in matter of engineering, construction or maintenance projects which will affect the revenue streams in a positive way.

11 Conclusions

Task 1.1.2 of Capacity4Rail project shew how interesting is the collaborative approach to invent and develop new concepts with contributions of many skills from all partners.

At the time of writing this deliverable, both concepts are being prototyped and are close to be tested à CEDEX Track Box in Madrid. Feedback from prototyping and results from testing should lead to an improved version for each concept. Further developments of these 2 concepts will be described in D1.1.3.